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The importance of mathematics in health and human judgment: Numeracy, risk communication, and medical decision making

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Abstract

Mathematics achievement is important in its own right, and is increasingly recognized as crucial to the nation's economy [National Mathematics Panel, 2006. National Mathematics Advisory Panel: Strengthening Math Education Through Research. Accessed September 29, 2006 from http://www.ed.gov/about/bdscomm/list/mathpanel/factsheet.html.; National Science Board, 2006. National Science Board Commission on 21st Century Education in Science, Technology, Engineering, and Mathematics. Accessed September 29, 2006 from http://www.nsf.gov/nsb/edu_com/.]. National surveys suggest that Americans are not proficient in mathematics and lack the kinds of numeracy skills that would seem to be necessary for tasks of everyday life such as informed medical decision making. Recent research on numeracy in medical decision making has shown that many adults fail to solve simple ratio and decimal problems, concepts that are prerequisites for understanding health-relevant risk communications. Along with research in education and cognitive development, this work demonstrates that adults have difficulty with a broad range of ratio concepts (including fractions, proportions, and probability judgments). Research confirms that this difficulty, as measured by content-neutral numeracy tests, predicts poorer health outcomes, less accurate perception of health risks, and a compromised ability to make medical decisions. We conclude that numeracy, so-called on analogy with literacy, is similarly essential for making health and other social judgments in everyday life, and that a new focus on explanatory theory is needed to address common errors in understanding and applying numerical information.
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In this article, we examine the current context for research on mathematical proficiency, also called "numeracy" (e.g., Paulos, 1989). This context includes low performance on national tests of mathematical achievement, especially relative to other nations, but high expectations for mathematical proficiency among the workforce in a technologically driven economy. Moreover, mathematical proficiency is essential for tasks of everyday living, beyond those required in the workplace. In health and medical decision making, in particular, understanding numerical information (e.g., about risks and outcomes of treatments) is literally a matter of life and death. Recent trends emphasizing patient-centered decision making and evidence-based medicine put a greater premium on understanding such information. That is, the burden of decision making has been shifted to patients, who need to understand numerical information about their own

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health, and physicians are now expected to base their practice on quantitative research. Although literacy has long been viewed as a basic skill essential to a minimal quality of life in a modern economy, facility with numbers has been seen as a specialized and optional skill. However, the latter assumption is rapidly yielding to the realization that numeracy is as basic a skill as literacy, despite the fact that many people confess to finding mathematics difficult and counter-intuitive (e.g., Reyna & Brainerd, 1993).

Fortunately, research exists on the psychological processes underlying numeracy that sheds light on sources of difficulty for most reasoners (see Reyna & Brainerd, in press). That literature pinpoints ratio concepts (e.g., fractions) as particularly challenging. Interestingly, when one examines the commonly used instruments to assess numeracy in health and medical decision making, they, too, center on fractions, decimals, percentages, proportions and other ratio concepts involved in understanding risks and probabilities. Hence, research literatures spanning cognitive development (on fractions, proportions, and probability judgment), judgment and decision making (on ratio bias), and health-related risk communication (on numeracy) all converge on similar conclusions about the difficulty of understanding ratio concepts. We discuss implications for the effective use of numerical information in risk communication, given these individual and group differences in numeracy.

1. The national context

1.1. National performance in mathematics

Mathematical proficiency is increasingly recognized as fundamental to economic success for individuals and for nations. To illustrate, on April 18, 2006, the National Mathematics Advisory Panel was established by Executive Order of the President of the United States. The Order begins: "To help keep America competitive, support American talent and creativity, encourage innovation throughout the American economy, and help State, local, territorial, and tribal governments give the Nation's children and youth the education they need to succeed, it shall be the policy of the United States to foster greater knowledge of and improved performance in mathematics among American students." One impetus for this Executive Order was the relatively low performance of American students on standardized tests of mathematical achievement (although overall performance improved between 1978 and 2004; Perie, Moran, & Lutkus, 2005). As shown in Fig. 1, the National Assessment of Educational Progress (NAEP), a nationally representative assessment of mathematical achievement, indicates that only 36% of fourth graders and 30% of eighth graders were proficient at grade-level mathematics in 2005 (Perie, Grigg, & Dion, 2005). As shown in Table 1, the ability to "show

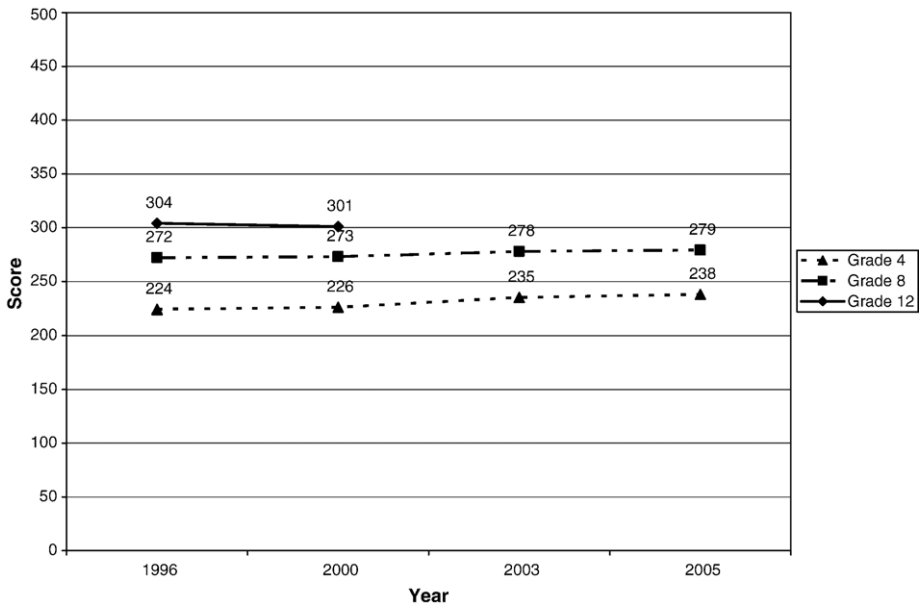

Fig. 1.

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