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KNOWING HANDS

Whenever you get dressed, carry objects, write, draw, or gesture, you express knowledge about how to get things done with your hands. Ironically, that knowledge is often difficult to express. Typically, you can't say what you know. Still, it would be enormously useful to identify the knowledge underlying manual control. The design of equipment and transportation systems might better anticipate the abilities and limitations of users, and methods of teaching and rehabilitating skills might also improve. This book, the first on the cognitive psychology of manual control, uncovers the hidden knowledge that hands express. Organized around key topics in this emerging area, including the role of the will in manual control, illusions concerning hand position sense, and the coordination of manual actions with others, *Knowing Hands* explains the planning and control of manual actions in everyday life.

David A. Rosenbaum is a cognitive psychologist whose main interests are human perception and performance. He attended Swarthmore College and Stanford University, where he received his PhD. He worked at Bell Laboratories, Hampshire College, the University of Massachusetts, Amherst, and Pennsylvania State University. He is currently Distinguished Professor of Psychology at the University of California, Riverside. Rosenbaum was the Editor of the *Journal of Experimental Psychology: Human Perception and Performance* and a recipient of a John Simon Guggenheim Memorial Foundation Fellowship. Cambridge University Press 978-1-107-09472-7 — Knowing Hands David A. Rosenbaum Frontmatter <u>More Information</u>

Knowing Hands

The Cognitive Psychology of Manual Control

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I dedicate this book to the friends, colleagues, and students with whom I have had the privilege of studying the cognitive psychology of manual control.

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Contents

Pre	pface
1	Introducing Hands
2	Building Hands
3	Energizing Hands
4	Willing Hands
5	Seeing Hands
6	Hearing Hands
7	Feeling Hands
8	Joining Hands
9	Extending Hands
No	<i>tes</i>
Rej	ferences
Inc	lex

Cambridge University Press 978-1-107-09472-7 — Knowing Hands David A. Rosenbaum Frontmatter <u>More Information</u>

Preface

The new building in which I am writing this, the home of Penn State's Psychology Department (on the University Park campus), was built with forklifts, cranes, and hydraulic lifts. But more important for what's to come here, virtually every inch of it was touched by human hands. The men and women who built this place guided each girder by hand, inserted each bolt by hand, and attached each panel by hand. With their hands, and often with their *bare* hands, the workers laid every carpet, flipped every switch, and checked every valve. The workers' hands were knowing hands. How the workers used their hands reflected knowledge they had from years of experience and eons of evolution.

Hands that know deserve better understanding than they've gotten. Though we use our hands for so much of what we do – for building, drawing, sculpting, and strumming – we know surprisingly little about how manual control actually works. If we knew more, we'd be able to develop better hands for robots, better prostheses for amputees, and better means of teaching manual skills.

For whom is this book written? For anyone with hands, of course, or, for that matter, anyone with just one hand or no hands. Anyone who has wondered why s/he prefers to use one hand or the other, why some people are handy and others are all thumbs should find this book useful.

This is not a how-to book, however. You won't find advice here on how to trim your nails, how to apply cream to your skin, or how to turn your hands into masterful massaging machines. I'm not a physician, nor am I a physical or occupational therapist. I'm a psychologist or, more specifically, a *cognitive* psychologist.

Cognitive psychologists study basic mental function. Cognitive psychology has its origins in epistemology, the branch of philosophy concerned with knowledge. The core question of epistemology is, "What do we know

ix

Cambridge University Press 978-1-107-09472-7 — Knowing Hands David A. Rosenbaum Frontmatter <u>More Information</u>

Preface

and how do we know it?" Given this question, cognitive psychology has largely focused on the way knowledge is acquired through perception, attention, and learning. Less attention has been paid to the way knowledge is expressed physically, even though all physical actions, or at least all physical actions performed with some degree of skill, express knowledge.

The science of knowing must include a study of knowing expressed through performance. Otherwise that science – known as cognitive science, which has cognitive psychology as one of its strands (the other strands being linguistics, philosophy, computer science, neuroscience, and anthropology) – would just be the science of information *absorption* and *storage*. It would say nothing about how we express what we know.

Oddly, the cognitive substrates of physical action have been largely neglected in cognitive psychology. This neglect troubled me right from the start in my exposure to the field. As an undergraduate and then as a graduate student, I was happy to accept the idea that perception, attention, and learning are important. But I wondered about action, too. I was surprised to discover that the field was almost completely dominated by the study of information intake and storage. Very little was known or was being done on the means by which we plan and control our physical behavior. One exception was language production, a form of expression that seems more clearly related to thinking than other physical acts like lifting chairs or scrubbing floors. Once you think about the control of these less intellectual tasks, however, you quickly appreciate that they too require considerable intelligence. Otherwise, there would be more robotic chair lifters and more robotic floor scrubbers. A few robots today might be able to do these tasks, but none of them can do so in the rough-and-tumble real world where chairs can be any which way and floors can be in whatever state. Generally speaking, robots today lead protected lives, functioning in environments that are tailor-made to their limits. In this regard, they are dramatically different from their real-life animal brethren who can handle most any physical challenge coming at a moment's notice.

When I was a graduate student and recognized that physical action takes a lot of intelligence, I decided to help redress the imbalance between the study of information *intake* on one hand and the study of information *output* on the other. When I made this decision I couldn't tell whether it would turn out to be a smart choice or a foolish one. If it turned out to be a foolish decision, then I'd end up lifting chairs or scrubbing floors for a living – legitimate jobs, to be sure. Still, the existence of this book suggests that my decision kept me employed in cognitive psychology. I've spent enough time thinking about the cognitive psychology of physical action,

Х

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Preface

and the cognitive psychology of manual control in particular, that I feel I've reached a point where I can offer a quorum of material on this subject.

Why focus on hand actions in particular? Plainly, actions can be produced with many parts of the body. Speaking uses the mouth, nodding uses the head, walking uses the legs. Even paradigmatically manual activities like typing, welding, and throwing darts require the participation of parts of the body other than the hands. To type, you must sit or stand so your body is stable and you can reach the keyboard. To weld, you must orient your torso and legs to safely support the weight of your tools. To throw darts, you must stabilize your body appropriately. The motions of your hands can never be divorced from the motions of the rest of you. Still, your hands, more clearly than any other part of your body (except perhaps your face), let you express intelligence in a wide range of activities, including tool use. Understanding how manual activities are controlled can reveal a lot about intelligence.

Hands and their activities are worthy topics, but why write a book about them? I have four reasons. One is to make as public as possible how much intelligence is expressed by hands. Even the simplest manual act, like picking up a piece of paper or tying a knot, reflects a tremendous amount of knowledge. You can appreciate this by asking yourself, as you pick up a piece of paper or tie a knot, "What did I need to know to do that?" If you ask the question in terms of the information a robot would need to perform the tasks, you can begin to appreciate what a vast fund of knowledge you have at your fingertips.

My second reason for writing this book is to point to the practical benefits that can derive from this area of study. It's important for society to explicate hand knowledge. Think about the boats that transport raw goods to garment factories in places like Bangladesh. A lot of trouble is taken to get these goods to the factory workers. Ultimately, the materials are shipped to intelligent eyes and hands that can do what no robotic systems can currently do: deal with complex, uncertain arrangements of nonrigid materials to be pieced together into pants, shirts, underwear, and the like. If routine sewing and cutting could be done by robots located close to where the raw goods originate, the problem of shipping goods thousands of miles to lowwage workers would evaporate.

I have written this book partly to lay out the knowledge that could bring that day closer. I am aware that the problem would arise of how else to employ the garment workers, but worrying about that problem shouldn't deter us from designing smarter robots. People who no longer copy books by hand or calculate numbers by hand – people who used to be called "computers" – have found other forms of employment.

Cambridge University Press 978-1-107-09472-7 — Knowing Hands David A. Rosenbaum Frontmatter <u>More Information</u>

xii

Preface

My third reason for writing this book is to share the fascinating findings that have come along in connection with hands. Here are just a few examples, offered here to whet your appetite. First, it turns out that if you hold a *warm* cup in your hands, you're more likely to think the person you're talking to is friendly than if you hold a *cold* cup in your hands. Second, if you see a rubber hand being stroked while your own unseen hand is stroked, you can actually feel your own hand where the rubber hand is. Third, if you hold a string with a weight dangling beneath it and try *not* to swing the weight, you will swing it more than if you *do* try to swing the weight. This is the manual analog of trying not to think of a white bear.

My fourth reason for writing this book is to describe a theory of manual control that my colleagues and I have developed. The theory, or its main idea, is simple enough that I can state it here in this preface: Movements of the body (including movements of the hands) are directed to goal postures. According to the theory, if you reach for a glass, you move, or try to move, to a desired final body position. If you throw a punch, you move, or try to move, to a desired goal posture. If the punch is meant to do serious damage, its goal posture may, counterintuitively, bring your hand beyond your opponent's face. Finally, if you throw a ball rather than a punch, your aim, at least from the perspective of the theory, is to reach a goal posture that happens to afford, on the way to its arrival, release of the ball with a force that affords a correct trajectory. The idea that movements are made to goal postures is supported by a wide range of facts from cognitive psychology and physiology. I will present those facts here, intermingled with other facts pertaining to other aspects of manual control on which the theory doesn't turn directly. The goal state I hope to bring you to is feeling enlightened about the cognitive psychology of manual control.

Writing a book is a social endeavor. It reflects the collective inputs of the many people from whom an author learns. In my case, my thinking has benefited from the input and support of others, whom I want to thank here. Katie Chapman, Chase Coelho, Iman Feghhi, Lanyun Gong, and John Huhn were my graduate students when I wrote this book. Cory Potts was my lab manager and then became a grad student in my lab. Gordon Bower, Laurel Buxbaum, Phil Kellman, Mark Latash, Kristina Neely, Florent Paclet, Bob Sainburg, Breanna Studenka, Jonathan Vaughan, Carolee Winstein, Brad Wyble, and Vladimir Zatsiorsky were colleagues from whom I gained insight while I drafted the book. My friend Kosta Dussias told me about cool things he encountered on the web and elsewhere that I wouldn't have known about otherwise. My wife, Judith Kroll, was, as always,

Cambridge University Press 978-1-107-09472-7 — Knowing Hands David A. Rosenbaum Frontmatter <u>More Information</u>

Preface

my closest friend and soul mate. My daughters, Sarah and Nora Kroll-Rosenbaum, along with their spouses, Michael Wohl (Sarah's husband) and Laura Karpman (Nora's wife), were supportive as well. My grandson, Benny Karpman, reminded me, as he passed through infancy, toddlerhood, and on to boyhood, how much it takes to master manual and other physical skills. My granddaughter, Greta Wohl, who was a baby when I completed this work, reminded me as well how we all move from being tiny, helpless, but very active blobs to more self-sufficient beings.

Once the book was drafted, I asked a number of colleagues to look it over and give me comments on any aspect of it, including, especially, material related to their own interests and expertise. I want to thank those who kindly took time out of their busy schedules to look at this work: Sian Beilock, Laurel Buxbaum, Rajal Cohen, Digby Elliott, Karen Emmorey, Mark Fischman, John Franchak, Liz Franz, Scott Frey, Oliver Herbort, Kit Hume, Rachel Keen, Roberta Klatzky, Göran Lundborg, Susan Goldin Meadow, Michael Graziano, Rich Jagacinski, Steve Jax, Tim Lee, Ruud Meulenbroek, Cory Potts, Cathy Reed, Teenu Sanjeevan, Thomas Schack, Christian Seegelke, Ladan Shams, Robrecht van der Wel, Dan Weiss, Jeff Wagman, Dan Willingham, Mike Wininger, Jessica Witt, Gaby Wulf, Kathrin Wunsch, Howie Zelaznik, and Mounia Ziat. Any faults in this book are mine, not theirs.

The theory outlined in this book was mainly developed with two colleagues: Ruud Meulenbroek of Radboud University (Nijmegen, The Netherlands) and Jonathan Vaughan of Hamilton College (Clinton, New York). Sadly, Jon died before this book was completed. Had he been alive and well enough to critique the work, it would have certainly turned out better than it did. When I dedicated this book to those with whom I've had the privilege of studying the cognitive psychology of manual control, Jon was at the top of the list.

Over the years, my research has benefited from grants from the National Science Foundation (NSF), the National Institutes of Health, Penn State's Social Science Research Institute, and the German and Dutch equivalents of the American NSF. Preparation of this book was also made possible by a fellowship from the John Simon Guggenheim Memorial Foundation, awarded for the 2012–2013 academic year. I had the luxury of deferring the fellowship for a year to be able to spend my sabbatical with my wife, Judith Kroll, who also got a Guggenheim, making us, as far as we know, the first couple in the history of psychology to get two independent Guggenheim Fellowships. (Judy and I work on different topics. Her area of expertise is bilingualism.)

xiii

Cambridge University Press 978-1-107-09472-7 — Knowing Hands David A. Rosenbaum Frontmatter <u>More Information</u>

xiv

Preface

Leafing through this book, you'll find very few pictures. A book like this could be a veritable art gallery. At first I conceived it as such, but then I found that I could express in words what the pictures would have conveyed, or at least I felt like that was the case. I decided to go essentially picture-less because I was inspired by the existence of many fine books that have few or no pictures. I was also daunted by the complexity of dealing with pictures of different styles. I toyed with the idea of having someone pose with various hand postures, but was deterred by the selection problem that would ensue: Which pictures to show and why? So, in the end, with the exception of the art on the cover, this book is graphic only in what you may picture in your own mind.

To the extent that the book is professional in appearance, that is due in no small measure to the great help provided by those involved in its production. For their always-on-time, always-cordial, and alwaysknowledgeable assistance, I thank Emma Collison, Adam Hooper, and Brianda Reyes of Cambridge University Press, and Velmurugan Inbasigamoni and his colleagues at Integra Software Services Pvt. Ltd. Matthew Bennett, the Executive Publisher for Psychology at Cambridge University Press, made the decision to sign me. He gave me useful feedback and helpful guidance whenever I needed it. His assistance and faith in me were invaluable.

If you have questions or suggestions about the material in this book, including suggested corrections, please let me know. My email address is rosenb13@gmail.com. My physical location changed on July 1, 2016, from University Park, Pennsylvania, where I was on the faculty at Penn State University from 1994, to Riverside, California, where I joined the faculty at the University of California, still retaining my ties to Penn State, where I was honored to be named an emeritus faculty member.

Now I invite you to turn the page or scroll to continue reading. Performing either act draws on knowledge it took you a lifetime to acquire.