Decoding the Development of Mathematical Thinking

A review of

Development of Mathematical Cognition: Neural Substrates and Genetic Influences

By Daniel B. Berch, David C. Geary, and Kathleen Mann Koepke (Eds.)

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Abstract

A review of the book *Development of Mathematical Cognition: Neural Substrates and Genetic Influences,* edited by Daniel Berch, David Geary, and Kathleen Mann Koepke. This book provides a comprehensive snapshot of current debates in the field of mathematical cognition, particularly through the lens of developmental cognitive neuroscience and genetics. The chapters each provide a unique perspective on the development of mathematical thinking and learning. The intended audience includes researchers and advanced graduate students in the fields of cognition, cognitive neuroscience, and developmental psychology, though the book should be accessible to nonspecialists who have some training in one or more of these fields.

Mathematical cognition is concerned with the basic cognitive processes used when people engage in a variety of tasks involving numbers and arithmetic. Relative to domains within cognitive psychology such as language, problem solving, and reasoning, mathematical cognition is quite young. In fact, as a Ph.D. student, my introduction to the field of mathematical cognition was marked by the publication of Campbell's (2005) *Handbook of Mathematical Cognition*. That handbook was one of the first comprehensive collections of the theories and techniques that had evolved within the field. Before its publication, a student of mathematical cognition had to learn the field by wading through the numerous articles scattered throughout the various scholarly journals in cognition and experimental psychology.

A decade later, the volume of work dedicated to understanding mathematical cognition has exploded. No longer is is possible to summarize the field of mathematical cognition within one volume. Such growth is exemplified by the publication of the recent Elsevier book series "Mathematical Cognition and Learning" (e.g., Geary, Berch, & Mann Koepke, 2015), of which the book under review is the second volume. With its focus on the role of brain and genetics in the development of mathematical cognition *Development of Mathematical Cognition: Neural Substrates and Genetic Influences* represents a specialized, yet accessible review of the current state of knowledge in numerical and mathematical development.

Background and Structure

Before describing the book more fully, I would like to take a brief moment to give a bit of history of this book series. The "Mathematical Cognition and Learning" book series is the outgrowth of a five-year series of conferences, beginning in 2013, that were designed to facilitate the sharing of scholarship and ideas among a diverse group of researchers working broadly within the field of mathematical cognition and learning. The proceedings of each conference, with its own unique theme, has been distilled into an edited volume. The present book under review is the result of the 2014 conference.

The book contains 12 chapters broadly structured into two parts. The first chapter provides an introduction to the topics that the reader will encounter in the remaining 11 chapters. Chapters 2 through 10 each focus on a unique neural aspect of mathematical thinking, with topics ranging among symbolic and nonsymbolic number representation, mental arithmetic, memory systems, embodiment, and dyscalculia. Each of these chapters summarizes recent data from behavioral experiments as well as imaging and electrophysiological work. Finally, chapters 11 and 12 discuss the role of genetics in explaining individual differences in mathematical development.

Topic Coverage

One of the major strengths of this book is that by limiting the theme specifically to the roles of brain and genetics in mathematical development, the chapters can each provide a fairly comprehensive summary of recent work. Though each chapter focuses on a different topic, each topic is woven nicely into the overall story. What is that story, one might ask? In his foreword, noted mathematical cognition researcher Brian Butterworth calls for understanding "…what the child brings to learning arithmetic, which we can think of as the learner's 'starter kit'." (p. xiii). It is in this call that we find the story of this volume; namely, what sort of tools in this "starter kit" do children bring to the table when they begin learning mathematics?

Collectively, the chapters in the book combine to give some insight on this question. While each chapter is unique, together the chapters highlight several prominent open questions, such as finding the link between numerical symbols and approximate, nonsymbolic representations of quantity that we share with other animal species. Other questions are raised within the book. For example, which cognitive and neural systems are involved as children transition from procedure-based to retrieval-based arithmetic strategies? What is the nature of the cognitive system(s) underlying mathematical proficiency? While these questions are far from having definitive answers, the studies that each chapter reviews are sure to fuel the debates on these issues for a long time to come. Finally, some attention is paid to the nature of mathematical disabilities (e.g., dyscalculia), and the use of genetic syndromes as a model for understanding such disabilities.

One specific strength of the book is the introductory chapter by Berch, Geary, and Mann Koepke. This chapter provides a remarkably concise introduction developmental mathematical cognition and the various brain imaging methods used it its study. Particularly, the section on criticisms of fMRI does a good job of presenting an even-handed critique of the fMRI technique, while simultaneously presenting the case that some of these critiques may have been unfairly generalized to the field as a whole. I think the editors succeed in promoting a healthy dose of cautious skepticism in the reader, maintaining a position that, when applied correctly, imaging techniques can be an important tool for advancing the development of cognitive theories.

Finally, most of the chapters not only provide the reader with a snapshot of the field from the perspective of the chapter's author, but also some open questions that will ultimately determine the next steps in research. The inclusion of these open questions will prove to be a vital resource for graduate students who are interested in studying mathematical development, as well as for seasoned researchers who are wanting to expand the scope of their own work.

Audience

As mentioned in the preface to the book, *Development of Mathematical Cognition: Neural Substrates and Genetic Influences* is targeted primarily at researchers and advanced graduate students in the fields of cognition, cognitive neuroscience, and developmental psychology. The editors also claim that the book would be of interest to researchers and students in mathematics education and special education. My own assessment is that anyone without specific training in the methods of cognitive psychology and cognitive neuroscience will have quite a bit of difficulty with this volume. The reader will undoubtedly need a level of sophistication that comes from advanced training in one or more of these fields. That being said, I tend to be optimistic, and I think nonspecialists can learn a lot from this book, as the chapters are well-written and give the reader a good introduction to the topic. The chapters are dense, but this is to be expected from such a volume. As long as the reader is willing to spend some time with these chapters, there is a lot to be gained from the effort. But be forewarned; this is not a "bedtime reading" book. Readers looking for a non-technical introduction to mathematical cognition would be well served to read the excellent books by Dehaene (2011) and Butterworth (1999).

In summary, *Development of Mathematical Cognition: Neural Substrates and Genetic Influences* is an excellent book that should be on the desk of anyone who does research in numerical and mathematical cognition. In fact, I would recommend that any such person should obtain every volume in the "Mathematical Cognition and Learning" series. I predict that the chapters contained within will become the primary source material for graduate courses and seminars for a long time to come. I think the editors are to be commended for their excellent work in putting together this influential contribution to the literature on mathematical cognition and learning.

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Biography

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