* Although numeracy was initially described as a unidimensional construct, more recent research suggests that it is more complex. For example, measures of subjective numeracy predict different behaviors than measures of objective numeracy, and research by Ellen Peters unpacks numeracy into numeric confidence and ability. Further, there are criticisms that measures of numeracy are conflated with literacy and logic given that numeracy is often assessed via word problems. Review the various measures of numeracy and discuss their predictive validity, considering a larger umbrella of related constructs including health literacy (which often involved comprehension of numerical information) and graph literacy. Which measure (or measures) would you recommend including in studies of medical decision making? (these recommendations may differ by context)

Comprehensive Exam Answers: Victoria Shaffer

What measurements of numeracy exist? (objective, subjective, numeric confidence, word problems, etc.)

Understanding of numerical information is vital in many fields, however, given that cross-communication in differing fields of research is not yet widespread and thorough, many different measures of numeracy therefore exist. It is important to note that for these various measures of what is considered under the umbrella macro-construct of ‘Numeracy’, that in many cases, they are measuring slightly different concepts. A brief review of some of the various measures of numeracy in contemporary literature follows.

One of the original measurements of numeracy in the field of psychometric measurement, Subjective numeracy is also seen as one of the easiest ones to measure (Thompson, Mielicki, Rivera, Fitzsimmons, Scheibe, Sidney, Taber, and Waters 2022). Subjective numeracy is defined by Dr. Angela Fagerlin as the “self-assessment of quantitative ability”. As subjective numeracy relies on a self-assessment and not on actual mathematical calculations, the measure can be administered more quickly, and is easy to adapt for digital use (Fagerlin, Zikmund-Fisher, Ubel, Jankovic, Derry and Smith 2007). It is noteworthy that the Subjective numeracy, as measured using Fagerlin’s Subjective Numeracy Scale (SNS), is significantly correlated with the Lipkus objective numeracy scale, yet regularly is seen by participants as both less stressful and less frustrating to complete. Regarding practical applications, high subjective numeracy scores don’t just measure self-assessment about the ability to work with fractions and percentages, but ‘numerical confidence’ as well (Peters, Tompkins, Knoll, Ardoin, Shoots-Reinhard, and Meara 2019). This numerical confidence even has an interaction effect with actual numerical ability, as Peters research on financial and medical outcomes indicates. Humans with high confidence and ability, have the best financial and medical outcomes, and those with high confidence and low ability, have the worst outcomes. Independently, low subjective numeracy also predicts less persistence with difficult or impossible mathematical problems.

Another of the early measures of numeracy in the field of psychology, Objective numeracy, defined as “The ability to understand and use probabilistic and mathematical concepts”, has been used by psychologists to develop greater understanding of risk communication, especially how it relates to healthcare (Tompkins 2015). Subjective numeracy has generally been measured through various calculation exercises that consist of word problems and/or interpretation of tables (e.g., “If the chance of getting a disease is 10% how many people would be expected to get the disease out of 100?”; Lipkus, Samsa, Rimer, 2001). Some examples include the Lipkus Objective Numeracy Scale, the Rasch Numeracy Scale, and the Berlin Numeracy Test. In contrast to ‘subjective’ numeracy, objective numeracy is seen as more difficult and time intensive to measure. Considering these issues, why would we care to measure subjective numeracy? According to Organization for Economic Co-operation and Development (OECD) data, approximately a third of adult Americans are unable to locate basic quantitative data and utilize it to solve problems as simple as adding two numbers together (OECD, 2013). While numeric confidence doesn’t necessarily have to be tied to ability, we still need data on actual ability, and objective measures of calculation should exist to capture that nuance.

It is important to note that the field of psychometrics does not have a monopoly on the concept of measuring numerical ability; Math cognition researchers have been measuring what many psychologists would consider Numeracy under the broader umbrella of “Math Cognition Measures” for decades. These consists of several measures from the field of math cognition that directly measure various sub-elements of numerical cognition skill. General magnitude understanding, for example, can be operationalized as precision when estimating values on a number-line, with larger percentage of absolute error indicating worse numerical ability. Precise understanding of large magnitudes is tested by determining where to place a 1-million-unit marker on a line between zero and 1 billion (shockingly, as many as half of adults incorrectly believe one million sits at the midpoint between 0 and 1 billion; Landy, Silbert, and Goldin 2013). Ability to reason with fractions and ratios understanding more generally, can be tested by arranging a mix of various irregular fractions into correct order. Accuracy in comparing magnitudes can be tested by briefly looking at two fractions and being asked to select which one was the largest, greater correct proportions indicate better numerical skill at assessing relative magnitude. Arithmetic accuracy is generally measured with three sub-measures, fractional arithmetic, whole number arithmetic, and multi-step arithmetic. Fractional arithmetic is assessed with performance on basic addition, subtraction, multiplication, and division, involving one whole number and one fraction, in operation with each other. Greater accuracy indicates more fractional arithmetic ability. Whole number arithmetic is assessed with a ‘race’ to complete as many two-digit whole-number arithmetic problems as possible, split evenly between addition, subtraction, and multiplication. Greater volume of answers completed correctly indicates more whole number arithmetic fluency. Multi-step arithmetic is assessed with problems wherein common denominators for numbers need to be determined, and then these fractions need to be added or subtracted to each other. Again, greater accuracy indicates more multi-step arithmetic ability. There are many advantages of “Math Cognition Measures’, that is in contrast to measures of objective numeracy designed by psychometricians. One large advantage is that many of these math cognition measures can work perfectly fine with natural numbers (positive integers), whereas the fractions and percentages needed for many measures of objective numeracy can often be more confusing (Thompson 2022). Furthermore, many objective numeracy measures are presented using word problems (e.g. “In the BIG BUCKS LOTTERY, the chances of winning a $10.00 prize is 1%. What is your best guess about how many people would win a $10.00 prize if 1,000 people each by a single ticket to BIG BUCKS?”), which means that there are additional non-math barriers to solving the problem, making it difficult to disentangle the ‘pure’ effect of mathematical ability. Math cognition researchers furthermore believe that the psychometric objective and subjective measures of numeracy predict health-decision choices so well because they all relate to the fundamental mathematical ability of understanding various ratios. We can see that the existing objective measures directly assess the ability to calculate with ratios, and the subjective measures comprise entirely of self-assessments about one’s willingness to work and understand ratios. Medical decision making regularly involves rational numbers and requires judgement of risk, for oneself and others. Given these characteristics, direct “Math Cognition Measures” that address these can be seen as particularly valuable.