Introduction

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The research discussed in this volume stems, in part, from work on health literacy. Health literacy is "the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions" (nnlm.gov). When people hear the term health literacy, they may think of a patient's ability to read medical information and understand medical terminology; however, health literacy not only includes literacy, but also *numeracy*.

A broad and basic definition of numeracy is *the ability to use and understand numbers*. Terms related to, and often used synonymously with, numeracy include quantitative literacy, health numeracy, and statistical literacy. Table I.1 highlights several examples of how these terms have been defined in previous research and throughout this book.

As shown in Table I.1, the terms used to describe numerical reasoning refer to a range of abilities, from the very basic (knowing which number is larger than another) to advanced (statistical terminology). We provide these examples to demonstrate the breadth of the concept at hand and encourage the reader to be mindful of the use of these terms throughout this book.

Large national samples have found that there is a significant proportion of the population who have only basic numeracy skills or less (meaning partial mastery or no mastery of grade-level skills). For example, 47% of adults who completed the National Adult Literacy Survey (NALS) were in the lowest two (of five) levels of performance (Kirsch et al., 2002). A more recent national survey of adults found that 36% are at or below basic levels (Kutner et al., 2006). Deficits in basic numeric ability are not only found in the general population, but also in subgroups of highly educated individuals (e.g., Lipkus et al., 2001; Anderson et al., 2014).

Along with basic numeracy, statistics is an essential part of the numeric language of medicine. However, unlike basic numeric abilities, statistics have not always had such a central role in medicine. The rise of statistical reasoning occurred due to the need to establish state records as well as catalog diseases, viruses, and plague events that impacted human and

Table I.1. *Definitions for numeracy and related terms.*

Term	Definition	Source
Numeracy	The term numeracy describes the aggregate of skills, knowledge, beliefs, dispositions, and habits of mind – as well as the general communicative and problem-solving skills – that is needed in order to effectively handle real-world situations or interpretative tasks with embedded mathematical or quantifiable elements.	Gal (1995, para. 9)
Numeracy	Numeracy, in the sense of knowledge and mastery of systems for quantification, measurement and calculation, is a practice-driven competence rather than abstract academic knowledge of "mathematics." Proficiency in numeracy varies with people's backgrounds and experience.	Adelsward and Sachs (1996, p. 1186)
Numeracy	The specific aspect of literacy that involves solving problems requiring understanding and use of quantitative information is sometimes called numeracy. Numeracy skills include understanding basic calculations, time and money, measurement, estimation, logic, and performing multistep operations. Most importantly, numeracy also involves the ability to infer what mathematical concepts need to be applied when interpreting specific situations.	Montori and Rothman (2005, p. 1071)
Quantitative literacy	The knowledge and skills required to apply arithmetic operations, either alone or sequentially, using numbers embedded in printed materials.	Kirsch et al. (2002, pp. 3–4)
Health numeracy	The degree to which individuals have the capacity to access, process, interpret, communicate, and act on numerical, quantitative, graphical, biostatistical, and probabilistic health information needed to make effective health decisions.	Golbeck et al. (2005, p. 375)
Health numeracy	The individual-level skills needed to understand and use quantitative health information, including basic computation skills, ability to use information in documents and non-text formats such as graphs, and ability to communicate orally.	Ancker and Kaufman (2007, p. 713)
Physician numeracy	Understanding the statistical aspects of and terminology associated with the design, analysis, and results of original research.	Rao and Kanter (2010)
Patient numeracy	The ability of patients to understand and use quantitative health data.	Chapter 2 in this volume
Statistical literacy	The ability to use and understand health statistics.	Chapter 4 in this volume

Adapted from Reyna et al., 2009.

animal populations. In the world of Newtonian certainty, statistics was looked down upon because it was concerned with probabilities. Although statistics were seen as a lesser science, "taming chance" became essential for critical and epidemiological thinking (Hacking 1964, 1975, 1999).

Only in the late nineteenth and early twentieth centuries did science and statistical methods merge and become a currency for genetics, economics, physics, medicine, etc. (Hacking 1964, 1975, 1999). Around this time the Flexner report was published (1910), which emphasized the importance of integrating research findings into medical education and decision making. The ability to use and understand statistical information is not only important for physicians and policy makers, but also for patients as they are increasingly involved in their health and healthcare.

The focus of this book is not only about individuals' numeracy and ability to use statistics, but how these abilities are associated with judgments and decision making about health. The next section introduces the study of judgments and decision making.

Judgments and decision making

The decision sciences investigate judgments and decision making using a scientific approach. The study of the decision sciences expanded during the cognitive revolution with the development of Herbert Simon's theory of bounded rationality (Simon 1955, 1978), which states that decision making is limited to the information we have, the amount of time we have to make a decision, and the limitations of our cognition. From Simon's seminal work, Kahneman and Tversky (1979), Gerd Gigerenzer and his colleagues (e.g., Gigerenzer & Goldstein, 1996), and too many others to mention, have made significant contributions to our understanding of judgment and decision making. Shortly after the decision sciences began, a subfield focused on decisions in medical contexts was established (Chapman & Sonnenberg, 2003; Elstein, 2004; Elstein et al., 1978).

Research on decision making generally takes one of three approaches: descriptive, normative, and prescriptive (Baron, 2000). Descriptive approaches describe how decisions are typically made, normative approaches describe ideal decision making, and prescriptive approaches focus on improving decision making, by prescribing how decisions ought to be made. Each approach contributes to our understanding of decision making, and examples of each perspective can be found throughout this book. All of the chapters discuss the descriptive approach, such as describing patient decision making in Chapter 4 and describing decision making about genetic testing in Chapter 6. The ideal that decisions can be made

using systematic reviews of the latest evidence (evidence-based medicine) could be considered as a normative approach discussed throughout this book. Though examples of the prescriptive approach can be found throughout the book, it is especially prevalent in the last five chapters, which focus on improving decision making.

Intersection of numerical reasoning and judgments and decision making

The focus of this book is the intersection of the study of numerical reasoning and the study of judgment and decision making in the health context. Research examining how individuals' numeracy level is associated with decision making took hold in the late 1990s and early 2000s with publications by Schwartz and colleagues (1997), Lipkus and colleagues (2001), and others. For example, Schwartz and colleagues (1997) found that 40% of women with high numeracy scores had accurate breast cancer risk estimates compared to 5.8% of women with low numeracy scores. Many studies since have added to this growing field. The chapters of this volume provide further examples on a range of health topics.

Research on numeracy and decision making is especially important in light of how clinical medicine has evolved. For example, there is now a greater emphasis on collaborative decision making between patients and physicians. Rather than physicians making decisions *for* the patients, they are making decisions *with* the patients. With patients having a more active role in their healthcare, their knowledge and understanding about numeric information is becoming more relevant. There is also a greater emphasis on making decisions based on research findings (evidence-based medicine), which requires that doctors and patients understand the statistics used to describe study results. These and other aspects of clinical medicine as related to numeracy and decision making will be discussed in more detail throughout this book.

The organization of this book

The chapters in this book discuss how numerical reasoning skills impact healthcare and how these skills are associated with individuals' decision making. Importantly, the book also examines how we might improve numerical reasoning and judgments and decision making about health, and directions for future research.

We begin with a chapter that introduces the concept of numeracy and the tools used to measure numeracy, which is central to

all of the chapters in this volume.While the original numeracy measures assessed performance on basic math tasks, such as converting between percentages and frequencies, new scales have been developed in recent years that offer unique advantages over the original measures. In Chapter 1, Cokely and colleagues provide a useful resource for those who wish to conduct research on numeracy by providing descriptions of different numeracy measures. These include the early measures by Schwartz and colleagues and Lipkus and colleagues, the Numeracy Understanding in Medicine Instrument (NUMi), the Abbreviated Numeracy Scale, and the adaptive Berlin numeracy test. Along with the history of numeracy measures, the advantages and disadvantages of the measures are discussed and suggestions for improving numeracy measurement are given.

Society, physicians, and patients

Chapter 2 by Multmeier, Gaissmaier, and Wegwarth, examines numeracy and society. The authors explain "collective statistical illiteracy," which refers to how society, including journalists, politicians, policy makers, and other professionals, all perpetuate misunderstandings about quantitative health information. While the following two chapters focus more on the individual, this chapter examines the impact of numeracy on a societal level, such as how our understanding of numeric information is shaped by public health messages, media, and advertising.

Changes in clinical medicine, such as increased reliance on evidence-based medicine and collaborative decision making, requires that physicians be able to use and understand numeric information and statistics. However, the statistics used in clinical medicine are becoming more advanced and studies assessing physicians' abilities to use numbers and statistics suggest that their abilities could be improved. Chapter 3 reviews physicians' numeracy and statistical literacy skills and discusses statistical literacy training during medical school. The authors also discuss what could be done to better prepare physicians for the statistical tasks that are relevant to providing the highest quality of care.

In Chapter 4, Zikmund-Fisher, Mayman, and Fagerlin describe how numeracy should help patients have more accurate risk perceptions, help them better use numeric information, and complete numeric tasks needed to manage a disease. They also describe how numeracy ability has been found to be associated with health outcomes, such as frequency of emergency department visits and ability to quit smoking. This chapter focuses on how numeracy is associated with health actions and health outcomes more than previous discussions of patient numeracy.

Applied contexts

Though numeric ability is relevant to an abundance of healthcare situations, two contexts are discussed in depth in this book. Chapter 5, which is on numeracy and diabetes care and management, provides an example of how numeracy has been applied to the care and management of a specific disease in order to improve heath and health outcomes. A considerable amount of work has been done to understand the problems that low numerate patients have with managing diabetes, as well as to develop tools to measure, predict, prevent, and assist diabetic patients. Berkman and Cavanaugh explain how low numeracy has been associated with knowledge about diabetes, self-efficacy for managing diabetes, self-care behaviors, and glycemic control. Current and future research on the impact of numeracy on diabetes care, including the development of tools and interventions, are also reviewed.

The other chapter in this section provides an example of how numeracy challenges must be considered and reconsidered as healthcare evolves. Medical advances bring about new numeracy challenges for patients and physicians. In the case of genetic screening, recent technological advances have increased the amount of numeric information that is available to patients about their screening test results. These advances in technology are only helpful in so far as patients and healthcare providers are able to correctly interpret the test results and appropriately apply the information to their decision making. In Chapter 6, Dukhovny and Wilkins-Haug discuss the numeracy skills that are important to the various types of genetic screening tests and suggest directions for future research in light of the advancements in genetic screening.

Improving healthcare for individuals with low numeracy

The final five chapters focus on helping individuals who have low numeracy skills. In Chapter 7, Garcia-Retamero and Cokely describe how visual aids such as line plots, bar charts, pies, and icon arrays can be used to improve people's ability to use and understand numeric information. Individuals who have low numeracy skills but have high graph literacy (i.e., ability to understand information in graph form) show significant improvements in understanding quantitative information when visual aids are used to communicate numeric information. They further show that visual aids can help to reduce or eliminate number-related biases and heuristics, and that they can be used in behavioral interventions to improve the clarity of information provided.

By addressing problems with communication, misunderstandings about numeric information can be corrected rather than perpetuated. The communication of numeric information takes place on many levels such as from a doctor to a patient, a television advertisement to the public, a government announcement to a patient, and so on. In Chapter 8, Peters discusses the communication barriers of the communicator, the consumer, and system.

Chapter 9 addresses healthcare systems. Paulus and Stewart discuss how the Geisinger healthcare system has been nationally recognized for providing high-quality healthcare at below average costs (www.geisinger.org/about/healthier). The Geisinger system values rigorous data collection through the use of health technology (e.g., electronic health records) in order to implement evidence-based practices and quality improvement. The authors discuss how numeracy research might be incorporated into these quality improvement efforts to improve performance and quality of care.

Another approach is to better understand the theoretical framework that explains how people understand numbers and how that understanding is associated with decision making. In Chapter 10, Reyna and Brust-Renck discuss the strengths and weaknesses of four theoretical frameworks and suggest directions for further theory development. The four approaches are: (1) our perception and distortion of numbers, as well as use of cognitive and neuropsychological data, (2) cognitive effort, memory, and the various ways that information can be organized, (3) examining the performance of two cognitive systems, fast and slow, and (4) how individuals utilize numbers by focusing on the meaning, or gist, of the numeric information.

In Chapter 11 Schwartz challenges whether it is beneficial to provide numeric information to all patients. Using research on numeracy and medical decision making, Schwartz discusses practical and ethical problems with providing numeric information to patients and addresses the challenging but important question about what information to provide patients. He ends the chapter with a discussion about how to study the impact of providing numeric information on the quality of patient decision making, and how these findings would inform the ethical concerns of limited disclosure.

Conclusion

This volume, which is the first to be published on numerical reasoning and decision making in health, examines the numeracy research from the perspectives of society, physicians, and patients. It also discusses the

theoretical and methodological aspects of numeracy research, and provides insights and advice from the leading experts on how to improve the problems caused by low numeracy.

This book will be a useful resource for professionals in diverse health-related fields including academics, policy makers, physicians, and other healthcare providers. For example, medical educators and healthcare administrators may find Chapters 2, 3, 4, 9, and 11 useful when developing hospital policies and adapting the healthcare environment to help patients with low numeracy skills. Healthcare providers may especially benefit from reading Chapters 2, 3, 4, 7, 8, and 11 when trying to better understand the impact of low numeracy skills and how they can help patients. Researchers working to apply numeracy research to specific areas of healthcare can utilize Chapters 5 and 6 as models for their work and Chapter 1 to choose a numeracy measure. The book is written for individuals at a wide range of knowledge levels. Those who are not familiar with the concept of numeracy will be provided with an up-to-date overview of numeracy research with Chapters 1–4. Those who are familiar with research on numeracy will enjoy the fresh insights into theory, policy, and approaches to helping low numerate patients that can be found in all chapters, but particularly Chapters 5–11.

Over the past decade there has been growing interest in how individuals' numeric ability impacts healthcare. This is because low numeric ability has been found to be a widespread problem, and because researchers are describing ways in which numeric ability is associated with medical decision making. This book is written for researchers, clinicians, patients, academics, students, health policy makers, and those interested in health disparities. It is aimed at the larger culture of scholarship with regard to the relationships between numerical reasoning and judgments and decisions about health and healthcare. In diverse ways the authors discuss how to improve numerical reasoning in health contexts, and gathering ideas about future research directions are primary goals of this book.

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