Adults Learning About Probability and Risk in Health-Related Contexts: Creating an Online Learning Instrument

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After a brief introduction to the conceptualization of health numeracy and thinking behind our online health numeracy teaching and learning instrument, we outline how we created lessons about probability, chance and risk. Our major challenge came from the fact that although adults need a good understanding of major probabilistic ideas (many of which are not intuitive), that understanding should not come from formal definitions, theorems and algorithms, as in mathematics courses. Given the diversity of the background preparation, knowledge and demands of our intended users, we built a trajectory from the very basic principles (such as understanding what 25% actually represents), to dealing with data uncertainty, to explaining conditional probabilities and the law of total probability (as they are needed in reasoning about medical testing). We illustrate this trajectory with sample questions from our instrument.

Introduction

The National Institutes of Health (NIH, 2016) claims that "Health risks can sometimes be confusing, but they're important to understand. Knowing the risks you and your family may face can help you find ways to avoid health problems. It can also keep you from fretting over unlikely threats." Risks, often communicated in numeric formats (as percent or relative frequency), fall into the domain of health numeracy. Proficiency in numeracy has "demonstrated a positive association with communication and medical care outcomes including greater understanding of health information and risk statistics." (Schapira et al., 2004).

Inadequate numeracy is a serious problem. Canadian Council of Learning reported that "60% of adults in Canada lack the capacity to obtain, understand and act upon health information and services and to make appropriate health decisions on their own" (CCL, 2008). Assessing the numeracy among medical professionals, Wegwarth, Wagner, & Gigerenzer (2017) write: "Many physicians do not know or understand the medical evidence behind screening tests, do not adequately counsel (asymptomatic) people on screening, and make recommendations that conflict with existing guidelines on informed choice." Highlighting the tension between researchers in health sciences and health practitioners, Barraclough (2004) criticizes the presentation of statistical arguments in research papers: "How many doctors have a clue what it means? Of all the areas of mathematics, probability, and its inscrutable daughter statistics, are the most slippery to grasp."

In order to address numeracy in a range of health-related contexts, we decided to build an online teaching and learning instrument, aimed at health care professionals, students in health-related fields, patients and their families, and, hopefully, general population.

Online Teaching and Learning Instrument

Our teaching and learning instrument (TLI) was built on the conceptualization of health numeracy that we developed (Gula & Lovric, 2019), based on existing literature about (health) numeracy and health literacy, and on examining manuals, brochures, info-sheets and other documents that are used to communicate health-related information.

Borrowing the structure from the language app Duolingo (https://www.duolingo.com/), we divided the health numeracy material into small units (lessons), which are designed in such a way that a user can complete one lesson in five minutes or less. Each lesson addresses a single topic or a single idea, and consists of five to ten questions. A user learns by reflecting and attempting to answer each question, and then by reading feedback provided as part of the answer.

In terms of its digital life, the didactical functionalities of our TLI are: the function of learning environment for practicing skills; and the function of learning environment for fostering the development of conceptual understanding (Drijvers, Boon, & Van Reeuwijk, 2010). As health care professionals, patients, and their families are among the intended users of the TLI, our design needed to align with the principles of adult learning, as outlined, for instance, in Griffiths & Stone (2013). The probabilistic content needs to be learned "in context for a specific purpose; reason for learning is to solve a problem/ apply it" (Brooks, 2013, p.142).

Teaching Probability

Given the diversity of the backgrounds, knowledge and demands of our intended users, we built a trajectory from the basic principles, to dealing with data uncertainty, which is "one of the most difficult aspects of risk communication" (Ahmed et al., 2012), to explaining conditional probabilities and the law of total probability (needed in reasoning about medical testing) - with minimum mathematics possible (which means no formulas nor symbols), and always in concrete situations.

We assumed that a typical user of our TLI does not possess algebraic competencies (e.g., working with math symbols and formulas), nor has time or means to take course(s) to learn about it. Our major challenge has been the fact that although adults do need a good understanding of major probabilistic ideas, that understanding should not come from formal definitions, theorems and algorithms, as in mathematics courses. We kept in mind that, as probabilistic reasoning is not intuitive (Kahneman, 2013), we had to build that intuition, starting with common-sense reasoning about familiar situations and models.

Our TLI organizes thinking about uncertainty, risk and chance into four units: *Introduction to probabilistic models*, which relies on user's intuition to discuss basic probabilistic ideas; *Probability and risk in health: Intuition and concepts*, where the intuitive models from the previous unit are transferred to health-related situations; *Calculating probability and probabilistic reasoning*, which further develops the probability, to include concepts of independence, conditional probability, and contingency tables; and *Narratives involving probability, chance and risk*, where the user tests their probabilistic understandings within authentic contexts.

Sample TLI Questions

A good way to illustrate our TLI is to discuss a sample of questions selected from the probability units.

Before reaching probability, a user gains proficiency in thinking about basic relations between numbers, including ratio and percent. Within probability, this proficiency is employed to answer the following question: "The risk of side effects of a medication used to treat human papillomavirus is 4 out of 10 for women and 4 out of 15 for men. True or false: Women who use this medication are less likely than men to experience side effects."

This kind of a question is widely used in testing numeracy skills; see, for instance, *Objective Numeracy Scale* in Lipkus et al. (2001). Related to this scale is the following fill-in-the-blank question: "About 3 in every 5 patients who take antidepressants experience side effects. The chance that a randomly selected person on antidepressants will experience side effects is __%." Besides probing user's knowledge about ratios and percents, this question brings together two ways in which probabilistic information is presented: as a relative frequency and as a percent (alternative ways include graphs and diagrams). The decision about which of the two frames to use is essential in effective communication of risk (Gigerenzer et al, 2006).

The following question, based on Veenstra et al. (1999), is about the risk of side effects: "Steroids are associated with numerous side effects that lead to increased patient morbidity and mortality: […] the incidence of steroid-related hypertension (15%), post transplantation diabetes mellitus (10%), peripheral fractures (2%), avascular necrosis of the hip (8%), and cataracts (22%)." The user is asked to identify which side effect is the most likely to occur.

Evidence suggests that an average person finds the numeric information given in this quote confusing, and has difficulties ranking the risks (which side effect is the most/ least likely to occur?). In this case, a more productive approach (Gigerenzer et al., 2006) would be to use the relative frequencies. However, this is prone to misinterpretations as well. Fuller et al. (2002) write: "quoting a risk of death of one in five (that is 20%) might be interpreted by a patient as 5%, altering their decision to undergo treatment with potentially fatal consequences. Similarly, a one in 20 risk interpreted as 20% might dissuade a patient from choosing a potentially beneficial intervention."

What does 25% really mean? It means 1 in 4, but that does not answer the question. If the chance of picking a red ball from a box of coloured balls is 1 in 4, does it mean that if we pick four balls, one will be red? The answer is – it does not have to be. However, as we keep repeating the experiment (one thousand, one million times, etc.), the ratio of red balls that we pick will be getting closer to 1 in 4.

Here is a question from our TLI that tests this understanding: "About 25% of people with diabetes have high blood pressure. We randomly select a group of people with diabetes. Which of the following is the *least likely* to occur?

a. In a group of 4 people with diabetes, 1 has high blood pressure
b. In a group of 40 people with diabetes, about 10 have high blood pressure
c. In a group of 400 people with diabetes, about 100 have high blood pressure"

The correct answer is a. The explanation to this question (which a user can access irrespective of whether they answered correctly or not) includes the key fact that larger samples show smaller deviations from expected values; i.e., as the group size decreases, the difference between the expected and actual values increases.

Given that most health care professionals are not familiar with mathematical formulas, the approaches to certain topics in probability need to be reworked. That is the case of Bayes' formula and the Law of Total Probability, which require conditional probability. A typical scenario where these mathematical tools are needed concerns the case where the prevalence is known (such as "1 percent of patients suffer from some disease"), together with information about the false positive/ false alarm rate (if a patient does not have the disease, the false positive is the probability that they nevertheless test positive) and sensitivity (if a patient has the disease, the sensitivity is the probability that they test positive; from this information, one can derive the false negative rate).

The approach we took for the TLI is to teach a user, through a sequence of lessons, how to create a contingency table based on the given data. Once this is accomplished, answering the important question – what is the chance that a person who tested positive for the disease, actually has it – is reduced to looking up the numbers in the table, and, understanding what they mean, performing simple algebraic operations. As well, by building a contingency table, users can investigate how the answer to the question above depends on the prevalence (which is essential in interpreting test results).

To see how the entire TLI is organized, and to experience it, please visit bit.ly/henupr.

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