* 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.)

* Objective
  + Thompson 2022:
    - Number researchers and psychologists use different terminology/measures to assess obj numeracy.
      * Psychologists often use Rasch scale or Berlin test, which require calculation to solve, instead of using ‘natural numbers’
      * Additionally, these problems are seen as word problems, which are hard to understand and result in ‘impulsive calculation’
      * “When people read a math problem and immediately begin solving it before trying to make sense of the underlying structure of the problem”
    - Obj numeracy is predictive of health-decision making because these scales measure understanding of ratios:
      * Composed of items that assess ability to calculate ratios, vital for health decisions.
    - Number researchers often use number line estimation task, measuring adults symbolic number mappings, this means we don’t need calculation, and we DIRECTLY measure the ‘ratio understanding’ vital to decision making.
  + Asdfasdf
  + Asdfasdf
* Subjective
  + Peters 2019: numeric confidence is seen as just as vital
    - Has an interaction effect, high confidence/ability = best outcomes, but high confidence/low ability = worst outcomes
    - Less confidence = less persistence.
    - Ideally, should try to increase both equally, not one or the other individually.
  + Thompson 2022: Psychologists use SNS because it self-reports math ability without needing to calculate answers, and is quick to administer
    - Subjective scale has self-assessment about ability to work with fractions and percentages.
* Word problems
  + SFSDFSDFSDF
  + SDFSDFSDF
  + SDFSDFDF
* Innumeracy
  + Thompson 2022: Leveraging Math Cognition to Combat Health Innumeracy:
    - Argues that all ‘innumeracy’ is ‘natural number bias’
    - “Tendency to apply knowledge about natural numbers to all numbers, is underlying other biases behind decision making.”
* “Math Cognition Measures”: From Thompson 2021/22, several measures from math cognition field that directly measure various sub-elements of math skill
  + Number line
  + Magnitude comparison
  + Arithmetic
  + Multi-step Arithmetic

What is the predictive validity/value of measures of numeracy?

Innumeracy in the Wild: More subjective numeracy predicts greater confidence in using math skills, and willingness to use them more often. Has value in

Numeracy and the ACA: Opportunities and Challenges: The more numerate you are, the more accurate your estimates of risk are when given factual information about the odds.

Thompson 2022: Performance on the Number Line test (hard obj num measure), correlated with future overall math achievement, and we avoid the problems w/ word problems! Also predicts health decision-making performance, above and beyond objective and subjective measures commonly used in psychology.

Siegler 2012: Weak numeracy earlier in life relates to poorer math performance in later childhood

Peters 2019: Less numeric confidence = engage less and persist less with numeric information, understand it less well, and make less actions in number-heavy decisions, and make normatively ‘worse’ choices. More objective numeracy = makes better choices than less numerate, thinks longer using numbers, trust numeric information more. The less objective numerate = vulnerable to decision heuristics/shortcuts, framing effects, etc.

Objective numeracy = better health behaviors and outcomes, more protective health behaviors (e.g. exercise or condoms),

Gakumo 2016: Studied health numeracy (subcomponent of numeracy) and patient/provider communication for older African Americans with HIV. The patients themselves know that the #’s are important! Accurate recall of these values correlated highly with

Thompson 2021: Greater accuracy in understanding of ‘magnitude’, multi-step arithmetic, and lower math anxiety predicted greater health-decision making accuracy. Conversely, in a non-health context, greater ‘attentiveness’ to math was the only significant predictor!

Important! The reliable and valid measures of objective math cognition measures, which were easier and quicker to administer, and did not require word problems, were predictive of success, whereas the traditional measures of objective and subjective numeracy (Fagerlin Subjective Numeracy Scale, Rasch-based objective numeracy scale). This is ESPECIALLY important in contexts of medicine, and these ways of portraying questions.

Petrova 2018: Study directly on how numeracy (for both patients and physicians) affects communication during cancer screening.

* Physician numeracy can be relatively weak and does lead to some issues
  + Worse medicare recommendations, inaccurate inferences, and inability/reluctance to communicate numerically with patients.
* Physicians with the highest (v. lowest) numeracy in the sample had 7 times the odds of offering complete and balanced information about screening to patients – an effect size indicating high clinical relevance. Specifically, they were more likely to communicate mortality rates and risks from overtreatment.
* Physicians with higher numeracy were also less likely to mistakenly believe that increased detection or survival rates from screening show that screening saves lives

Ciampa 2010: Those with low subjective numeracy are more likely to perceive that they receive low-quality provider communication. Those with low objective numeracy report actually higher likelihood of their communication needs being met (doesn’t know what they’re missing?)

Garcia-Retamero 2017: Meta-analysis and overview

* Numeracy is robustly related to:
  + The accuracy of perceptions of health related benefits and risks for patients
  + Quality of medical decision making and SDM between doctors and patients
  + Health outcomes for patients
* Less numeracy is linked to worse understanding of side effects
  + There is more difficulty reasoning on the underlying structure of the data.
* Low numeracy linked to more interest in paternalistic model of medical decision making
  + Less interest in traditional ‘shared decision making’
* Greater health issues
  + Relative risk for constant management type disease is 40% greater than those with high numeracy (diabetes, etc.)
* Greater numeracy leads to better choices not just because of normative theory, but:
  + More explicit EV calculation and verbalization of EV computations, including transforming probabilities and translated percentages.
  + Greater and more elaborative processing as a whole, with more time deliberating over choices (not just making calculations faster!)
  + More emotional reactions to probability (higher sensitivity to probability)
    - In contrast, less numerate are affected more heavily by incidental affect.

Garcia-Retamero 2009: Low numeracy is more easily biased by the way health-related numerical information is framed!

Rolison 2020: Low objective numeracy and low subjective numeracy are both associated with poor risk comprehension.

Galesic 2011: 2000 people surveyed, evenly split b/w german and American, were quizzed on SDM behavior (passive, collaborative, active). More numerate people were active and preferred to be more active, collaborative was relatively common for high and low numeracy, and passive was more common for low numeracy than others. Low numerate people had a high desire for MORE passivity!

Keller 2009: Compared various levels of numeracy on interpretation of risk communication formats, such as paling perspective, etc. ratio, pictogram. lower numerate did not distinguish b/w high and low risk levels for down syndrome when given either of the 3 formats for either DS or colon cancer. High numerate did not distinguish b/w high and low risk when given ratio format, but did when given pictogram or paling perspective scale for DS. The more numerate seem to be better able to interpret various depictions of risk information

Hess 2010: Visual perception of risk communication and the role of subjective numeracy (SNS scale). There was a strong correlation b/w subj numeracy and time spent looking at the PPS as well as total number of ‘gaze events’. Interpretation is that participants w/ lower subj numeracy need more time and more gazes to extract info from the graph. Total number of areas not correlated w/ subjective numeracy. Except when considered as proportion of total gazes, wherein higher subj numeracy meant looking at more things faster in a shorter period of time (more efficient). In Summary, subjects with lower subjective numeracy seem to have trouble getting info from the PPS. Thus, need to customize graphics to simplify the process for lower numeracy individuals.

Zikmund-Fisher 2014a: Lower-numerates have trouble recognizing that a jump in A1C from slightly to moderately out of range was worth immediate response. Important distinction b/w patients knowing test numbers, versus grasping the personal meeting of that data. Also, lower numeracy skills in most patients is linked to difficulty interpreting test outcome data. Patients “Cannot get a feeling of ‘goodness’ or ‘badness’” from the data.

What related constructs have impact (health literacy, graph literacy, etc)

* Math Anxiety
  + Thompson 2022: Math anxiety, and NOT induced stress, associated with performance on obj and subj numeracy measures, it is thus it’s own unique construct that interacts with other measures?
  + Rolison 2020: High math anxiety is associated with poor risk comprehension, however, when controlling for objective numeracy, this effect disappears.
  + Math anxiety is negatively related to subjective numeracy, reducing risk-comprehension ability/tasks
* Natural Number Bias: Thompson 2022
  + Thought to be the overall driver/mechanism behind poor ‘numeracy’.
    - Inability to engage in relational reasoning (considering concepts in isolation rather than in relation to each other)
  + Encompasses several sub-concepts of bias
    - Ratio bias, Denominator Neglect, 1 in X phenomena
    - Subjects directly mention that they focus on numerators in isolation, and that covid lethality was undersold as it compared absolute numbers to flu deaths.
    - 1 in x phenomena likely due to the heuristic, smaller components = larger magnitude, simply that larger denominators are smaller magnitudes.
  + Underlying elements?
    - Perceptual limits – A person can see 4 > 2 much faster than 104 > 102, even if objective difference is the same.
      * More distance b/w numbers, easier to discriminate b/w them.
    - Natural numbers are very common
      * ½ are seen much more often than 15/30 for example, as 1 and 2 are super common numbers!
      * Even in adults, 300 pennies is seen as worth more than 3 dollars
  + There are some cases when it’s good though!
* Gist Understanding: Thompson 2022/ Van Hoof 2020
  + Understanding of magnitude is the building block of math
    - Gist of magnitude allows people to estimate what is needed for good decisions.
    - GIST usage increases with age.
  + Thus, learning goes from the gist understanding (rough magnitudes) to exact information, to using gist reasoning by considering approximate magnitudes.
  + Dual process theory – explains how people have all the required knowledge and skill to solve a task, can make a mistake, because they are affected by erroneous intuitive reasoning
    - When reasoning with fractions, people must first inhibit their prepotent, automatic whole number response to later engage in more effortful, strategic reasoning and processing of the ratio’s magnitude
  + Natural number bias exists in learners accuracy, especially when considering reaction time (system 1 vs system 2 thinking on the answer). Participants had higher accuracy on congruent vs incongruent tasks, some participants were perfect in both classes regardless.
    - Incongruent tasks took longer than congruent tasks, even for the most accurate ones.
    - Time pressure/reduction in time led to a general decrease in accuracy, but significant more decrease on incongruent items than congruent ones
    - For people who did perfect in the first trials (no time pressure), we STILL saw that a time decrease lead to a larger decrease on incongruent vs congruent items.
    - “There is a crucial difference between mistakes coming from a learners’ misconception on the subject and a mistake coming from an intuitive response”
      * Vital for determining how to address similar problems moving forward!
* Health Literacy
  + Gakumo 2016: finds that lower levels of health-literacy independently correlates strongly with poorer treatment adherence/viral load suppression.
  + Zikmund-Fisher 2014a: Health literacy independently predicts difficulty with identifying out of range test results in health information. Additionally, it is moderately correlated with numeracy.
    - However, 10% had lower numeracy and higher literacy, 6% had higher numeracy and lower literacy.
    - The combined effect of lower literacy AND lower numeracy more than halves probability of identifying out of range values (77% to 38% for diabetics and 65% to 30%)
    - Usefulness of medical information was highly correlated w/ literacy and numeracy, but overall was not perceived as super high in general (not found to be super useful!)
  + Nutbeam 2008: Health literacy is defined as “The degree to which individuals have the capacity to obtain, process and understand basic health information and services needed to make appropriate health decisions.”
    - Weak health literacy is linked to less knowledge about medications taking, less able to read and understand the labels of the medication itself, difficulties adhering to hospital instructions, and increased mortality!
  + Zikmund-Fisher 2017: Health literacy is also strongly correlated with better accuracy when looking at urgency differences scores for potential medical issues (identify if an out of range result is an actual problem)
* Graph Literacy
  + Okan 2011: Defined as “The ability to understand graphically presented information”
    - Patients with high graph literacy were able to benefit more from information being presented using icons, and had greater confidence and accuracy in risk reduction estimates. For those with weak graph literacy, there was less improvement in accuracy and none on confidence when given icons.
    - Graph literacy can affect the extent to which people benefit from visual aids designed to overcome judgement biases due to weak numeracy!
      * Specifically, the impact of denominator neglect (which itself is a subsection of natural number bias)
  + Zikmund-Fisher 2014b: Graph literacy is linked to risk perception and recall for pictographs. Generally, those who were more numerate or graphically literate were able to have a stronger correlation between the actual risk of getting it and the risk perception (more accurate/well calibrated). The less numerate seemed to process the icon arrays differently from the more numerate
    - Counting of icons vs not being the big difference
    - “We speculate that less numerate subjects found it easier to determine the ‘‘gist’’ (to use Reyna’s term of the risk when blocks made the ‘‘part/whole’’ relationship visually simpler”
  + Zikmund-Fisher 2017: Graph literacy has a strong relationship when predicting the ability for patients to distinguish between urgent and non-urgent deviations in lab test resutls
* Risk Literacy: Seen as practical ability to evaluate/understand risk to make skilled/informed choices
  + Garcia-Retamero 2019:
  + Rolison 2020: Several numeracy measures relate to it directly and independently.

What measure/s would you recommend for studies in medical decision making? (different recommendations based on context!)

Innumeracy in the wild:

* Providing evaluability is different for patients vs doctors, and is critical for success regardless!
* Graphical risk presentation is useful for highly numerate, but not the less numerate, unless it’s a highly simplified graphic.
* Attributes can be difficult to evaluate without context!

Numeracy and the ACA: Opportunities x Challenges:

* Emphasize how bad the public’s baseline numeracy is here, lets us frame what we need to/should be doing
* Different levels and scales of quantitative literacy, from below basic, basic, intermediate, and proficient
  + Proficient is seen as what is needed to make good health care choices in the marketplace??
  + 22% are below basic, 33% basic, 33% intermediate, and 13% are proficient.
* Emphasize that people making choices are under super heavy affect (high mental pressure) and that also frames what we should recommend.
  + Affective engagement can change ability and resources available to engage in critical thinking.
  + Health problems can both directly and indirectly impact the capacity for thinking in the dual process concept.
  + Numeracy is measured under NORMAL circumstances, if ABNORMAL circumstances are standard for health concepts, then there is a risk of this reduced numeracy hurting people specifically making health choices.
* Things we can prioritize for our target group
* Provide numeric information
* Reduce effort
* Provide evaluative meaning
* Draw attention to important information
* Set up appropriate systems
* Fewer options
  + if only certain options are valuable or important, you should maybe try presenting only them
* Provide less information
  + Any information that isn’t important should be removed
  + Perhaps try a ‘slimmed’ down version of the experience?
* Use appropriate visuals
  + Pictographs or icon arrays can indicate how much likelihood of having an issue
  + For common outcomes, bar charts are good!
* Use evaluative labels when you want to get some action happening!
* Order information such that the most important information is first or last
  + Important meaning here… largest cost or potential for cost?
* Use fonts that draw attention to important information
  + Mostly UI and visual design choices for our intervention itself?
* Ensure and Identify the goals of the communication
  + Make sure to clearly re-iterate what this is, and have it inform the core of the design itself
* Use defaults?
  + Provide a ‘default’ plan with most of the selections already made, and then see if the person themselves wants to alter the plan??

Thompson 2022:

* Number lines illustrate magnitude
  + This primes subjects to use the ‘correct’ skills
  + Also allows for comparison of magnitudes to each other very easily
  + Leverages spatial-numeric relationships

Gakumo 2016: Patients know the #’s are important, and they WANT to have DIRECT access to the values, as well as INFORMATION on how to use those values!

* Thus, providing simple information and clear emphasis on the differences of levels instead of exactly describing them is better
* If the numbers are confusing, then mutual communication is vital to understand the number, and ideally use less detail!

Petrova 2018: Clear evidence exists that physicians are willing and able to adapt their risk communication to suit the patient’s level of numeracy. This effect was largely independent of their own numeracy level! This is great news that physicians can be flexible in their measure-giving or recommendations.

Ciampa 2010: Survey on patient numeracy, communication, and screening.

* Found that 22.6% of population have low objective numeracy, 39.4% had low subjective numeracy, in a large (1436) survey of individuals age 50 and older.

Garcia-Retamero 2009: The US audience had a greater problem with risk assessment than the comparison group from Germany, icon based arrays worked well even for those with lower numeracy.

Schapira 2019: Using computer test of health numeracy (for breast cancer consultation). Pilot study of Computer Adapted Test of Numeracy Understanding in Medicine Instrument (CAT-NUMi) before cancer treatment consultation for women w/ stage 0-3 breast cancer. The CAT-NUMi tool itself is adaptive, giving harder or easier questions based on how well the person performed on the previous elements. Also, the tool was rated as very good / excellent by 65%, and fair by 33%, with only 2% considering it poor. Additionally, the tool automatically generates a report (in two languages! Spanish and English) for how to communicate to patients with higher or lower numeracy. Physicians also rated it as excellent/vg clarity, and helpfulness as relatively good (40% vg/ex, 54% fair). Specifically, Physicians modified their communication somewhat/a lot in 33% of the consultations!