

The Borg CR Scales® Folder

Methods for measuring intensity of experience.

Gunnar Borg, Professor em. and Elisabet Borg, lecturer, Stockholm University

Our sensory perceptions provide us with a good picture of the reality in which we live. We can orient ourselves in our surroundings, and adapt in the best possible fashion, identify objects, food that is bad, polluted air and noise. Our senses also make us understand ourselves, our inner world in health and in sickness. It is essential that we listen to our body signals - to perceived exertion and fatigue, to hunger and satiation, aches and pains, difficulty, discomfort, stress and other emotions. Most of the impressions aren't especially strong, but instead weak. The tone of a conversation, the music at the department store, the saltiness of food, the light in the room and the annoyance of the ventilation are all only moderately intense. But sometimes we experience extreme stimuli: we're blinded by the sunlight; we burn our mouths on the soup; feel extreme anxiety; or are inflicted with pain.

In many situations we need to measure the intensity of a perception. Saying that it's noisy, that you're out of breath or in pain, isn't enough. It's important to know how strong the experience is. Within clinical diagnosis, we need to determine subjective symptoms. In investigations of the working environment, we try to measure the degree of strain and difficulty of physical as well as psychological nature. In sports and exercise, we strive to identify degree of exertion in order to attain the best training intensity. The importance of determining intensity of experience has been recognized from time immemorial. But scientific studies are relatively modern. The German physicist, G. T. Fechner, proposed during the 1800s that the perceptual intensity grows with the logarithm of the physical intensity. He based this on theoretical ideas, and no satisfactory scaling method was developed. The common approach was (and often still is) to use a simple "category scale" with, for example, numbers from one to five tied to verbal expressions, placed "symmetrically". Such scales do not have satisfactory metrical features. They offer, however, possibilities for rough estimations of intensity levels.

In the 1950s, S.S. Stevens at Harvard, developed methods for "ratio scaling" (for example, so called "magnitude estimation"). The purpose was to measure perceptual intensity on a ratio scale analogous to those in natural science, that is, a scale with an arbitrary unit, equal step sizes and an absolute zero. Thanks to Stevens and collaborators, stimulus (S)-response (R)-functions could now be empirically determined. These functions could commonly be described by simple power functions, $R=cS^n$. For some modalities these were negatively accelerating (e.g., loudness) for others positively (e.g., subjective force). The methods presuppose that people can use numbers in a mathematically appropriate way. They were shown to work well for determinations of relative S-R functions, but not for natural level determinations and comparisons between individuals.

The Borg CR scales® are very special scales. They are constructed to take advantage of the good properties of Stevens' ratio (R) scaling and, simultaneously, those of category (C) scaling, thus using verbal expressions and numbers in a congruent way for determinations of direct levels on a ratio scale. They are general scales for measuring intensities of most kinds of experiences and feelings. They were founded on ideas and experiments presented by G. Borg (1962), developed by G. Borg during the 1970s, and first presented during The International Congress of Psychology in Leipzig in 1980. Several different CR-scales have been tested, finally resulting in the 0-10 Borg CR10 Scale® and the more fine-graded 0-100 Borg CR100 Scale® (also called the centiMax (cM) scale). "Category-Ratio" scaling has opened up new opportunities for meaningful and direct scaling of perceptions, i.e., for "verbally level anchored ratio scaling". The primary use is in clinical diagnosis, in determination of perceived exertion, chest pain (angina), and other kinds of pain, breathlessness (and "dyspnea") and fatigue. Applications are found in medicine, sports, ergonomics and human factors, and also for other perceptions in everyday life.

Careful reflection and research has been performed to identify the principles and demands for an optimal creation of a CR-scale. One main is to endeavour "ratio scaling". By this we do not mean that scaling can be performed with a perfect ratio scale (impossible). The so called psychophysical "ratio scaling" methods, can only give responses on a "semi-ratio scale". When results obtained are treated as if they belong to a true ratio scale, higher predictive power is obtained than would otherwise be possible. Other reasons are: use of competent observers for scale construction; psychophysical functions in agreement with magnitude estimation; Borg's Range Model for interindividual and interprocess comparisons; psychophysiological foundations; the size of the subjective dynamic range; quantitative semantics for interpretation and preciseness of verbal anchors; congruence between numbers and anchors; a main anchor as a "fixed star"; avoiding end effects; iteration based on empirical trials; direct scaling method with two-way communication. There is no existing way how to give weight to these reasons. We have trusted our own competence and experience. In this creative process we have also used a unique design, a new way how to shape a scale (among other things with regard to visual analogy), that deviates from all other scales and makes it internationally original.

A supplementary power function was proposed: $R = a + c(S - b)^n$, where a and b refer to the starting point of the curve, which depends upon intensities at rest without external stimulation (or the absolute threshold). This function is also adapted to physiological descriptions.

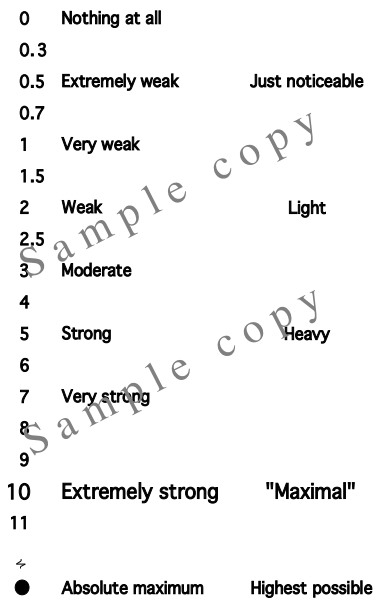


Figure 1. The Borg CR10 Scale®. © G. Borg, 1982, 1998, 2004.

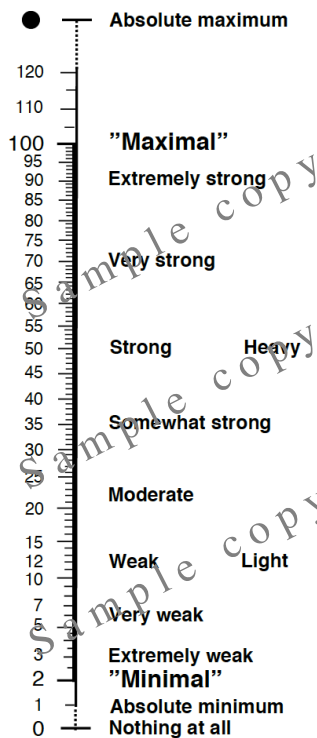


Figure 2. The Borg CR100 Scale®. © G. Borg and E. Borg, 1994, 2001; E. Borg, 2007.

One drawback with the CR10 scale is that it sometimes is confused with simple scales from one to ten. Another problem, especially in applied studies, is a tendency of using only whole numbers on the scale. This may distort the ratio properties of the scale and cause deviations in the S-R functions. The Borg CR100 Scale® may be regarded

as a more fine-graded alternative to the CR10 scale, and does not have these problems.

Testing perceived exertion. When determining perceived exertion, it is common to use the Borg RPE Scale¹, but the CR scales are used as well. All scales have their pros and cons. The RPE scale's linear growth function (linear with regard to aerobic demands) may, during certain conditions, be considered an advantage. The CR scales give non-linear, somewhat positively accelerating growth functions, that are more perceptually correct. This can be preferable when testing patients with very strong symptoms, such as pain or dyspnea. With regard to risk "dangerous exertion" probably doesn't grow linearly with increased load, but according to a positively accelerating function. There is a nonlinear relation between the RPE scale and the CR scales. A table for transformation between the the RPE scale and the CR-scales is found on page 3 (see also G. Borg, 1998).

For healthy subjects, only "overall perceived exertion" mainly depending upon "peripheral" muscle fatigue and "central" breathlessness is often rated.

In aerobic training for good health it is not necessary to exercise "Very hard". It is enough to keep an RPE level between 11-15 (2-5 on the CR10 scale, or 13-50 cM on the CR100 scale). In strength ("resistance") training the RPE level can be higher.

For patients doing work tests, it's advisable to ask for "chest pain", "breathlessness" that may change to difficulties breathing (dyspnea), and "fatigue" in the working muscles (e.g. legs), and if any additional symptoms. It is during an exercise test important to ask how strong the feeling is *before* the exercise and *during* the whole test (about 15 seconds before the work load is increased) and also *after* the test is interrupted. The final ratings are important to know, but also how they increase during the test. In healthy people breathlessness and leg exertion often increases in about the same way and without any real chest pain. For patients with a severe or possible lung or heart disease a cautious test is performed. The physiological determination then also include ECG, blood-pressure, etc., and the test is finished depending upon obtained responses, that also should include ratings up to about R=5 (CR10). All subjective symptoms may increase in a similar way to begin with for an easy work. When the work then gets harder the breathlessness may increase very much and turn into very strong dyspnea, or the chest pain (angina) may increase abruptly. A new feeling, a new quality of the symptom is experienced, causing this change, often without a similar change in leg fatigue. For such a sudden change of symptoms to occur, the patient must have adequate muscle strength to work hard enough to provoke the symptoms. The growth function is then of great interest to determine, e.g. in the form of a power function or a ratio-response index (RI). The RI may show the ratio between the final response divided by a response in the beginning of the test, e.g., at

¹ Interval scale from 6 to 20 (See G. Borg, 1998).

R=3 (CR10) or R=25 (CR100) (or at a “breaking point”)². This may be compared with the similar index for leg fatigue. It is then also important to ask about the symptoms *after* the test has ended, especially since some symptoms may continue to grow after the test has been interrupted, or not decline as fast as they normally should.

For ordinary healthy people, a work test on bicycle ergometer or tread mill is commonly performed as a submaximal test and interrupted according to physiological criteria, e.g., a heart rate of about 80% of the total dynamic range (around 170 bpm for the age group from 20 to 40 years and then lower depending upon age), or according to a perceptual criteria, e.g., R=7 (CR10) or R=70 (CR100) (around R=17 on the Borg RPE Scale®). Well-trained, healthy people and athletes often perform a max-test with determinations of oxygen consumption together with heart rate and ratings.

Pain testing. The CR10 scale is now commonly used in diagnosis of patients with cardio-pulmonary diseases. It is also used to evaluate muscle and joint problems and various kinds of pains. An advantage over VAS (the Visual Analogue Scale) is its good metric features (both for levels and functions), and the fact that it can be used for two-way communication, that is from the patient to the medical staff and from the staff to the patient when making recommendations for therapy. After the patient has been given the instructions, he/she should be asked about previous pain experiences and how they would be rated on the scale. One way to improve comparisons – especially in the case of intersubjectivity – is to use a “universal reference”, for example, a previous experience of maximal exertion. If the level of that feeling is “10”, how intense have the pain experiences been? The patient may be asked: If you use “10” as the most intense exertion you have ever experienced, how intense would you say that your worst pain experiences have been? If they have been weaker, use a number less than “10”. If they've been greater say “11” or “12”. If they have been much greater say “15” or even more. In this way a special anchor for the pain intensity can be obtained. (Above 15 is seldom meaningful). The worst experienced pain should then be used as a reference and set at “10”.

Testing other perceptions and feelings. The CR scales can be used to measure most types of experiences, not just exertion and pain, but also brightness, loudness and noise, taste and smell, feeling sick, satiation (e.g., with anorexia patients), etc. They can be used to rate the perceived difficulty of mental tasks, the ease of understanding instructions or using certain equipment. The CR10 and CR100 have been used in other contexts, for example, when measuring the strength of feelings and moods. Every time the scale is used for a particular type of experience, supplementary instructions can be given without changing the original verbal expressions (such as “Weak” and “Strong”) and their positioning on the scale. The congruence between numbers and words must always be kept as it is on the scale. The number ten (10) on the CR10 scale and hundred (100) on the CR100 scale are the

Table 1. Approximate transformation table for ratings according to the Borg RPE Scale®, the Borg CR10 Scale® and the Borg CR100 (centiMax) Scale®.

RPE	CR10	CR100	RPE	CR10	CR100
6	0	0	14.5	5	50
7	0.3	2	15	5.5	55
8	0.5	3	15.5	6	60
8.5	0.7	4.5	16	6.5	65
9	1.0	6	16.5	7	70
10	1.5	9	17	7.5	75
11	2	12	17.5	8	80
11.5	2.5	17	18	9	90
12	3	23	19	10	100
13	3.5	30	19.5	11	110
13.5	4	35	20	12	120
14	4.5	42			

fundamental anchors and must be well defined and explained. When giving a special instruction for a certain attribute, the words “Weak” and “Strong” may be supplemented, e.g., when testing loudness by exchanging “Heavy” with “Loud”.

Instructions. There has to be a complete instruction that starts with general information about the relation between the numbers and the verbal anchors, showing the meaning of a certain number. This follows by a detailed instruction for ratings (R) of perceived (P) exertion (E) (RPE). The magnitude of an almost maximal perceived exertion is something that most people have experienced. It is therefore, a rather schematized conception, with a high intersubjective similarity in meaning. Ratings of pain and other symptoms can then be compared with conceptions of perceived exertion.

Correct “Instructions” must be used. They are obtained from *Borg Perception* together with copies of the scale. In scientific experiments the “Instructions” are commonly followed well. However, in applied usage the testleaders are sometimes careless about this which may lead to misunderstandings and not valid results. There have been several legal cases. Be therefore careful to follow the “Instructions”. A patient may be given the scale with instructions to read in the waiting room. The test-leader will then only have to remind the patient about the most essential things, e.g., what to rate. Don’t change the main anchors and the design of the scale. There must not be any “modifications”!

The old “Borg RPE Scale®” (6-20) is commonly used for physical training and rehabilitation (see Pedersen, Saltin, 2006). Since the CR Scales are also used for “RPE” Table 1 is enclosed showing how to transform values between scales.

Test administration. After the main Instructions, specific training material can be used, e.g. Borg's blackness test. It is possible to use example questions such as the blackness of velvet (about “9” on the CR10 scale); the sourness of a

² or computed as a ratio between the performance at R=7 and R=3 (CR10)

lemon (about "6 to 8"), the sweetness of a ripe banana (about "3"); the loudness of normal conversation (about "2.5") etc. The test leader must be certain that the person understands the instructions and should check this by using, among other things, the above questions. The instruction to perceived exertion should always be used for information and training, even if the modality to be tested is quite different. In diagnostic tests it is often advisable to ask about several symptoms, not only those that are in focus, but also some more "neutral" ones, that should not be affected by a disease, but possibly by

Literature

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Gunnar Borg, PhD, MD hc, is professor emeritus of Perception and Psychophysics at Stockholm University. He introduced the field of perceived exertion in the 1960s, and has won international renown for developing methods for measuring intensity of experience. The "Category – Ratio" scaling method is a very special "instrument" since it combines the richness of words with the exactness of numbers. It is, thus, the first scale constructed as a "level anchored ratio scale". The fields of application are wide ranging, including determinations of subjective somatic symptoms, such as pain, perceived exertion and breathlessness (dyspnea), and most kinds of ordinary perceptions and emotions. Borg has organized and chaired many international symposia and has lectured worldwide. He received the 1998 Award from The International Association for Applied Psychology, "for exceptional contributions to the advancement of the science of psychology internationally". In 1998, he was also honoured with the Award for scientific contributions and applications in ergonomics by the Nordic Ergonomic Society. He is "Honorary Member" of the Swedish Society for Lung Medicine, and also of the Swedish Society of Sports Medicine. In 2009 Borg was elected honorary doctor in medicine at Umeå University, Sweden. He is also a member of the Royal Swedish Academy of Engineering Sciences and several international associations.

Elisabet Borg, PhD, is a much appreciated lecturer in research methods and statistics at the Department of Psychology, Stockholm University, and has written a Swedish textbook in statistics praised for its clarity. She has worked scientifically together with her father on several research problems, especially on developing the CR100 (centiMax) scale®. Her work has included symptoms evaluation of perceived exertion as well as psychophysical scaling of taste, loudness, perceived exertion, and emotions. She has lectured on several international conferences, and was one of the organizers of the Fechner Day 2003 conference of the ISP.

The use of a "Borg Scale" is recommended by several societies, e.g. American Heart Association, American College of Sports Medicine, American Thoracic Society, British Association for Cardiac Rehabilitation, and International Ergonomic Association, and several European Societies.. There are millions of people over the world that each year are exposed to one of the scales, and there are more than 500.000 relevant citations, showing the considerable and important applications.

Folder reference: See above! The folder can be obtained, with separate copies of scales and instructions, from BorgPerception AB, Elisabet Borg, Hantverkarsvägen 81, SE-184 32 Åkersberga, Sweden. E-mai: info@borgperception.se See also the website: <http://www.borgperception.se/>

personal "rating behaviour". – The special properties of CR-scaling are

a great advantage when working on obtained responses and interpreting results. It combines "The richness of language with the exactness of numbers" in a congruent way. The construction makes it possible to use parametric statistics including determinations of mathematical S-R-functions and "ratio-response indices". It is thus a new type of "ratio scaling", since it is a "Verbally Level Anchored Semi-Ratio Scale".