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Standard Practice for Defining and Calculating Individual and Group Sensory Thresholds from Forced-Choice Data Sets of Intermediate Size[1]

This standard is issued under the fixed designation E1432; 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.

INTRODUCTION

The purpose of this practice is to determine individual sensory thresholds for odor, taste, and other modalities and, when appropriate, calculate group thresholds. The practice takes as its starting point any sensory threshold data set of more than 100 presentations, collected by a forced-choice procedure. The usual procedure is the Three-Alternative Forced-Choice (3-AFC) (see ISO 13301), as exemplified by Dynamic Triangle Olfactometry. A similar practice, Practice E679, utilizes limited-size data sets of 50 to 100 3-AFC presentations, and is suitable as a rapid method to approximate group thresholds.

Collection of the data is not a part of this practice. The data are assumed to be valid; for example, it is assumed that the stimulus is defined properly, that each subject has been fully trained to recognize the stimulus and did indeed perceive it when it was present above his or her momentary threshold, and that the quality of dilution medium did not vary.

It is recognized that precise threshold values for a given substance do not exist in the same sense that values of vapor pressure exist. A panelist's ability to detect a stimulus varies as a result of random variations in factors such as alertness, attention, fatigue, events at the molecular level, health status, etc., the effects of which can usually be described in terms of a probability function. At low concentrations of an odorant or tastant, the probability of detection by a given individual is typically 0.0 and at high concentrations it is 1.0, and there is a range of concentrations in which the probability of detection is between these limits. By definition, the threshold is the concentration for which the probability of detection of the stimulus is 0.5 (that is, 50 % above chance, by a given individual, under the conditions of the test).

Thresholds may be determined (*1*) for an individual (or for individuals one by one), and (*2*) for a group (panel). While the determination of an individual threshold is a definable task, careful consideration of the composition of the group is necessary to ensure the determined threshold represents the group of interest.

There is a large degree of random error associated with estimating the probability of detection from less than approximately 500 3-AFC presentations. The reliability of the results can be increased greatly by enlarging the panel and by replicating the tests.

1. Scope

1.1 The definitions and procedures of this practice apply to the calculation of individual thresholds for any stimulus in any medium, from data sets of intermediate size, that is, consisting of more than 20 to 40 3-AFC presentations per individual. A group threshold may be calculated using 5 to 15 individual thresholds.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

[1] This practice is under the jurisdiction of ASTM Committee E18 on Sensory Evaluation and is the direct responsibility of Subcommittee E18.04 on Fundamentals of Sensory.

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2. Principles

2.1 The 3-AFC procedure is one of the set of n-AFC procedures, any of which could be used, in principle, for the measurement of sensory thresholds, as could the duo-trio, the triangular, and the two-out-of-five procedures.

2.2 For calculation of the threshold of one individual, this practice requires data sets taken at five or more concentration scale steps, typically six or seven steps, with each step differing from the previous step by a factor usually between 2 and 4, typically 3.0. The practice presupposes that the range of concentrations has been selected by pretesting, in order to ensure that the individual's threshold falls neither outside nor near the ends of the range, but well within it. At each concentration step, the individual must be tested several times, typically five or more times.

2.3 Individual thresholds, as determined in 2.2, may be used for calculation of a group (or panel) threshold. The size and composition of the panel (usually 5 to 15 members, preferably more) is determined according to the purpose for which the threshold is required and the limitations of the testing situation (see 7.2).

2.4 Pooling of the data sets from panel members to produce a single step calculation of the panel threshold is not permitted.

3. Referenced Documents

3.1 *ASTM Standards:*[2]

E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

E679 Practice for Determination of Odor and Taste Thresholds By a Forced-Choice Ascending Concentration Series Method of Limits

3.2 *CEN Standard:*[3]

EN 13725 Air Quality—Determination of Odour Concentration Using Dynamic Dilution Olfactometry

3.3 *ISO Standard:*[4]

ISO 13301 Sensory Analysis—Methodology—General guidance for Measuring Odour, Flavour, and Taste Detection Thresholds by a Three Alternative Forced Choice (3-AFC) Procedure

4. Terminology

4.1 *Definitions of Terms Specific to This Standard:*

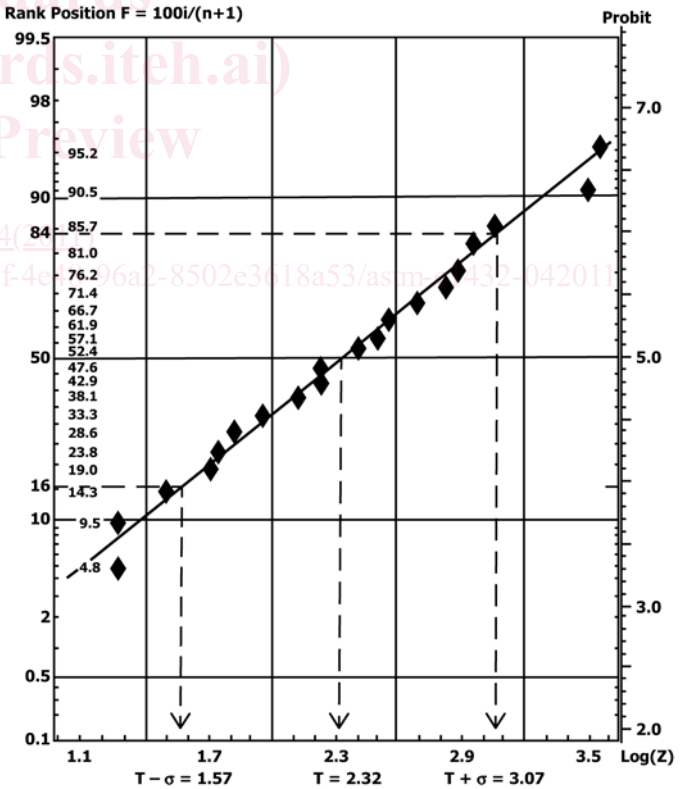
4.1.1 *Three-Alternative Forced-Choice (3-AFC) test procedure*—a test presentation used in many threshold tests. For example, in odor testing by Dynamic Triangle Olfactometry, the panelist is presented with three gas streams, only one of which contains the diluted odorant, while the other two contain odorless carrier gas. The panelist must indicate the one containing the added substance. (The 3-AFC procedure is different from the classical Triangle test, in which either one or two of the three samples may contain the added substance.)

4.1.2 *model*—an abstract or concrete analogy, usually mathematical, which represents in a useful way the functional elements of a system or process. In short, the experimenter's theory of what is guiding the results observed.

4.1.3 *statistical model*—a model assuming that the principal factor causing the results to deviate from the true value is a random error process. This can usually be described in terms of a probability function, for example, a bell-shaped curve, symmetrical or skewed. Errors are binomially distributed in the 3-AFC test procedure.

4.1.4 *threshold, detection*—the intensity of the stimulus that has a probability of 0.5 of being detected under the conditions of the test. The probability of detection at any intensity is not a fixed attribute of the observer, but rather a value which assumes that sensitivity varies as a result of random fluctuation in factors such as alertness, attention, fatigue, and events at the molecular level, the effects of which can be modeled by a probability function.

4.1.5 *individual threshold*—a threshold based on a series of judgments by a single panelist.



NOTE 1—This probability graph shows 20 panelists sorted by rank as described in 9.3.2. Data are adapted from French Standard X 43-101. Group threshold = T = 50 % point = $\log(Z_{50})$ = 2.32. Group standard deviation from % and 84 % points = σ = (3.07 − 1.57)/2 = 0.75 in log(Z) units. The 99 % point is off the graph but can be calculated as 2.32 + (0.75 × 2.327) = 4.07, where 2.327 is the % point on the abscissa of the normal curve of error.

FIG. 1 Group Threshold by Rank-Probability Graph

[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 British Standards Institution (BSI), 389 Chiswick High Rd., London W4 4AL, U.K., http://www.bsigroup.com.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

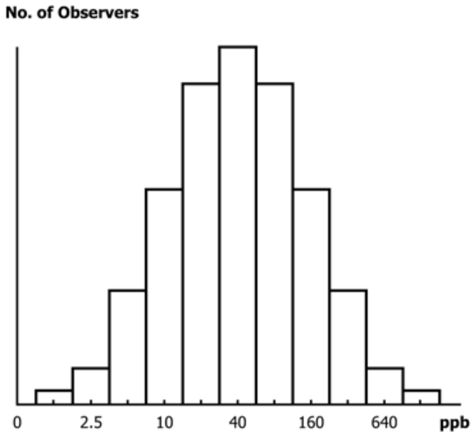


FIG. 2 Symmetrical, Bell-Shaped Distribution

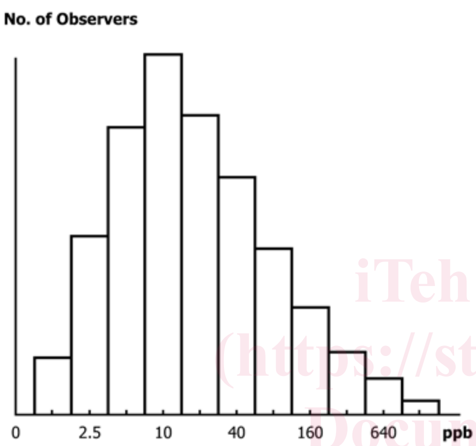


FIG. 3 Skewed Distribution

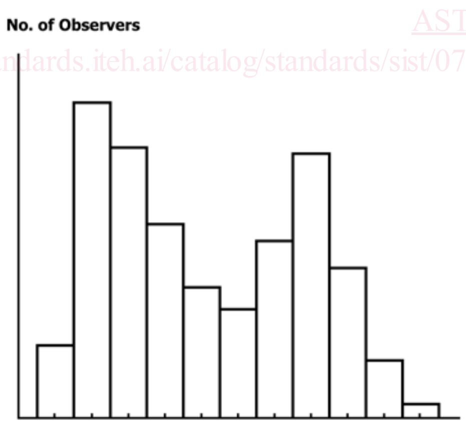


FIG. 4 Bi-Modal Distribution

4.1.6 *group threshold*—the average, median, geometric mean or other agreed measure (or an experimentally determined measure) of central tendency of the individual thresholds of the members of a group (panel). The meaning and significance of the term depends on what the group is selected to represent (see 7.2.2).

4.1.7 *scale step factor*—for a scale of dilutions presented to a panel, the factor by which each step differs from adjacent steps.

4.1.8 *dilution factor*—the following applies to flow olfactometry: If F_1 represents the flow of odorless gas which serves to dilute the flow of odorant, F_2, the dilution factor, Z, is given by:

$$Z = \frac{F_1 + F_2}{F_2} \tag{1}$$

where Z is dimensionless. F_1 and F_2 may be expressed, both in units of mass, or (preferably) both in units of volume; the report should state which. The term Z_{50} represents the dilution factor to threshold. Alternate terminology in use is as follows: dilution-to-threshold ratio (D/T or D-T); odor unit (OU); and effective dose (ED).

5. Summary of Practice

5.1 From a data set according to 2.2, calculate the threshold for one individual graphically or by linear regression according to 5.2, or by using a model fitting computer program according to 5.3.

5.2 Obtain the threshold in 5.1 by first calculating the proportion correct above chance for each concentration step. This is accomplished by deducting, from the proportion of correct choices, the proportion that would have been selected by chance in the absence of the stimulus (see 8.1.2). Then, for each individual calculate that concentration which has a probability of 0.5 of being detected under the conditions of the test. This is the individual threshold.

5.3 Alternatively obtain the threshold in 5.1 directly from the proportion of correct choices by non-linear regression using a computer program, as described in 8.2.2.

5.4 Always report the individual thresholds of the panelists. Depending on the purpose for which a threshold is required (see 7.2), and on the distribution found, a group threshold may be calculated as the arithmetic or geometric mean, the median, or another measure of central tendency, or it may be concluded that no group threshold can be calculated (see 7.4).

6. Significance and Use

6.1 Sensory thresholds are used to determine the potential of substances at low concentrations to impart odor, taste, skinfeel, etc. to some form of matter.

6.2 Thresholds are used, for example, in setting limits in air pollution, in noise abatement, in water treatment, and in food systems.

6.3 Thresholds are used to characterize and compare the sensitivity of individuals or groups to given stimuli, for example, in medicine, ethnic studies, and the study of animal species.

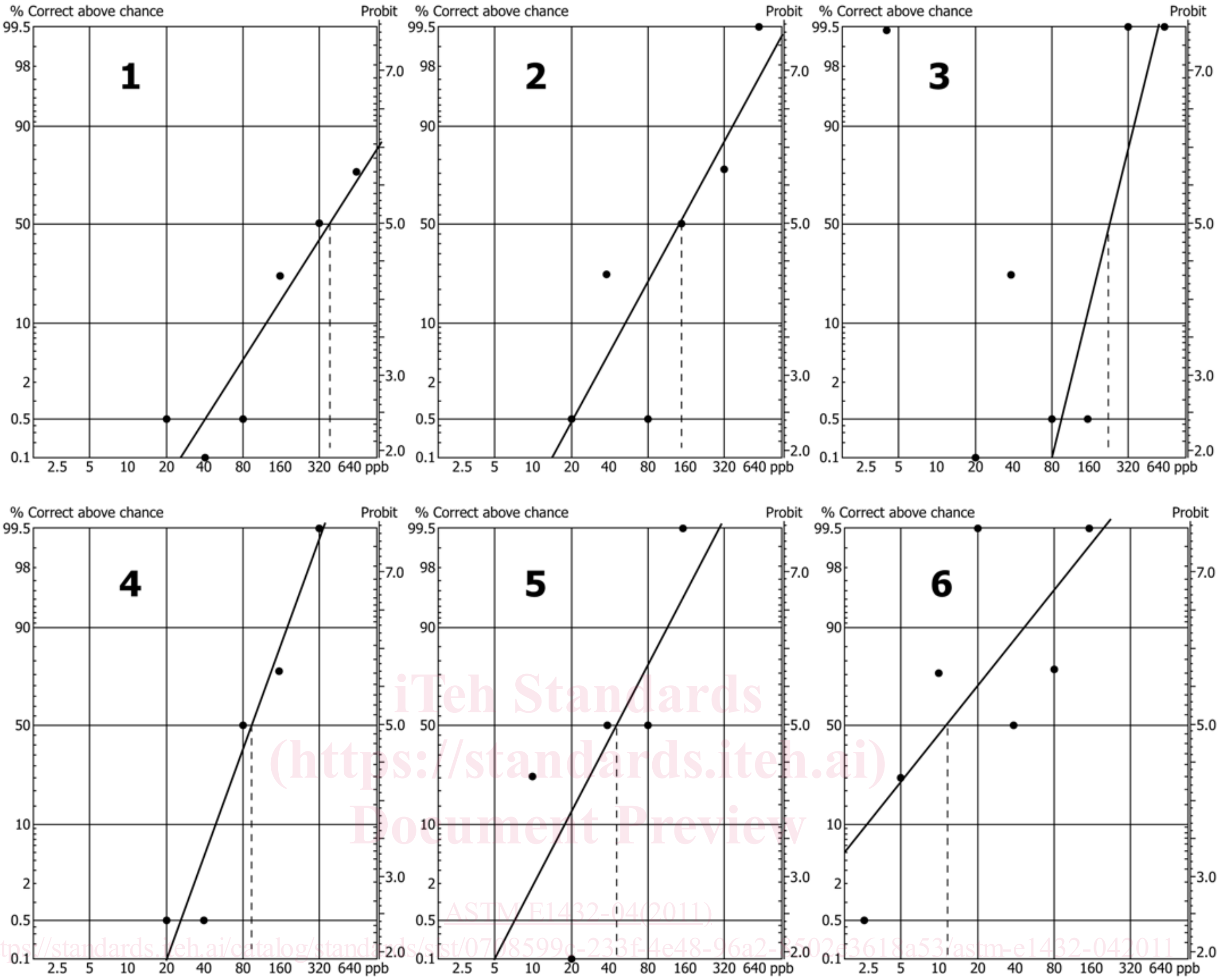
7. Panel Size and Composition Versus Purpose of Test

7.1 *Panel Size and Composition*—Panel variables should be chosen as a function of the purpose for which the resulting threshold is needed. The important panel variables are as follows:

7.1.1 Number of tests per panelist,

7.1.2 Number of panelists,

7.1.3 Selection of panelists to represent a given population, and



NOTE 1—The results (using Probits and linear regression) are as follows:

Panelist No.	1	2	3	4	5	6
Threshold, ppb	381	166	226	97	47	12

Group standard deviation (six panelists), σ = 0.539 in log (ppb) units.

FIG. 5 Graphic Estimation of Approximate Thresholds for the Six Panelists in 7.3

7.1.4 Degree of training.

7.2 *Purpose of Test*—It is useful to distinguish the following three categories:

7.2.1 *Comparing an Individual's Threshold With a Literature Value*—The test may be conducted, for example, to diagnose anosmia or ageusia, or to study sensitivity to pain, noise, or odor. This is the simplest category requiring a minimum of 20 to 40 3-AFC presentations to the individual in question (see 2.2). A number of training sessions may be required to establish the range of concentrations that will be used and to make certain that the individual is fully familiar with the stimulus to be detected as well as the mechanics of the test.

7.2.2 *A Population Threshold is Required,* for example, the odor threshold of a population exposed to a given pollutant, or the flavor threshold of consumers of a beverage for a given contaminant. In this case, recourse must be had to the rules of sampling from a population (see Ref (**1**)[5] and Practice E122), which require the following:

(1) That the population be accurately defined and delimited,

(2) That the sample drawn be truly random, that is, that every member of the population has a known chance of being selected, and

(3) That knowledge of the degree of variation occurring within the population exists or can be acquired in the course of formulating the plan of sampling.

[5] The boldface numbers in parentheses refer to the list of references at the end of this standard.