Designation: E1697 – 05 (Reapproved 2020)

Standard Test Method for Unipolar Magnitude Estimation of Sensory Attributes[1]

This standard is issued under the fixed designation E1697; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method describes a procedure for the application of unipolar magnitude estimation to the evaluation of the magnitude of sensory attributes. The test method covers procedures for the training of assessors to produce magnitude estimations and statistical evaluation of the estimations.

1.2 Magnitude estimation is a psychophysical scaling technique in which assessors assign numeric values to the magnitude of an attribute. The only constraint placed upon the assessor is that the values assigned should conform to a ratio principle. For example, if the attribute seems twice as strong in sample B when compared to sample A, sample B should receive a value which is twice the value assigned to sample A.

1.3 The intensity of attributes such as pleasantness, sweetness, saltiness or softness can be evaluated using magnitude estimation.

1.4 Magnitude estimation may provide advantages over other scaling methods, particularly when the number of assessors and the time available for training are limited. With approximately 1 h of training, a panel of 15 to 20 naive individuals can produce data of adequate precision and reproducibility. Any additional training that may be required to ensure that the assessors can properly identify the attribute being evaluated is beyond the scope of this test method.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E253 Terminology Relating to Sensory Evaluation of Materials and Products

E1871 Guide for Serving Protocol for Sensory Evaluation of Foods and Beverages

2.2 *ASTM Publications:*[3]

Manual 26 Sensory Testing Methods: 2nd Edition

STP 758 Guidelines for the Selection and Training of Sensory Panel Members

2.3 *ISO Standards:*[4]

ISO 11056:1999 Sensory Analysis—Methodology—Magnitude Estimation Method

ISO 4121:1987 Sensory Analysis—Methodology—Evaluation of Food Products by Methods Using Scales

ISO/DIS 5492:1990 Sensory Analysis—Vocabulary (1)

ISO 6658:1985 Sensory Analysis—Methodology—General Guidance

ISO/DIS 8586-1:1989 Sensory Analysis—Methodology—General Guide for Selection, Training and Monitoring Subjects—Part 1: Qualifying Subjects (1)

ISO 8589:1988 Sensory Analysis—General Guidance for the Design of Test Rooms

3. Terminology

3.1 *Definitions:*

3.1.1 For general definitions related to sensory evaluation, refer to Terminology E253.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *external modulus, n*—number assigned by the panel leader to describe the intensity of the external reference sample or the first sample of the sample set. The external modulus is sometimes referred to as a "fixed modulus" or just the "modulus." In this case the reference is said to be modulated.

3.2.2 *external reference sample for magnitude estimation, n*—sample designated as the one to which all others are to be compared, or to which the first sample of a set is to be compared, when each subsequent sample in the set is compared to the preceding sample. This sample is normally the first sample to be presented.

[1] This test method is under the jurisdiction of ASTM Committee E18 on Sensory Evaluation and is the direct responsibility of Subcommittee E18.03 on Sensory Theory and Statistics.

Current edition approved Feb. 1, 2020. Published February 2020. Originally approved in 1995. Last previous edition approved in 2012 as E1697 – 05 (2012)ε1. DOI: 10.1520/E1697-05R20.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from ASTM Headquarters, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428–29593.

[4] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

3.2.3 *internal modulus, n*—number assigned by the assessor to describe the intensity of the external reference sample or the first sample of the sample set. The internal modulus is sometimes referred to as a "non-fixed modulus." When an internal modulus is used, the reference is sometimes said to be unmodulated.

3.2.4 *internal reference sample for magnitude estimation, n*—sample present in the experimental set, which is presented to the assessor as if it were a test sample. The value assigned to this sample(s) can be used for normalizing assessors' data. If an external reference is used, the internal reference(s) are normally identical to it.

3.2.5 *magnitude estimation, n*—process of assigning values to the intensities of an attribute of products in such a way that the ratios of the values assigned and the assessor's perceptions of the attribute are the same.

3.2.6 *normalizing, v*—process of multiplying each assessor's raw data by, or adding to the logarithm of each assessor's raw data, a value which brings all the data onto a common scale. Also referred to as rescaling.

3.2.7 *Stevens' Equation, n*—also referred to as the Psychophysical Power Funtion:

$$R = KS^{n} \tag{1}$$

where:

R = the assessor's response (the perceived intensity),
K = a constant that reconciles the units of measurement used for R and S,
S = the stimulus (chemical concentration or physical force), and
n = the exponent of the power function and the slope of the regression curve for R and S when they are expressed in logarithmic units.

In practice, Stevens' Equation is generally transformed to logarithms, either common or natural:

$$lnR = lnK + nlnS \tag{2}$$

4. Summary of Test Method

4.1 Assessors judge the intensity of an attribute of a set of samples, presented in random order, on a ratio scale. For example, if one sample is given a value of 50 and a second sample is twice as strong, it will be given a value of 100. If it is half as strong it will be given a value of 25. There are three procedures that can be used.

4.1.1 Assessors are instructed to assign any value to describe the intensity of the first sample (external reference, which may or may not be part of the sample set). Assessors then rate the intensity of the following samples in relation to the value of the external reference.

4.1.2 The external reference is pre-assigned a value (modulus) to describe its intensity by the panel leader. Assessors rate the intensity of the following samples in relation to the external reference and the modulus.

4.1.3 Assessors rate the intensity of each subsequent sample in relation to the preceding sample. The first sample of the set may or may not have a modulus.

4.2 Individual judgments can be converted to a common scale by normalizing the data. Three normalizing methods can be used: internal standard normalizing, external calibration and, if a modulus is not used, no standard normalizing (method of averages). See 11.4 and Appendix X2 – Appendix X4.

4.3 Results are averaged using geometric means. Analysis of variance or other statistical analyses may be performed after the data have been converted to logarithms.

5. Significance and Use

5.1 Magnitude estimation may be used to measure and compare the intensities of attributes of a wide variety of products.

5.2 Magnitude estimation provides a large degree of flexibility for both the experimenter and the assessor. Once trained in magnitude estimation, assessors are generally able to apply their skill to a wide variety of sample types and attributes, with minimal additional training.

5.3 Magnitude estimation is not as susceptible to end-effects as interval scaling techniques. These can occur when assessors are not familiar with the entire range of sensations being presented. Under these circumstances, assessors may assign an early sample to a category which is too close to one end of the scale. Subsequently, they may "run out of scale" and be forced to assign perceptually different samples to the same category. This should not occur with magnitude estimation, as, in theory, there are an infinite number of categories.

5.4 Magnitude estimation is one frequently used technique that permits the representation of data in terms of Stevens' Power Law.

5.5 The disadvantages of magnitude estimation arise primarily from the requirements of the data analysis.

5.5.1 Permitting each assessor to choose a different numerical scale may produce significant assessor effects. This disadvantage can be overcome in a number of ways, as follows. The experimenter must choose the approach most appropriate for the circumstances.

5.5.1.1 Experiments can be designed such that analysis of variance can be used to remove the assessor effects and interactions.

5.5.1.2 Alternatively, assessors can be forced to a common scale, either by training or by use of external reference samples with assigned values (modulus).

5.5.1.3 Finally, each assessor's data can be brought to a common scale by one of a variety of normalizing methods.

5.5.2 Logarithms must be applied before carrying out data analysis. This becomes problematic if values are near threshold, as a logarithm of zero cannot be taken (see 11.2.1).

5.6 Magnitude estimation should be used:

5.6.1 When end-effects are a concern, for example when assessors are not familiar with the entire range of sensations being presented.

5.6.2 When Stevens' Power Law is to be applied to the data.

5.6.3 Generally, in central location testing with assessors trained in the technique. It is not appropriate for home use or mall intercept testing with consumers.

5.7 This test method is only meant to be used with assessors who are specifically trained in magnitude estimation. Do not use this method with untrained assessors or untrained consumers.

6. Conditions of Testing

6.1 The general conditions for testing, such as the location, preparations, presentation and coding of samples, and the selection and training of assessors are described in the standards for general methodology, such as ISO 6658, ISO/DIS 8586-1, ISO 8589, ASTM STP 758, or those describing methods using scales and categories, for example, ISO 4121 and ASTM Manual 26, and for specific serving protocols in Guide E1871.

7. Selection and Training of Assessors

7.1 Refer to ISO 8586-1 or ASTM STP 758 for all the general considerations concerning the selection and training of assessors. Refer to ISO 11056 for considerations specific to magnitude estimation.

7.2 As is true for all methods of sensory evaluation, the panel leader will have to make judgments as to the level of proficiency required of the assessors. The objectives of the test, the availability of assessors, the costs of securing additional assessors and of additional training should all be considered in the design of a training program. Assessors generally reach a stable level of proficiency in the method itself after three to four exercises in assigning magnitudes.

7.3 Estimating the areas of geometric shapes has proven very useful for introducing assessors to the basic concepts of magnitude estimation. A set of 18 figures composed of six circles, six equilateral triangles, and six squares ranging in size from approximately 2 to 200 cm^2 has been used successfully for training assessors (see Table 1).

7.4 Prior to presenting the figures, the panel leader instructs the candidate in the principles of the method. This instruction should include, but is not necessarily limited to the following three points.

7.4.1 If the attribute is not present, the value 0 should be assigned.

7.4.2 There is no upper limit to the scale.

7.4.3 Values should be assigned on a ratio basis: if the attribute is twice as intense, it should receive a rating twice as large.

TABLE 1 Training Exercise Shapes

NOTE 1—Two 11.1-cm squares are included as a measure of reproducibility.

Dimensions/Areas (cm/cm^2)					
Circles		Triangles		Squares	
Radius	Area	Edge	Area	Edge	Area
1.4	6.2	2.2	2.1	3.2	10.2
2.5	19.6	4.1	7.3	4.2	17.6
3.7	43.0	7.6	25.0	8.5	72.3
5.4	91.6	12.2	64.4	11.1	123.2
6.8	145.3	15.5	104.0	11.1	123.2
8.3	216.4	19.2	159.6	14.2	201.6

7.5 Assessors have a tendency to use "round numbers" such as 5, 10, 20, 25, and so forth. This should be pointed out explicitly during training. Assessors should be encouraged, "given permission," to use all numbers. Assessors are also influenced by the ratios mentioned in training. Therefore, care should be taken to mention a variety of different ratios, for example, 3:1 and ⅓, 7.5, 2.4, not just 2:1 and ½ .

7.6 *Assigning Codes to Figures*—The figures are presented singly, centered on an 8.5 × 11 in. sheet of white paper. The assessor states his magnitude estimate; the estimation is recorded. The 8.5-cm square is presented first with the instruction to assign it a value between 30 and 100. The balance of the geometric figures should be shuffled prior to each test so that the type of geometric figure and the size of the areas do not form a particular pattern.

7.7 *Comparing Results*—After completing the full set of shape estimates, assessors should be allowed to compare their results with the averaged results of the group. If this is not practical, the results from a previous group can also be used. The objective is to provide positive feedback, that is, to reassure the assessors that they understand the exercise. Care should be taken not to create the impression that there is a "right" answer. Unless their results are very different, departures from the group results should be explained as order effects, that is, their responses are affected by the order in which they evaluate the samples. They should be reassured that despite individual order effects, the group's results will be accurate.

7.8 If the assessors' results are very different, review the principles of the method again. If the panel leader judges that a assessor cannot be trained in the method, the training should be discontinued at this point and the assessor excused.

7.9 Once the panel has successfully completed the area estimation exercise, further training should be carried out with the commodity or type of test substance to be used in the main trial(s). This gives the assessor experience in applying magnitude estimation to attributes characterizing the test sample.

7.10 The panel leader may need to design exercises for training assessors to properly identify the attributes to be evaluated. The need for this will depend on the objectives and requirements of the test.

8. Number of Assessors Required

8.1 As is true for other forms of scaling, the number of assessors necessary for a given task depends on the complexity of the task, how close together the various test samples are in the attribute being evaluated, the amount of training the assessors have received, and the importance to be attached to the decision based on the test results (c.f. ISO 8586-1). Issues of statistical power need to be resolved based on the variance associated with a particular evaluation and the magnitude of the differences that need to be detected.

9. Reference Samples

9.1 *External References*—The panel leader specifies to the assessors that the reference sample has a value of, for example, 30, 50, 100, or whatever seems appropriate to the panel leader.