Assessment, analysis and interpretation of Patient-Reported Outcomes (PROs)

Day 2
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3. PRINCIPLES OF MEASUREMENT SCALES
Measurement of an attribute

• The purpose of measurement is to quantify an attribute

• **Measurement** is the assignment of numbers to an attribute according to a rule of correspondence

• For example, the number of symptoms from a checklist would give a score to every patient according to a simple rule
  – This correspondence does not necessarily hold in the other direction
    • Patients with the same score might have different sets of symptoms
  – This rule might produce measurement of only a limited range of the attribute
    • Cannot measure below its *floor* or above its *ceiling*
Inferred measurement

- Psychometric tests are different from “proper” measurements we routinely use – such as temperature, weight, length etc.
- A questionnaire should be viewed as a series of small experiments (observations) outcomes of which are recorded
  - from which a measure is inferred (van der Linden & Hambleton);
  - These outcomes often have no metric of their own;
  - Observations in tests need to be mapped to numerical data
Experiments, observations, items...

- Questionnaires aim to gather information on “objectively scorable” items
  - It is decided before the test administration how responses to items should be scored

- Item is a stimulus to which a response is collected
  - Item stem
  - Response options
    - Many types (open-ended, multiple choice, binary response, graded response or Likert scale, ranking or forced-choice, etc.)
Scoring items – some initial questions

• Graded responses (*Likert* scales) typically assign consecutive integers to response categories

• Assumptions
  – Linearity
  – Equal intervals
  – All respondents interpret response categories in the same way

• Are these assumptions reasonable?
Levels of measurement

• **Ratio**
  – Length (meters), or weight (kilos)
  – *Interval* between 15m and 16m is exactly the same as the interval between 1m and 2m
  – An object 2m long is “twice as long” as an object 1m long

• **Interval**
  – Temperature (Celsius)
  – Difference between 15° and 16° is exactly the same as between 1° and 2° with respect to the attribute
  • This might not be obvious from observations

• **Ordinal**
  – Hardness of minerals (Mohs scratch scale)
  – Ranges from the hardest (diamond) to the softest (talc)
  – The only meaning reflected in the scale is the *order* of hardness
Ordinal scales

• Let a be the measurement of attribute A, and b the measurement of attribute B
• Fundamental properties
  – Identity rules
    1. either a=b or a≠b
    2. If a=b then b=a
    3. if a=b and b=c then a=c
  – Order relations
    4. either a>b or a<=b
    5. If a>b and b>c then a>c
• Allowed operations
  – Any order-preserving (monotonic) transformations
Interval scales

- Let $a$ be the measurement of attribute $A$, and $b$ the measurement of attribute $B$
- Fundamental properties
  - All properties of ordinal scales plus
  - Additivity rules
    6. $a+b = b+a$
    7. If $a=c$ and $b=d$ then $a+b=c+d$
    8. $(a+b)+c = a+(b+c)$
- Allowed operations
  - Origin and unit of the scale are arbitrary
  - Linear transformations only
Ratio scales

• Let $a$ be the measurement of attribute $A$, and $b$ the measurement of attribute $B$

• Fundamental properties
  – All properties of interval scales plus
  – Zero rules
    9. $a + 0 = a$
    10. If $a = c$ and $b > 0$ then $a + b > c$
  – Zero is an absence of the attribute

• Allowed operations
  – Unit of the scale is arbitrary
  – Ratio transformations only
Choosing a metric

• **Metric** is a set of scale values for the observations
  – Includes choosing an **origin** and a **unit** of measurement
  – Decide which observation corresponds to number 0, and what difference between observations corresponds to number 1

• For our simple symptom-counting checklist, we can
  • Use the number of symptoms (**criterion-referenced measurement**),
  • or subtract the population mean, and divide by its SD (standardized, or **norm-referenced measurement**),
  • or take a natural logarithm of the odds (ratio of the number of criteria “met” to the number of criteria “failed”), etc.
  • ....and still satisfy the basic requirement of measurement

  – However, changing the scale by a transformation might alter some statistical hypotheses (e.g. linearity of a relationship)
Criterion-referencing

• Raw scores often have an absolute reference to behaviour

  I have had ("very mild") bodily pain during the past 4 weeks

  – Do we need to relate that report to others’ reports?
  – If a patient meets all criteria for a diagnosis, this needs no comparison with other patients
  – Usefulness and virtue of raw scores are often neglected
Norm-referencing

• Choosing metric on the basis of distribution of scores obtained from a population of interest
  – Origin is the mean and unit the SD
  – Might make sense in large-scale public health programmes

• The same instrument can be referred to a criterion or to a norm
  – Depends on motivation: e.g. detection of psychopathology versus its general incidence in the country