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Beyond Comprehension: The Role of Numeracy in Judgments and Decisions

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Abstract

When making decisions, people must frequently take into account numerical information, but not all individuals have the ability to understand and use numbers. Less numerate individuals comprehend less numerical information; but numeracy goes beyond comprehension, relating systematically to psychological mechanisms. In particular, greater numeracy has been associated with reduced susceptibility to framing effects, less influence of nonnumerical information such as mood states, and greater sensitivity to different levels of numerical risk. This greater number sensitivity has been linked with number-related affective reactions reported by the highly numerate. I briefly discuss methods to increase number use in decisions and policy implications of numeracy research.

Keywords

numeracy, decision making, judgments, risk perception, risk communication

Numerical information must frequently be considered when making decisions (consider stock prices, earthquake risks, calorie counts). But numbers can be difficult to evaluate because they are abstract symbols, and context changes their good/bad meaning (9ºF, $9 billion, 9% chance of a tsunami). They are provided nonetheless because they are intended (and assumed) to be useful. Having access to and understanding numbers is often considered a basic requirement for good decisions.

However, individual differences in number ability exist, and even highly educated individuals do not always comprehend numbers when making decisions (e.g., Lipkus, Samsa, & Rimer, 2001). Recent research suggests that people differ substantially in numeracy (defined as the ability to understand probabilistic and mathematical concepts), and many people are "innumerate." Results from the National Adult Literacy Survey indicate that about half of Americans lack the minimal skills necessary to use numbers embedded in common printed materials (e.g., only 48% of this nationally representative sample could calculate correct change from menu prices). Potentially vulnerable populations (including Hispanics, African Americans, adults 65 years and older, and poorer and less educated adults) attained lower average scores; females scored lower than males (Kutner et al., 2007).

Numeracy abilities are related to, but separable from, general intelligence. Inferior-parietal lesions can destroy numerical knowledge without impairing nonnumerical knowledge (Dehaene, 1997). Retired bookkeepers and accountants with age-related declines in nonnumerical memory had similar numerical memory to young adults (Castel, 2007). Numeracy's effects can be examined when controlling for other proxies of general intelligence (e.g., SAT scores; Stanovich & West, 2008).

Numeracy itself is assessed with objective measures (used in the present reported studies; Lipkus et al., 2001) and subjective measures (e.g., "How good are you at working with percentages?"; Fagerlin, Zikmund-Fisher, et al., 2007). Subjective measures are generally faster and less stressful for participants but have questionable accuracy (Dunning, Heath, & Suls, 2004).

Beyond Comprehension

Numeracy goes beyond number comprehension, influencing the processing of numerical and nonnumerical information. This article discusses recent research concerning differences between more and less numerate individuals in how they process and use information in judgments and decisions. In particular, greater numeracy has been associated with reduced susceptibility to framing effects, less influence of nonnumerical information, greater sensitivity to numbers, and stronger, more precise number-related affect.

Transforming numbers and framing effects

Results of framing studies demonstrate that information providers can influence decisions without distorting information,

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merely by framing numeric outcomes in normatively equivalent formats (Levin, Schneider, & Gaeth, 1998). Highly numerate individuals, however, may be more likely to know, retrieve, and use appropriate numerical principles. Thus, they should be more likely to transform given information frames into normative equivalents and be less susceptible to framing effects compared to the less numerate. Peters et al. (2006) asked participants to rate the work quality of undergraduates described in positive frames (e.g., Emily got 74% correct) or negative frames (e.g., Emily got 26% incorrect). As hypothesized, highly numerate decision makers showed significantly smaller framing effects than did the less numerate, who rated work quality substantially higher in the positive than in the negative frame.

Risk communicators also make choices about presenting statistical likelihoods of adverse consequences; again, normatively equivalent formats elicit different responses. In particular, greater risk is perceived when situations are described in frequentistic formats (e.g., 10 of 100 mental patients are estimated to commit violence) than when they are described in probabilistic terms ("10%" substituted for "10"). When available, the frequentistic format is thought to elicit frightening images of the risk whereas the percentage format elicits more abstract thoughts about small chances (Slovic, Finucane, Peters, & MacGregor, 2002; although see Reyna, Nelson, Han, & Dieckmann, 2009). Peters et al. (2006) hypothesized and found that highly numerate individuals were not susceptible to this effect, presumably because they transformed numbers from the provided format into an equivalent format (e.g., from "10% out of 100" to "10 out of 100") and had both formats available. Less numerate participants perceived greater risks with frequencies than with percentages (see also Dieckmann, Slovic, & Peters, 2009; Peters, Hart, & Fraenkel, 2011). Numeracy's effect remained significant when SAT scores were controlled for.

Information in decisions appears to be processed using two different modes of thought: an analytical mode (e.g., presumably active in number transformations) and an intuitive mode (e.g., Loewenstein, Weber, Hsee, & Welch, 2001; Stanovich & West, 2008). Evidence suggests that good judgments and decisions (and bad ones) can emerge from either mode depending on characteristics of the task and decision maker (Epstein, 1994; Slovic & Peters, 2006). Whereas the intuitive mode is highly effective but sometimes biased, the analytical system often generates good decisions but can result in "poorer judgments [than] intuitive impressions" (Epstein, 1994, p.719). Highly numerate individuals understand numbers and numerical principles better and appear more likely to apply those mechanics in decisions. They also rely on their superior number intuitions (e.g., Halberda, Mazzocco, & Feigenson, 2008; Peters, Slovic, Västfjäll, & Mertz, 2008). Reyna et al. (2009), in fact, theorize that with greater numeracy comes more reliance on number-related intuitions. Less numerate decision makers rely more instead on nonnumerical information and are more susceptible, for example, to the framing and format effects previously described.

Influence of nonnumeric information

Decisions often require taking into account competing numerical and nonnumerical information (e.g., taste vs. calories; luxury vs. cost); how one resolves these conflicts can have important consequences. Numeracy appears to moderate the relative influence of these forms of information, with less numerate individuals influenced more by nonnumerical information.

In one study, judgments of the less numerate about hospital attractiveness were influenced more by their moods than were those of the highly numerate (i.e., how good or bad the less numerate reported feeling immediately prior to the experiment was associated with higher and lower attractiveness, respectively). The ratings of the highly numerate were correlated instead with a numerical-quality indicator. In another study, Västfjäll, Peters, and Starmer (2011) experimentally manipulated mood prior to asking participants to price a lottery ticket. Less numerate participants were influenced more by the mood induction, providing higher prices in the positive-mood condition than in the negative-mood condition.

In a conceptually-related paper, Dieckmann et al. (2009) presented highly educated participants with three terrorism forecasts, one at a time. In each, an intelligence forecaster provided both narrative evidence concerning a possible terrorist attack (e.g., a foreign newspaper printed a militant group's warning of an attack) and a summary likelihood assessment (1%, 5%, 10%). The order in which participants read the three narratives was counterbalanced across participants as was the order of the likelihood assessments; as a result, narratives were paired with different likelihood assessments across participants. After each forecast, participants rated the narrative's credibility and coherence and rated how likely they perceived the possible attack. As predicted, less numerate individuals were insensitive to the numerical risk assessments provided. Their likelihood perceptions instead were associated with their rated perceptions of the narratives; the more credible and coherent the evidence appeared, the more likely they rated an attack. The highly numerate were less sensitive to perceptions of the narratives and rated the likelihood of an attack as higher when its provided numerical risk assessment was higher.

These results are consistent with the idea that less numerate decision makers are influenced more than the highly numerate by nonnumerical, often emotional, information that competes with numerical information. Compared to the less numerate, highly numerate individuals instead appear more sensitive to decision-related numbers.

Influence of numeric information

Of course, hypothetical studies may not be meaningful enough for less numerate decision makers to expend effort to use their more limited mathematical abilities. Lipkus, Peters, Kimmick, Liotcheva, and Marcom (2010) turned to a consequential decision in which all participants presumably were motivated to process and use provided numerical information. Specifically, participants were 105 women with early-stage breast cancers faced with a treatment decision to prevent possible cancer recurrence. Personalized 10-year survival estimates for four treatments were provided, and numeracy's association with efficacy perceptions was explored. Similar to the findings of earlier studies that used hypothetical scenarios, perceptions of more numerate patients were significantly more sensitive to these statistics than were those of the less numerate, whether patients responded on a numerical-likelihood scale or a non-numerical, subjective-benefit scale. Numeracy appears to influence abilities to interpret and use numbers even in consequential situations.

An interesting question is whether highly numerate decision makers' greater sensitivity to numbers is based on normative analysis or on intuition. Cokely and Kelley (2009) presented participants with 40 hypothetical choices between certain and risky options (e.g., \$125 or 30% chance to win \$900). Consistent with normative theory, highly numerate individuals made more high-expected-value choices—that is, preferring a higher-expected-value gamble, such as .3 × \$900 (\$270) over \$125. However, based on coding of retrospective verbal protocols, such individuals' choices appeared rarely to result from expected-value calculations. Instead, numeracy's relation with choice was mediated by the number of simple (often number-related) considerations made (e.g., number comparisons, such as "\$900 is a lot more than \$125"; probability transformations, such as 20% chance to win equals 80% to not win). Individuals who retrospectively verbalized more considerations also took longer to make a choice.

Additional studies should explore how numeracy influences depth of number processing in decisions. Individuals all may process the gist of information more than its verbatim meaning (Reyna, 2004), but highly numerate individuals may derive a richer gist from numbers (including their affective meaning), because they extract number magnitudes more readily, use early controlled processes that qualitatively change intuitive output (Jacoby, Shimizu, Daniels, & Rhodes, 2005), or desire greater accuracy with numbers and expend more effort (Payne, Bettman, & Johnson, 1993).

Affective meaning and numeracy

Denes-Raj and Epstein (1994) demonstrated that, with a chance to win a prize by drawing a red jellybean from a bowl, participants often elected to draw from a large bowl containing a greater absolute number, but smaller proportion, of red beans (9 in 100, 9%) rather than from a small bowl with fewer red beans but a better winning probability (1 in 10, 10%), even with the probabilities stated beneath each bowl. The authors of the study interpreted their findings as due to affective images of nine winning beans in the large bowl dominating the small bowl's superior, explicitly-presented (but abstract) 10% chance. Reyna and Brainerd (2008) argue instead that confusion in part–whole relations in the bowls results in denominator neglect, a "minor mental book-keeping confusion rather than a fundamental flaw" (p. 95). Availability of the explicit probabilities presumably should eliminate this confusion. However, the less numerate may attend less to and draw less precise affective meaning from a comparison of explicit probabilities and make worse choices. Consistent with this, Peters et al. (2006) found that 33% and 5% of less and more numerate adults, respectively, chose the larger, inferior bowl. The choice effect remained significant even when controlling for SAT scores. In addition, compared to the less numerate, the highly numerate reported greater affective precision about Bowl A's 9% chance ("How clear a feeling do you have about [its] goodness or badness?"); their affect to the inferior 9% odds ("How good or bad does [it] make you feel?") was directionally more negative. Peters et al. (2006) concluded that an affective process may underlie their greater number use.

If that conclusion is correct, then highly numerate individuals may sometimes overuse numbers and respond less rationally than the less numerate. In Study 4 of Peters et al. (2006), one group of participants rated the attractiveness of a no-loss gamble (7/36 chances to win \$9; otherwise, win \$0) on a 0 to 20 scale; a second group rated a similar gamble with a small loss (7/36 chances to win \$9; otherwise lose 5¢). Participants also rated their affect and affective precision to the \$9 on the scales described in the paragraph above. The experimenters hypothesized and found that highly numerate participants rated the objectively worse bet as more attractive and reported more positive affect and more precise affect to the \$9 (they had a more positive and a more clear feeling about the \$9) in the loss's presence. Affect partially mediated the relation between the numeracy-by-condition interaction and attractiveness. Thus, although greater numeracy usually leads to better decisions when numerical information is involved, it appears associated sometimes with an overuse of number comparisons. Note, however, that these particular results could indicate that the small loss allowed the highly numerate to become sensitive to the monetary outcome and appreciate the bet's value—a superior judgment (Bateman, Dent, Peters, Slovic, & Starmer, 2007).

As Shakespeare's Hamlet once said, "there is nothing either good or bad, but thinking makes it so" (Edwards, 1985, 2.2.247–248); highly numerate individuals may think more about numbers than do the less numerate, with this thinking influencing affective reactions and judgments. The results demonstrate the malleability of the meaning, utility, and weighting of even very familiar monetary outcomes. We may have \$9 in our back pockets, but because numbers are abstract symbols, we may not use those numbers until their meaning is derived through comparison with another number; highly numerate individuals appear more likely to compare numbers and/or derive affect from the comparison.

Increasing Number Use

In general, highly numerate decision makers make better decisions than the less numerate when numbers are involved; they also respond more consistently than less numerate individuals across normatively equivalent formats. The less numerate demonstrate lower comprehension and greater preference reversals across these same formats. In the short-term, information providers can improve number use, particularly among less numerate consumers, by

- requiring less cognitive effort (e.g., reducing the number of attributes or options in a single decision to increase comprehension and sensitivity to numeric risk levels; Peters, Dieckmann, Dixon, Hibbard, & Mertz, 2007; Zikmund-Fisher, Angott, & Ubel, 2011)
- labeling numbers' evaluative meaning (e.g., labeling numbers as "poor" or "excellent"; studies have demonstrated that, compared to their absence, the presence of labels facilitates information integration and alters choice. Labels did not significantly influence verbatim or gist recall for numbers, but did increase the relative accessibility of feelings versus thoughts about the options; Peters et al., 2009)
- supplementing numeric information with visual representations (e.g., pictographs and other graphical displays that allow each class in a part–whole relation to be represented discretely, Garcia-Retamero & Galesic, 2009; Reyna & Brainerd, 2008; this must be done carefully as all visual representations do not work equally well; see reviews by Fagerlin, Ubel, Smith, & Zikmund-Fisher, 2007; Lipkus, 2007).

In the longer term, the ultimate nudge toward improving number use may be more years of formal education (Nisbett, 2009) or greater statistical education (Fong, Krantz, & Nisbett, 1986). Results from a Ghanaian field study, for example, suggested that more years of formal education were associated with greater uptake of HIV-related protective-health behaviors (e.g., condom use) and more knowledge about HIV/AIDs risks. In a structural-equation-model analysis, education's effects were mediated by numeracy, cognitive abilities, and decision-making abilities (Peters, Baker, Dieckmann, Leon, & Collins, 2010). Thus, education may have long-term effects, in part through numeracy, that influence risk perceptions, decisions, and behaviors (see also Bruine de Bruin, Parker, & Fischhoff, 2007; Stanovich & West, 2008). Future experimental research should attempt to disentangle aspects of education (e.g., numeracy, cognitive abilities, decision abilities) that have the greatest promise for promoting better decisions.

Conclusions

Numbers are merely abstract symbols. Numeracy research suggests that decision makers may not use numbers until available data are compared and contrasted to determine their affective meaning or until the data acquire meaning, such as through evaluative labels. When numerical information is not used in decisions, competing sources of nonnumerical information may be substituted instead, particularly by less numerate individuals. Numeracy appears to matter in decisions, even among highly educated populations and after controlling for proxies of general intelligence.

This research has implications for the success of public policies aimed at controlling costs and improving quality through the power of the informed consumer. With more information and choices available than ever before, decision makers should be able to increase control over their life experiences and outcomes. But, choices are often difficult, numerical information is not always transparent, and education can be inadequate. As a result, less numerate populations may not accrue the same benefits from choice opportunities that highly numerate individuals do. This difference has the potential to increase health and wealth disparities if ignored.

Recommended Reading

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Peters, E., Hibbard, J. H., Slovic, P., & Dieckmann, N. F. (2007). Numeracy skill and the communication, comprehension, and use of risk and benefit information. *Health Affairs, 26*, 741–748. Provides a discussion of methods to make numeric risk and benefit information more transparent to individuals who differ in numeracy.

Peters, E., Västfjäll, D., Slovic, P., Mertz, C. K., Mazzocco, K., & Dickert, S. (2006). (See References). One of the first papers to raise attention about the role of numeracy in decision processes.

Reyna, V. F., Nelson, W. L., Han, P. K., & Dieckmann, N. F. (2009). (See References). A clearly written, relatively comprehensive review for readers who wish to expand their knowledge about numeracy and its influence in health risk perceptions and decisions; also relates findings to various dual-process-theory predictions.

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