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Interpretation of Many-Valuedness in Quality-of-Life Instruments †

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Abstract: Assessment instruments for functioning in general and quality of life in particular often involve discrete scales with three, four, or five values, or Visual Analogue Scales (VAS) with a range 0–100. VAS scales often need to be downsized and discretized using intervals or clusters. Cutoff points for these intervals/clusters need to be carefully selected and justified. Our objective was to underline the importance of providing clear interpretations of many-valuedness appearing in quality-of-life (QoL) instruments, and to present a methodology for the provision of such clearness. Doing so, we view QoL scales as originating within the World Health Organization (WHO).

Keywords: assessment instruments; health; quality of life; visual analogue scales

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1. Introduction

Discretization of the numeric VAS scales aims to map the numeric scale (0–100) into a pre-selected set of finite and ordered values, typically named rather than symbolized. Two-valued scales are seldom used, and three-valued discrete scales, e.g., named “LOW, MEDIUM, HIGH”, or “STOP, WAIT, GO”, or similar, are also often seen to be too coarse-grained. Attention must also be paid to semantic interpretations of these names, so that interpretations are strictly connected with the numerical-to-symbolic function that that maps numeric values of a scale to corresponding symbolic values using cutoffs. Whereas a set of three symbolic and ordered values may often be too coarse-grained, adopting seven, eight, nine, or more symbolic values in a discrete scale may similarly appear as too fine-grained. The idea of discretization is indeed that each value in the discrete scale is well-understood and clearly separated from other values, as compared to separation in a VAS scale.

The visual analogue scale being numerical enables the measurement of the distance between values in the scale and makes it suitable for analysis using statistical methods. A discrete scale is only ordinal without metrics and is then suitable for symbolic and logical computations.

VAS has been used in various forms since the second half of the 19th century. Graphic rating methods were studied in the 1920s [1], referring to human visualizing power described back in the 1880s by Galton [2], discretizing that power into nine groups, respectively, named Highest, First Suboctile, First Octile, First Quartile, Middlemost, Last Quartile, Last Octile, Last Suboctile, Lowest.

Galton’s approach could be seen as blending skewed and non-skewed situations in the sense that the use of percentiles stems from skewedness, whereas the exponentiality in shifts between quartile and octile favors views of variances in log-normal distributions, occasionally referred to as the Galton distribution. Galton also favored the use of geometric means, often seen as better matching the median in distributions being more log-normal than normal [2].

Our objective was to underline the importance of providing clear interpretations of many-valuedness appearing in quality-of-life (QoL) instruments, and to present a methodology for the provision of such clearness.

2. Materials and Methods

We obtained access to the quality-of-life instruments studied and their manuals on the website of the World Health Organization.

The EQ-5D-5L User Guide recommends presenting data using a measure of central tendency and a measure of dispersion. In the non-skewed case, central tendency and dispersion could be mean value and standard deviation, respectively. In the skewed case, central tendency could be median, and dispersion could be modelled by the interquartile range. In some large evaluation studies, the mean EQ VAS was 86 and the median was 75 (refs. 36 and 37 in the Guide) [3].

WHO-FIC's (World Health Organization Family of International Classifications) ICF classification for functioning, and its generic 5-value scale, generally use accepted semantic names for the discrete values (Table 1) [4–6]:

Table 1. ICF qualifiers (WHO-FIC's).

xxx.0 NO problem	(none, absent, negligible,. . .)	0–4%
xxx.1 MILD problem	(slight, low,. . .)	5–24%
xxx.2 MODERATE problem	(medium, fair,...)	25–49%
xxx.3 SEVERE problem	(high, extreme,. . .)	50–95%
xxx.4 COMPLETE problem	(total,. . .)	96–100%

This provision of distribution can in fact also in its reverse be seen as a 5-value scale transforming to a 0–100 distribution.

The WHO Family of International Classifications and Terminologies includes the International Statistical Classification of Diseases and Related Health Problems (ICD), the International Classification of Functioning, Disability and Health (ICF), and the International Classification of Health Interventions (ICHI). These are known as the Reference Classifications that "serve as the global standards for health data, clinical documentation and statistical aggregation".

Apart from the Reference Classifications, there are other classifications including International Classification of Diseases for Oncology, International Classification of Primary Care, International Classification of External Causes of Injury (ICECI), Technical aids for persons with disabilities, The Anatomical Therapeutic Chemical Classification System with Defined Daily Doses (ATC/DDD), International Classification for Nursing Practice (ICNP), Verbal autopsy standards: ascertaining and attributing causes of death tool, and The Startup Mortality List (ICD-10-SMoL) [3].

3. Results and Discussion

The shape of VAS distributions resembles geometric distributions. These are appealing, as they can be viewed as Bernoulli trials (or binomial trial), i.e., a random experiment with exactly two possible outcomes, respectively, for "good" and "bad", or "success" and "failure". The probability of success remains constant for the context where the experiment is performed.

The probability mass function for the geometric distribution is (1):

$$P(X = k) = (1 - p)^{k-1} \cdot p \quad (1)$$

with the corresponding cumulative distribution (2):

$$P(X \leq k) = 1 - (1 - p)^k \tag{2}$$

This can be seen as providing the first step in establishing cutoff points for intervals. If using four intervals, the expected value could be seen as separating the middle two intervals, and if using five intervals, the expected value is the midpoint of the third (middle) interval. In this case, a MODERATE VAS value would represent the expected value as the inverse value of the probability of feeling good or would intuitively reflect how many times a person would feel no more than MODERATE before feeling better than that.

We can see how a geometric distribution is close to describing VAS values in a population. The geometric distribution is a special case of the binomial distribution which is based on Bernoulli trials. The probability of an event related with a health condition escalating towards affecting activities in daily life ("yes, I have symptoms that affect my daily activities", as logically opposed to "no, I have no symptoms or no symptoms that affect my daily activities"), seen as the parameter in a Bernoulli random variable, enables us to view the geometric distribution as repeated trials within a population and stop after finding the first case of an adverse reaction. The cumulative probability can then be seen as corresponding to the cumulative frequency of VAS values. Clearly, one must be careful not to overemphasize this connection, but the resemblance between the accumulations enables us to establish explanations to cutoffs selected in those VAS accumulations.

Once discrete scales are provided, as such, like in ICF, or given by discretizations, that ordinal scale together with a value representing "missing" or "not (yet) known" becomes subject to algebraic operation. Typical approaches involve the use of quantales [7]. For a 6-point set, there are 33,391 quantales, and below, we show a typical quantale. Notably, the aggregation of MILD and SEVERE, in that order, is not the same as the aggregation of SEVERE and MILD (Table 2).

Table 2. Six-point set of a typical quantale.

*	*Not Known*	*NO*	*MILD*	*MODERATE*	*SEVERE*	*COMPLETE*
Not Known	Not Known	NO	MILD	MOD	SEV	COM
NO	NO	NO	MILD	MILD	SEV	COM
MILD	MILD	MILD	MILD	MILD	COM	COM
MODERATE	MOD	MILD	MILD	MILD	COM	COM
SEVERE	SEV	SEV	SEV	SEV	COM	COM
COMPLETE	COM	COM	COM	COM	COM	COM

* Quantales and study the categories enriched in them.

4. Conclusions

The applicability of many-valuedness, algebraically and logically, is shown in the context of the ICF's qualifiers and VAS scale discretization. A strength is the ability to compute with "*unknown*" values. In some cases, a not known value is neutral in the sense that nothing is said about its relation to the other elements. In other cases, a missing value can be viewed as not necessarily bad and not necessarily good, depending on the context of the application.

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