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Do the Math

Review of 'Innumeracy in the wild:
Misunderstanding and misusing numbers'
by Ellen Peters

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(excluding references)

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> *Less depends upon the choice of words than upon this, that their introduction shall be justified by pregnant theorems*. – Carl Friedrich Gauss (1827) on the primacy of numeracy over literacy[1]

With Roman letters and Arabic numerals being the two preponderant symbol systems in most parts of the world, it is natural for psychologists to track individual differences in the mastery of these codes and to study the consequences of low (vs. high) levels of ability and skill. Innumeracy has thus become the companion of illiteracy. As some people have trouble reading and writing well, so do many have trouble running the numbers. Just like illiteracy is associated with poverty and poor education, so is innumeracy. Just like illiteracy begets disadvantages and inhibits progress in life, so does innumeracy. In his best-selling book, John Allen Poulos (1988) popularized the term 'innumeracy,' characterizing it explicitly as 'mathematical illiteracy' in the book title's byline. Poulos, a highly literate mathematician, relied mainly on compelling anecdotes. He argued that innumeracy is both hilarious and dangerous. He sought to educate. Better to laugh a little less but be safe.

Ellen Peters, a distinguished professor of Journalism and Communication at the University of Oregon, provides an overview of the state of the art of innumeracy research in her "*Innumeracy in the wild: Misunderstanding and misusing numbers*." Peters builds on Poulos's legacy by situatinginnumeracy within the web of contemporary psychology of judgment and decision making. Peters has more than 20 years of pertinent research under her belt. Her collaboration with Paul Slovic and others on the *affect heuristic* has become highly influential (Slovic, Finucane, Peters, & MacGregor, 2002). She has published many research

[1] This quote can be found here: https://en.wikiquote.org/wiki/Carl_Friedrich_Gauss

articles on (in)numeracy and the numerate may count the references in her book. I settle for the qualitative term "many."

In 2012, Peters published an introduction to research on innumeracy in the *Current Direction in Psychological Science*. At the time, her five main points were the following. First, individuals low in numeracy (the *innumerati* as it were) are more likely to fall prey to attribute framing effects (e.g., by falsely seeing a difference between a product said to contain 5% fat and one said to be 95% fat-free). Second, the innumerate are more likely to visualize scary but improbable events when these events are presented with the absolute frequencies with which they occur. Third, their judgments and decisions are more likely affected by incidental moods not relevant to the task. Fourth, they are more easily persuaded by information (true or false) that is presented in narrative instead of numerical form. Fifth, and not surprisingly, the innumerate have greater trouble computing – or even intuitively estimating – expected values.

The findings reported in 2012 still form the core of the story. The research base has become broader, though, and in Peters now raises additional questions of theoretical importance. The structure of the book might have been more effective. With a little sorting, we can distill these five issues related to conceptualization, measurement, causality, anomalies, and advice. Let's consider these issues in sequence.

Conceptualization

Peters distinguishes among three constructs, one of which is numeracy proper. This is what she calls *objective numeracy* and she defines it as "the ability to understand and use basic probability and mathematical concepts" (p. 5). Next, there is *subjective numeracy*, which is individuals' own – non-psychometric – assessment of their own numeracy, defined

as “a person’s confidence in her ability to understand numeric information and use mathematical concepts” (p. 9). It becomes clear that the latter cannot work as a proxy of the former. For an analog, see the interplay of confidence and ability in performance prediction (Krueger & Heck, in press). The main implication of an imperfect correlation between objective and subjective numeracy is that the law of regression guarantees specific discrepancies (Fiedler & Krueger, 2012). People are most likely to overestimate their own numeracy when their objective numeracy is very low or when their subjective numeracy is very high. Finally, there is the intuitive number sense, arising from the *approximate number system* (ANS), which is an evolution-grounded capacity to make ordinal distinctions among small numbers or volumes. Peters weaves discussions of the ANS into her narrative and dedicates a whole chapter to it in the middle of the book. One might have preferred to see a brief review of the ANS early on and then to let it go. The ANS is a building block of numeracy proper but it plays a minor role in the life-and-death decisions Peters is ultimately concerned about.

Numeracy proper intersects uncomfortably with the popular two-systems paradigm in the psychology of judgment and decision-making. Peters works in this tradition, and she tries to make it fit. Why does she not quite succeed. There are two difficulties. First, there is no single coherent two-systems theory. Any talk of a two-systems “architecture” of mind is somewhat loose and metaphorical, as Kahneman (2011) himself conceded (see Krueger, 2012, for a review). There are many parochial two-systems theories, whose architects squabble among themselves about the relative merits of their theories, providing a united front only when the very idea of two systems is being challenged. One might then expect a commitment, *expressis verbis*, which two-systems theory is being considered. Peters appears

to favor Epstein's (1990) cognitive-experiential self-theory. This is a sensible choice as Epstein recognized the complex role of affect in decision-making and the relevance of personality-based individual differences.

This theoretical heritage could have been made clearer. Readers bringing the usual two-systems expectations are otherwise left to puzzle over how individual differences intersect with systems of thought. An – admittedly heuristic – characterization of the generic two-systems ideology is that system-one thinking is intuitive, fast, reflexive, affective, etc., whereas system-two thinking is analytical, slow, reflective, cognitive, etc.. Alas, these features are not neatly cluster into two camps, as assumed by the two-systems metatheory (Melnikoff & Bargh, 2018). At least, in Epstein's theory, it makes sense to explore individual differences in experiential (System 1) and cognitive-reflective (System 2) reasoning. Yet, most two-systems approaches treat system-one thinking as a matter of 'general psychology,' not 'differential psychology.' Tversky and Kahneman (1974) set the tone when equating cognitive errors with optical illusions. This rhetorical flourish is problematic because it implies that poor thinking is irredeemable (Krueger, 1998). It places the burden of making corrections on System 2. Slow thinking yields nothing but afterthoughts, but still, researchers are free to explore individual differences in how well people are able to think these afterthoughts.

Measurement

Working in the tradition of Epstein, Stanovich, and Fischhoff, Peters treats numeracy like a personality trait (Bruine de Bruin, Parker, & Fischhoff; Stanovich & West, 2000). She notes its heritability and its amenability to improvement through hard work. The elephant in the room is general intelligence. Assuming that we know that general intelligence is and how

it is best measured (questions that remain open to debate after more than a century), we wonder whether numeracy is a distinctive mental trait or a special kind of sub-intelligence. Peters favors the latter. This is a sensible view; it would be refuted only if correlations between intelligence and numeracy were extremely high or very low or negative. How high are they? The book reveals little. Peters ask repeatedly whether numeracy predicts (negatively) decision errors and life outcomes independently of intelligence. Any evidence of incremental predictive validity vindicates numeracy, although one would still want to know whether numeracy is a stronger or weaker predictor than general intelligence. Some studies show no incremental validity. Peters is undeterred because numeracy might be related to the outcomes by way of its association with general intelligence. By this standard, a rejection of the numeracy hypothesis would require negative correlations with outcomes.

While treating numeracy as a mental trait is generally a sound strategy, Peters acknowledges some open psychometric questions. Numerous numeracy scales exist. Some of this material is presented in the appendix, giving readers an opportunity to reflect on the contents of the construct and to test themselves. A brief review of scale development research and its outcomes (e.g., estimates of reliability) would have been welcome.

Causality

Correlations between numeracy and rational decision-making or desirable life outcomes are one thing; causality is another. There would be – one assumes – no book if there was not enough evidence to make the causal claim at least plausible. It is notoriously difficult to extract causal mechanisms from correlational data, although it might be possible to do this more effectively than previously thought (Grosz, Rohrer, & Thoemmes, 2020). All told, the notion that the more numerate make better medical and financial decisions would

almost have to be true lest the construct had no validity. Peters (p. 115) concludes that "we know by now that the more objectively numerate are better decision makers than the less numerate," and she defends the claim that numeracy causes good decisions. Experimental studies are rare and hard to do because at the limit, they would require manipulations of a personality trait. To appreciate this difficulty, ask how you might demonstrate the causal force of intelligence in an experiment, in which half of the participants are temporarily made more intelligent. This leaves natural experiments of the type that can be done when differences in schooling occur. Peters does not say as much, but one wonders if some of the education in mathematics, as it exists today, should be replaced by courses that directly target the mitigation and elimination of innumeracy.

A more delicate question is whether subjective numeracy causes better performance. Subjective numeracy is to objective numeracy (numeracy proper) what confidence is to ability. A review of Moore's (2020) book on confidence research provides a sketch on how the two are related (Krueger & Heck, in press). It is very difficult to demonstrate that confidence *per se* has a causal effect. If people are underconfident, that is, if they think they are less numerate than they actually are, raising their confidence may allow them to perform at levels corresponding to their ability. Then, however, the question remains what the cause was: the increase in confidence or actual ability. If people are overconfident, failures are more likely than successes, where the latter should not occur given that true ability was not up to the task. Confidence alone cannot cause good outcomes and Peters (p. 173) concedes that "persisting more on an impossible task is wasted effort." When persistence pays off, it does so in settings where subjective numeracy is lower than objective numeracy.

Anomalies

Peters's master narrative is that numeracy is useful and benign. The data are largely consistent with this view. There are exceptions, though, and it is worth asking whether these exceptions are random or whether they are anomalies pointing to a more nuanced psychological reality. Anomalies, after all, cease to be anomalies when there are many of them. Peters finds several domains where high numeracy yields poor outcomes. Some numerical problems fool everyone, which recalls the old optical-illusion metaphor. Other problems make it look like the highly numerate explicitly compute expected values, when in fact they seem to rely on simple (heuristic!) cues. Still other problems stimulate confirmation bias, considered by some to be the mother of all cognitive sins. When the highly numerate are most likely to bend the evidence to their wishes, one should take note. Perhaps what we see is an intrusion of Machiavellian intelligence (Bereczkei, 2018). These complexities caution against any hasty equation of numeracy with System 2 thinking and innumeracy with System 1 thinking.

Advice

Having made her case for the causal power of numeracy, Peters dedicates four chapters (15 – 18) to the mitigation of innumeracy. A more numerate world would be heathier, wealthier, and happier, or so it is hoped. There is a suite of potential interventions, ranging from sensible communication and "information architecture," to the replacement of numbers with adequate words and stories, to the use of compelling visuals, and of course to more schooling. Only the latter strategy confronts innumeracy head-on. The other strategies, though promising, are designed to bypass innumeracy and thereby conceal its presence. Surprisingly, Peters overlooks the burgeoning literature on "nudging" and its less paternalistic cousin of "boosting" (Hertwig & Grüne-Yanov, 2017), which have evolved to

address some of the same issues presented here as instances of innumeracy (e.g., attribute framing effects).

Conclusion

Innumeracy in the wild is a timely and important book. Although there are some conceptual and structural concerns, Peters delivers an up-to-date review of the available research. The importance and the potential dangers of innumeracy are still not as evident to large sections of the public as they should be. As Peters notes, it is easier to joke about one's lack of mathematical understanding than about one's lacking reading skills. Alas, we still have gallows humor. Consider President Donald Trump, who, in a televised interview on 3 August, 2020, failed to grasp the difference between the death rate relative to the number tested and the death rate relative to the size of the population (Krueger, 2020). The President argued that the high number of tests for COVID-19 put the United States in a negative light in international comparison. He failed to see that reducing the number of tests would not affect the proportion of the population that has died, and that, in fact, reduced testing would increase the proportion of dead relative to the tested, thus making the United States look *worse*. Numeracy sought!

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