PLACING VERBAL DESCRIPTORS ON A RATIO SCALE

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Abstract

In an article 2001 Gunnar and Elisabet Borg made a careful examination of the different principles involved in the construction of Category-Ratio (CR) scales. One of these principles is to obtain congruence between anchors and numbers, using the relation found by Stevens and Galanter (1957) between a category and a ratio scale. In an experiment 29 subjects judged lifted weights with free magnitude estimation (part A) and on a 7-point category scale (part B). For magnitude estimation an exponent of n=1,22 was obtained and for the category scale the exponent was n=0,47. From this result a simple CR-scale was constructed giving good support to the position of the anchors on the Borg CR100 scale. Secondly, a transformation equation based on Eisler (1962) and Borg, G., and Borg, P. (1987) was used as another way to obtain ratio data from category data. Both methods were found to work well.

An interesting insight in the wide use of "rating scales" for all kinds of purposes is obtained with Google pictures on the subject. It seems, however, that most scales have been developed out of need and convenience, at the best with some rough "face validity" as to chosen verbal or pictorial descriptors, but with too little thought of the perceived value (or "intensity") of the descriptors, their interrelations and positioning on the scale continuum. As an example, the rating scale used as an illustration under "personality assessment" (2011) in the internet version of Encyclopedia Britannica, has the verbal anchors: {not at all; slightly; moderately; very; extremely} as if on a symmetrical interval scale. But is, for example, the subjective distance between "moderately" and "very" equal to the distance between "very" and "extremely"? Or, rephrased, what is the subjective relationship between for example "moderately"- "very" – "extremely"? May they be fit onto a ratio scale? And, if so: where?

In their article from 2001 (Borg, G., and Borg, E., 2001) summarize several important principles involved in the construction of Category-Ratio scales. One major principle has to do with obtaining "congruence between numbers and anchors". By using the special relation between a symmetrical category scale and a ratio scale (Stevens and Galanter, 1957) it is possible to adjust the verbal anchors so that the scales give data that grow linearly to each other (Borg, G., 1998). This needs to be further studied empirically.

By using the logarithmic function described by Eisler (1962) for the relationship between category and ratio scales, G. Borg and P. Borg (1987) tested a method to derive ratio data from data obtained with a category scale. In their article a 7-point symmetrical category scale was used together with previous, "surplus", information about the exponents usually obtained for three modalities: loudness, heaviness of lifted weights, and perceived exertion. The transformation equation used was

$$R = k \; x \; a^{C-d} + b \qquad (1)$$

where R is the transformed ratio data, k is a multiplicative constant, a is computed from $e^{(1/q)}$ from the Eisler equation, C is the category scale data, d is the value of the first category (often equal to 1), and *b* is a constant referring to scale problems close to the origin as well as to perceptual noise. The transformation seemed to work rather well, but has since not been applied.

The purpose of this study was twofold: firstly to use a within-subjects design to test the principle of obtaining congruence between numbers and verbal anchors. The resulting "CR-scale" will then be compared with the Borg CR100 scale® (e.g., Borg, E., 2007). Secondly, the method of deriving ratio data from category data will be tested and compared with empirically obtained ratio data. A suitable and easily administered modality for this purpose is the heaviness of lifted weights, with an average exponent in the psychophysical power function of n=1.45 (see e.g., Stevens, 1975).

Method

Twenty-nine university students (15 men and 14 women, 18 to 52 years of age) served as subjects in an experiment of weight lifting. Six weights served as stimuli: {0,10; 0,20; 0,40; 0,80; 1,6; and 2,4} kg. The weights were 1 liter containers of the same size (7 x 7 x 20 cm) filled with water, stones and metal in order to obtain the desired weights. Each weight was placed on one of three tables in randomized orders.

The experiment was conducted as a group experiment. Subjects came in three groups, each in turn randomized into one of three subgroups. Each subgroup was then randomized to judge the weights on two of the three tables so that two individual ratings were obtained for each weight. The weights were lifted with the subjects dominating hand and with the elbow resting on the table. Two scales were used. Firstly (part A), all subjects used free magnitude estimation (ME), and secondly (part B), after approx. 20 min. pause during which a further instruction was given, subjects used an ordinary 7 point category scale (Cat) with the verbal anchors: {nothing at all; very weak; weak; moderate; strong; very strong; maximal}. In the instruction for the category scale subjects were told to think of maximal as the "heaviest weight they had ever lifted before". (For the first of the three subgroups (N=10), only the first 5 stimuli were used, thus predictions for the last weight were obtained using the individuals' psychophysical power function.)

Results

Descriptive statistics are presented in Table 1. With ME, one male subject used an unusually large number range, explaining the high standard deviations. For both scales, psychophysical power functions ($R=cS^n$) were computed for the geometric mean values (Figure 1). For ME the power function obtained was $ME = 42.4 \times S^{1.22}$ (r^2 =.996, $F(1,4)$ = 1063, $p < .001$), and for the category scale the power function obtained was $Cat = 4.16 \times S^{0.469}$ ($r^2 > .999$, $F(1,4) = 16851$, $p < .001$).

With a within-subjects design the assumption may be made that subjects perceive the weights as equally heavy regardless of what scale is used. As an example the weight of 0.8 kg that was on average judged as a little bit less than moderately heavy on the category scale, was at the same time judged as "32.5" with ME (Table 1 and dashed line of Figure 1). Thus category scale values can be translated into ratio scale values as shown in Figure 1 (crossing point is arbitrarily set at Maximal on the category scale). With a power function data may be transformed using: $ME = 1{,}04 \times Cat^{2{,}60}$ ($r^2 = .997$, $F(1,4) = 1242$, $p < .001$).

Table 2 shows the weights predicted from each category of the category scale and the corresponding values on the ratio scale (ME). The result is then transformed to a fitting number range that may be compared with the position of these verbal anchors on the Borg CR100 scale®.

Table 1. Mean values (m), standard deviations (sd) and geometric mean (gm) for magnitude estimation and category ratings of 6 weights (N=29).

	ME			Cat		
S (kg)	m	sd	gm	m	sd	gm
0.10	11	17	2.28	1.32	0.46	1.41
0.20	61	155	6.26	1.86	0.50	1.93
0.40	171	459	16.1	2.68	0.72	2.75
0.80	441	1264	32.5	3.59	0.86	3.74
1.60	1108	3119	70.8	5.09	0.83	5.18
2.40	4960	15438	120.3	6.09	0.77	6.24

Table 2. Verbal anchors and their categorical values (Cat) on the 7-point category scale, predicted weights, predicted ME values, scale values with "Maximal" = 100, and the scale value of these verbal anchors on the Borg CR100 scale® (Borg, E., 2007).

Verbal anchor	Cat	Pred Weight (kg)	Pred ME	Scale value = ME x 100/164,5	Borg CR100 scale®
Nothing at all	1	4.78×10^{-2}	1.04	0.6	0
Very weak	2	2.10×10^{-1}	6.32	4	6
Weak	3	4.98×10^{-1}	18.2	11	12
Moderate	4	9.19×10^{-1}	38.4	23	22
Strong	5	1.48	68.6	42	50
Very strong	6	2.18	110.1	67	70
Maximal	7	3.03	164.5	100	100

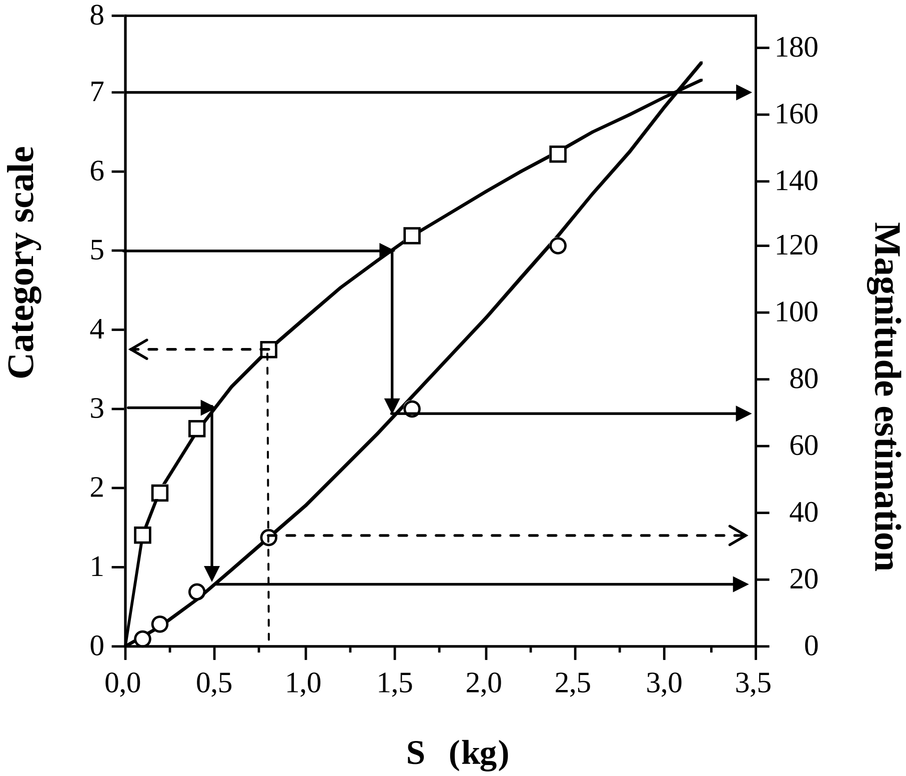

Figure 1. Obtaining congruence between the verbal anchors of the category scale and the numerical values of magnitude estimation using the two psychophysical functions.

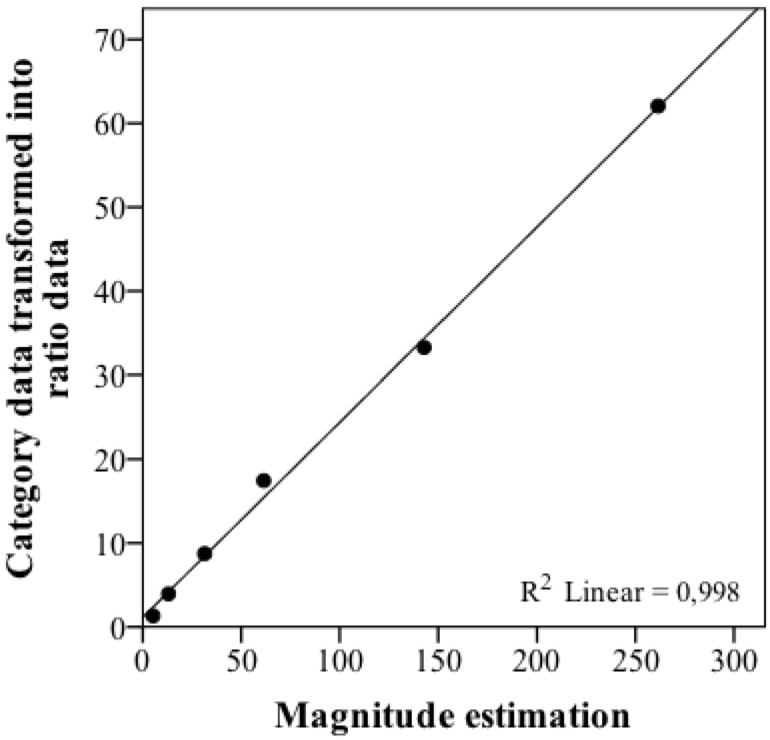

Figure 2. The ratio data transformed from the category data plotted with the data obtained with magnitude estimation.

To apply Eq. 1 to the category data, ratio data was first simulated for the weight stimuli using the general exponent of n = 1.45 (with a measure constant of c = 10, to get a more agreeable number range). With an iterative method the value of b was found to be -1.9, and the exponential equation, Eq. 2., was obtained ($r^2 = 0.998$, $F(1,4) = 2140.9$, $p < .001$).

$$R = 1.70 \times e^{0.60(C-1)} - 1.9 \quad (2)$$

This may be rewritten into the format of Eq. 1:

$$R = 1.70 \times 1.82^{(C-1)} - 1.9 \quad (3)$$

The ratio data estimated from Eq. 3 was plotted against the empirically obtained ratio data (ME) from Part A of this study (Figure 2). A correlation of r = 0.999 was found between Magnitude estimation and the transformed data. A psychophysical power function computed for the transformed data gave an exponent of n = 1.15 ($r^2 = 0.992$, $F(1,4) = 495.9$, $p < .001$).

Discussion

In this study, the exponent obtained for heaviness of lifted weights with magnitude estimation was n=1.22. This is a little lower than what is commonly obtained, i.e., n=1.45 (see, for example, Stevens, 1975). This discrepancy is probably depending upon factors such as individual rating behavior, the experimental situation, and random errors. However, it is likely that these factors influenced both scales in a similar way, and it should thus not have affected the main results of this study.

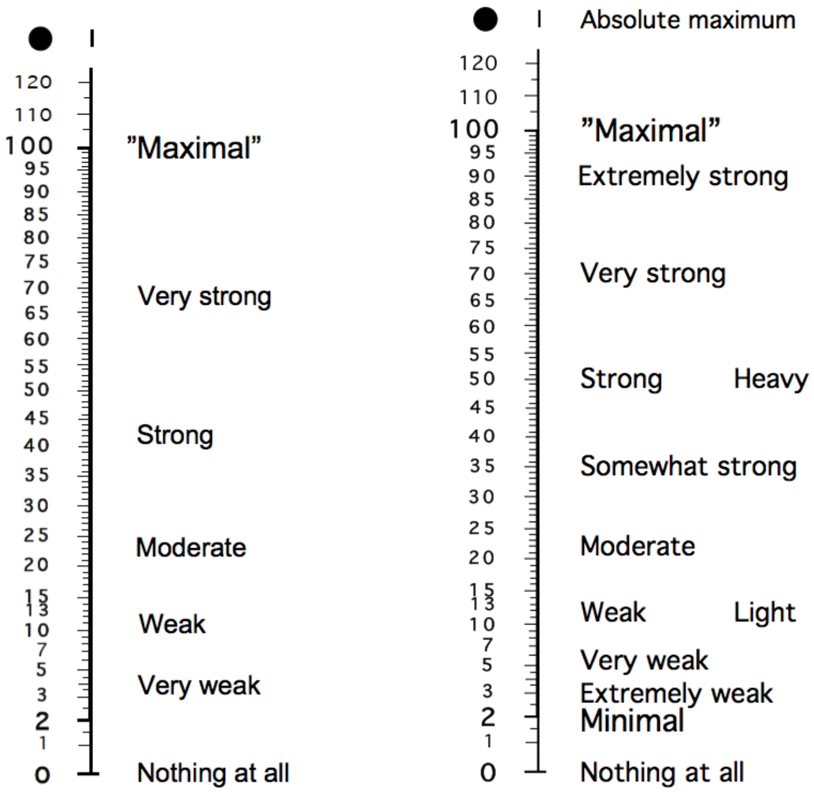

Figure 3. The CR100 scale constructed from data obtained in the present study (left) as compared to the Borg CR100 scale® (right) (© G. Borg and E. Borg, 1994, 2001, 2002; E. Borg, 2007).

The positions of the verbal anchors on the CR100 scale constructed from data in this study agrees very well with those on the Borg CR100 scale® (Borg, E., 2007), even if the latter has a few more anchors. The largest difference was obtained for the anchor "Strong" positioned at 42 and 50 respectively (Table 2 and Figure 3). In a previous version of the Borg CR100 scale®, "Strong" was placed at the number 45. As in the present study, however, this version did not have the verbal anchor "Somewhat strong". Apart from the principle demonstrated in this study, there are also several other important principles involved in the construction of the Borg CR100 scale®, for example Borg's Range Model, the size of the subjective dynamic range, quantitative semantics, and the value of facilitating two-way communication, just to mention a few, that give support for the obtained differences (Borg, G., and Borg, E., 2001).

The transformation equation presented by G. Borg and P. Borg (1987) was found to function very well and may thus be an interesting way of obtaining ratio data from category scale data. As can be seen from Figure 2 a very close correspondence was obtained between magnitude estimation and the transformed data, with a near perfect correlation (r=0.999). A psychophysical function based on the transformed data gave an exponent of n=1.15, just a little lower than what was actually obtained with ME. It is, however, suggested that the original form of the exponential function with the mathematical constant *e* should be used instead of Eq. 1:

$$R = k \times e^{a(C-d)} + b \qquad (4)$$

where R is the transformed ratio data, *k* and *a* are the constants of the exponential equation, *C* is the category scale data, *d* is the value of the first category (often equal to 1), and *b* may be obtained iteratively as a constant referring to scale problems close to the origin as well as to perceptual noise.

The two ways of combining ratio and category data demonstrated in this study functioned well. This opens up interesting possibilities of transforming category data from many different applications.

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