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Assessment of dyspnoea

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The recognition of dyspnoea or breathlessness and the assessment of its severity is clinically based on the intensity of functional activity, such as walking or stair-climbing, that is required to produce discomfort in the act of breathing. This approach is similar to the measurement of sensory intensity by determination of the smallest change in stimulus magnitude that an individual can reliably perceive, and then subsequently use in the summation of just noticeable differences (JND) in stimulus magnitude from the threshold of detection, to indicate magnitude. The criterion state in the assessment of breathlessness is obvious discomfort, where as with the Fechnerian approach the criterion state is a JND, which may be precisely defined. Both techniques are indirect, in that the sensory magnitude is inferred from the stimulus magnitude.

The fundamental process involved in making any measurement is the "matching" of one continuum (number continuum being one specific example) to another, while conforming to preset rules. The rules and the independent continuum define a "scale". The types of scaling may be grouped into; nominal, to distinguish one object or event from another; ordinal, to rank objects or events in order of magnitude; interval, to determine equality and magnitude of differences in objects or events whilst preserving rank order; and ratio, to determine ratio relationships. Stevens [23-27] made the initially controversial observation that there is no fundamental reason why sensory intensity cannot be matched with preset rules and showed that sensory intensity can be directly scaled by "open magnitude scaling". He went on to show that sensations varying in intensity (sound, light, lifted weights etc.) can be matched by a variety of continuums (cross modality matching), whilst observing the preset rule of ratio relationships. The perceptual magnitude (Y) of specific sensations increases in a unique way relative to the physical magnitude of a stimulus (ST) as expressed by the equation:

$$Y=K\cdot ST^n$$

For example, the perception of a lifted weight increases threefold when the physical intensity increases twofold; in this example n=1.6. He went on to validate the method by showing that other experimenters could reproduce the same results, that subjects could reproduce the same ratio relationships when asked to adjust the stimulus (magnitude production), and that the same ratio relationships were consistent across matching continuums when corrected for their known ratio properties. By comparing the differences in sensory magnitude with changing stimulus characteristics, this technique was very successful in measuring the quantitative effects of various stimulus characteristics on perceptual magnitude. However, its utility was largely confined to studies on groups of individuals, as the measurement technique showed considerable variability across individuals. Comparison across different individuals or the same individual on different occasions is not possible. Many systematic errors have been identified in the process of direct scaling bnt in most circumstances they can be avoided by modification of the experimental design [21-25]. More important than the technique itself, Stevens established that man can make reasonable estimates of sensory intensity directly.

In an attempt to estimate absolute sensory intensity and to compare intensity across individuals, category scaling techniques were introduced and proved to have considerable utility. However, when these techniques were compared to validated open magnitude scaling, systematic deviations were found [25-26]. In particular, the ratio of the increase in sensory magnitude relative to the ratio change in physical magnitude was no longer preserved. In general, for a given proportional change in physical magnitude, the increase in perceived magnitude was less than expected; there was not a linear relationship between the results of category and those of validated ratio scaling. As category scales did not have valid ratio relationships, Stevens considered these scales as inferior to his direct methods. However, the value of any scaling technique must be judged in terms of its utility and therefore in the context of the question being currently addressed. For many applications, category scaling may be more useful than open magnitude scaling.

In this issue, an approach to the measurement of the intensity of breathlessness is described. Central to this approach is a visual analogue scale. The operation performed in using this scale is based on the premise that sensory intensity varies from below the threshold of detection to a functionally defined maximum. Any given intensity lying between these extremes has a locality which can be defined by a point on the line. Stevens defined this kind of scale as a "partition scale", in that the sensory range is partitioned. Category scales force the subject to select defined categories (matching task) and are therefore discontinuous, where as partition scales allow for a much finer selection of categories, and hopefully greater precision. As with category scales in general true ratio properties are not preserved, and if one uses ratio scaling as a gold standard they lack true validity. What this means in practice is that a point selected at 50% of the line length does not imply an absolute magnitude equivalent to 50%. Rank order is preserved but ratios are not.

In the late fifties and early sixties, Borg applied open magnitude scaling to the sensation of perceived exertion [2, 3]. He found that as work intensity doubled perceived intensity increased threefold in keeping with Stevens's power law; in this instance $Y=K \cdot Work^{1.6}$ In order to use psychophysical scaling techniques in a clinical setting, it became apparent that comparison across individuals and across time was desirable. In essence a scale was required that incorporated absolute magnitude, ranging from zero to maximum, with valid ratio properties in between. He recognized that true ratio relationships were important, in that if physical magnitude (work intensity) doubled, perceptual magnitude should increase threefold in keeping with the known and validated power law. He reasoned that the physical range of stimulation is limited and can be empirically measured (maximum work capacity). He further reasoned that the sensory range is finite, varying from zero (threshold) to maximum. He was aware of the objections raised by Stevens concerning the difference in ratio properties between partition and open scales. However, knowing that the perceptual range is finite, the physical range is finite, and the ratio properties are known, he reasoned that it must be possible to construct a valid scale [5, 6].

In describing sensory intensity in everyday life, simple descriptive terms are used, such as "slight", "moderate", "severe" etc. Borg surmised that if descriptive terms indicating perceptual magnitude wer e tagged to numbers, the individuals might use the numbers in a manner different from a scale in which the numbers were used on their own [4, 7, 8]. Thus the problems he addressed were: firstly, what locality do the descriptors occupy in the range from zero to maximum, and secondly, what are the ratio properties of these descriptive terms. In a known sensory domain, he established the way people use a variety of descriptive terms and the relative precision of their usage. He defined precision for a given descriptor by determining the variability in its location in the physical range of the stimulus; for example, the exercise intensity expressed as percentage of maximum which the subjects rated as "severe". The second problem, of ratio relationships between the descriptive terms, was also empirically established. By tagging the simple descriptive terms to numbers, he constructed a scale with both ratio properties and properties of absolute intensity. This scale has simple descriptive terms tagged to numbers ranging from 0–10. It has proved remarkably easy to use in practice and is readily understood by patients from a variety of educational backgrounds and across languages. If valid, the Borg scale has attributes of absolute magnitude and ratio properties. However, this validation is not yet firmly established.

Inevitably, valid scales will have to conform to valid ratio properties. More complicated psychophysical scaling techniques can be used and an index of absolute magnitude derived but these are more cumbersome to use in practice than the Borg scale. By intermingling test stimuli of varying magnitudes with standard test stimuli of varying magnitudes from another sensory modality, any method of magnitude estimation (category, visual analogue, open) can be used as a null procedure. For example, if the sensation of interest is breathlessness and this is induced by exercise, the subject could wear ear-phones through which known sound intensities are delivered; if the subject estimates both sound intensity and breathlessness with the same scale, the locality of breathlessness in the sound intensity range may be defined, thus making the scale redundant.

All psychophysical scaling techniques have various strengths and deficiencies. The technique adopted depends on the specific questions asked and should be sufficiently valid to carry any conclusions made. Conclusions based on magnitude should take into account any departures from valid ratio scales. Hence with partition scales, true ratio relationships cannot be assumed. Measured changes do reflect a rank order effect but not absolute ratios; an increase from 2 to 4 on such a scale may not imply the same increase in sensation as an increase from 4 to 8, either in terms of ratio doubling or in terms of difference. There are ranges of techniques available and in any given situation one technique may be preferable to another, either because of the question asked or the feasibility of the scaling technique, and they should continue to be used within the limitations of their properties.

The major issue in this editorial is psychophysical techniques. The mechanisms involved in the generation of breathlessness are a side-issue, dealt with more completely in recent reviews [9, 16, 17]. I would, however, like to stress a number of points. We have learned a great deal from the application of psychophysical techniques. Firstly, various dimensions of respiratory sensation have been identified [1, 10, 11, 12, 14, 15, 18] and isolated including effort, tension, displacement (volume, flow, ventilation), impedance (elastance and resistance), pain (pleuritic, substernal discomfort with probing and inflammation, muscular pain). Secondly, discomfort mediated in the act of breathing is a sensory experience and should also be viewed in its sensory context. Thirdly, circumstantial evidence suggests that its presence is confined to situations in which the activity of the respiratory muscles is increased, such as loaded breathing, exercise, or where the muscles are weak due to mechanical disadvantage (hyperinflation) or intrinsic weakness [20].

Using various psychophysical scaling techniques, breathlessness can be induced by loaded breathing, exercise, or muscle weakness. The global quality of the sensory experience differs, as should be expected because of variations in the dimensions outlined above. However, despite these differences the intensity of breathlessness is for the most part closely related to the perceived effort to breathe. Effort mediated by an awareness of the intensity of motor command is the most important sensory component of perceived breathlessness as it is commonly experienced.

The tension generated by the inspiratory muscles, the duration of their activity, their static strength, the integration of the various inspiratory muscles, the length and velocity of their action, mechanical advantage due to geometric variability in the orientation of thei r action, impedance of the system, efficiency of gas exchange, metabolic demand, control of ventilation, have all been shown to contribute to the intensity of inspiratory effort and breathlessness.

Man is potentially aware of a variety of dimensions of respiratory sensation through the proprioceptive mechanisms shared with peripheral skeletal muscle. In response to behavioural learning, the normal quantitative relationships between these dimensions and graded activity are readily recognized. When the tension required to generate a given ventilation changes [9, 13], the effort required to generate a given ventilation, the ventilation required to perform a given activity, to mention only a few, change as "inappropriateness" reaches consciousness. This may precipitate the recognition of breathlessness but it is not the source of the sensation. Breathlessness, defined as discomfort in the act of breathing, may have a variety of causes but, under the vast majority of circumstances in which it arises, it remains uniquely related to respiratory effort.

Psychophysical techniques potentially provide a bridge between the wealth of knowledge related to the act of breathing and the symptoms experienced by patients. Their successful use will be dependent on our understanding of the problems and of the limitations and attributes of psychophysical techniques.

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