INTERNATIONAL STANDARD

ISO 10551

Second edition
2019-06

Ergonomics of the physical environment — Subjective judgement scales for assessing physical environments

Ergonomie de l'environnement physique — Échelles de jugements subjectifs pour l'évaluation des environnements physiques

Reference number
ISO 10551:2019(E)

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Published in Switzerland

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 5, *Ergonomics of the physical environment*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

This second edition cancels and replaces the first edition (ISO 10551:1995), which has been technically revised. The main changes compared to the previous edition are as follows:

— the title has been changed;

— the Scope has been reworded;

— new references have been added to Clause 2;

— new entries have been added to Clause 3;

— in 5.2.1, a unipolar scale has been added;

— Annex B has been changed;

— Annexes C to G have been added.

Introduction

By using this document, you can construct subjective scales that can be used to ask people how they feel about their physical environment. That is whether they find it too hot, whether there is any noise and if it is annoying, if the light is too bright, is it "smelly" and so on. By constructing the scales and using them correctly, you can see, in a cost-effective way, how people find the environment. The information can be applied to report on the environmental quality and to work out how to improve the environment.

People are exposed to a range of physical environments which can affect their health and safety, comfort and performance. An important method for assessing physical environments, particularly when considering psychological constructs such as comfort or satisfaction, is to use subjective scales. The type of scale used and how it is administered is important in influencing the subjective responses of people. There are principles for constructing scales and procedures for administering them that reduce bias and ensure validity and reliability of response. There are also generic types of scale that can be used across environmental stimuli, for example, scales on which people rate sensation or comfort or acceptability or preference and so on.

This document provides a description of principles of scale construction and procedures for use. It also provides examples of commonly used scales across environmental components. This document does not standardize any particular scale but it provides the principles upon which appropriate scales can be constructed. It is needed to provide consistency in the production of valid and reliable scales. It is particularly useful to people who wish to conduct an environmental survey, for example to assess post occupant satisfaction of new or existing buildings or other spaces, environments where dissatisfaction occurs and a diagnosis of the problems is required and for people who are investigating the relationship between conditions in the physical environment and human perception. A consistent approach to subjective scale construction and use also allows a meaningful comparison of data obtained from investigations internationally.

This document forms part of a group of international standards on the assessment of comfort, stress and strain in physical environments.

This series is concerned, in particular, with:

1) establishing specifications on methods for measuring and estimating the characteristic physical parameters of environments;

2) establishing methods for assessing stress in environments.

This document proposes a set of specifications on direct expert assessment of comfort/discomfort expressed by persons subjected to various degrees of stress during periods spent in physical environments. The data provided by this assessment can be used on its own or to supplement physical and physiological methods of assessing loads. The methods belong to a psychological approach consisting in gathering, as appropriate, the on-site opinions of persons exposed to the conditions under consideration (diagnosis) and, thus, can complement data provided by predictive approaches described elsewhere in this group. The information provided in this document can be used to construct valid subjective scales for use in determining how people feel in their physical environment. This document does not give guidance on questionnaire design and application although the scales may be used in the construction of questionnaires.

If persons exposed to environments are to be asked about their corresponding experiences or information requested on their cultural attitude in order to obtain the most appropriate subjective judgement scales, favourable relationships may usefully be established between these persons and the organization responsible, through the persons conducting the ergonomic investigation.

The environments which lend themselves to the application of subjective judgement scales relate to conditions which differ to a moderate degree from comfortable conditions. Under extreme conditions, physical and physiological assessment methods of the environmental load are preferred, provided that their results can be used as criteria for a decision. In particular, tolerance limits for load cannot be confidently based on subjective judgements and need to be decided in view of accepted health risk

criteria. The decision of whether a person is exposed to an extreme environment is not left to the person exposed as their judgement can be impaired by the conditions.

The opinions held by persons about their environment have a value in themselves. It is up to the ergonomist whether or not to take them into account. The reputation of these data for lack of reliability does not justify dismissing them out of hand. The aim of this document is precisely to improve their reliability by specifying the appropriate tools to use in collecting them and the requirement for using them.

Ergonomics of the physical environment — Subjective judgement scales for assessing physical environments

1 Scope

This document presents principles and examples of practical application for the construction of appropriate subjective scales for use in the assessment and evaluation of the physical environment. It does not standardize particular scales.

It considers scales of perception, comfort, preference, acceptability, expression form and tolerance, and environmental components such as thermal, visual, air quality, acoustic and vibration.

It does not consider other scales such as:

— scales related to the effects of the environment on the ability to read displays or signs, on manual performance or on psychological conditions such as mood, etc.;

— scales related to pain or scales related to stimuli that can lead to injury.

This document does not present principles of surveys (see Note) or questionnaire design. However, the scales that are developed using this document can be incorporated into surveys or questionnaires.

NOTE Environmental surveys are described in ISO 28802. ISO 28802 includes scales that are complementary to, and based upon, the principles of scale construction that are described in this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 13731, *Ergonomics of the thermal environment — Vocabulary and symbols*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13731 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 Subjective judgement scales for physical environments: Principles of scale construction and use

There are a number of subjective judgement scales for physical environments. They differ in whether emphasis is placed on some aspect of judgement:

— perceptual or affective (evaluative and preferential);

— global (encompassing the whole environment or organism) or localized;

— present or past;

— instantaneous or extended over a period of time.

They also differ as to the object of judgement: environment or person, the whole or its component parts, permanent or temporary situation.

This document retains judgements that people make about their own state as a whole. It distinguishes between perception, present affective assessment (comfort/discomfort) and future preference.

NOTE 1 This document also suggests supplementing the perceptual, evaluative and preferential judgement scales by a statement of acceptability and a scale of tolerance of environments

In most instances, the exposure to an environment lasts for several hours. Therefore, it is useful to gather the person's opinions throughout, by repeating the expression of the judgements at regular intervals, using exactly the same scales.

By repeatedly applying the same scales, the evolution with time of the comfort or strain experienced can be assessed and an integrated judgement obtained over the whole time of exposure by appropriate computation of the data (e.g. overall mean, overall change, variation, etc.).

Basic difficulties are encountered in any area which involves the use of language. In this regard, bias and variability in the data can result from inconsistencies and inappropriateness of accompanying instructions. Therefore, it becomes crucial to standardized preparatory instructions which explain the study, as well as the wording of the judgement scales. The terminology used to denote the degrees on the judgement scales is of special importance. This document specifies the principles used to develop subjective scales. The actual descriptors used can be influenced by the language structure and shall be established with subject experts from National Standards Body.

NOTE 2 International usage and acceptance of the scales in this document will result in the fixing of suitable wording of the degrees on the scales in various languages.

Other judgement scales are in use concerning the state of various parts of the body (e.g. head, torso, hands, feet), the total environment or various components of it, other aspects of the experience of the person or evaluations conducted over a certain period of time, including periods during which conditions have not been measured. Other scales, e.g. a bipolar affective evaluation scale, have been structured differently on the model of perception; such a scale is useful for taking into account pleasure and is more sensitive than the unipolar discomfort scale in the region near to comfort.

This document is limited to the five scales described in Clauses 4 and 5. The gathering of subjective judgement should first be concerned with localized sensations (parts of the body) and in constant conditions, given the current interest and application of these data. The second concern should be for data gathered under transient conditions, which are extremely important but are not yet sufficiently well known.

5 Perceptual, evaluation and preferential judgement scales

5.1 Instructions for using the judgement scales

It is important to distinguish between more objective ratings, such as sensations, and affective or evaluative ratings, such as comfort and pleasure. In everyday language, however, these dimensions are often confounded and distinctions are not made. In addition, the richness of the semantics for describing environments and responses to them depends on individuals, their experiences, their language and their culture, when investigating physical environments. Therefore, it is sometimes useful to first investigate the psychological dimension (or constructs) which individuals and groups use to describe their world[7].

Two commonly used approaches are semantic differential techniques and personal construct theory methods. The methods invoke factor analysis or multidimensional scaling techniques to build a psychological model of the way in which physical environments are perceived and "modelled" (represented in psychological space) by the person. Similar stimuli on a particular dimension (or all combinations of dimensions) are placed close together in the multidimensional model of psychological space.

The form and method of administering the scales are important. For example, a continuous form of the scale would be to draw a line through all points on the scale where subjective terms are placed. This would allow a person exposed to the environment to choose values between ratings (e.g. between cool and cold, a rating of –1,6 on a thermal sensation scale.). In an analysis of the results, this would enable parametric statistics to be used. However, it is possible that the investigator does not consider that data are "strong enough" for this and is prepared to use only ordinal data (ranks) and non-parametric statistics. These, and other, points are of importance and, for further information, the reader is referred to a text on the design and analysis of surveys and on the use of subjective assessment methods (see [6]).

The psychological interaction when the scale is administered can also influence the results. Usually, the subjects are given the scale and asked to tick the place which represent "how they feel now", for example. It is important to avoid ambiguity, which can lead to a person providing his or her own interpretation, for example, of what the environment is generally like or how other people perceive it. Other issues include range effects. The range provided, (e.g. hot to cold) influences the subject's judgement as do leading questions: (e.g. "you are uncomfortable, aren't you?"). The following important issues should be considered when constructing questionnaires:

— question specificity;

— language;

— clarity;

— leading questions;

— prestige;

— bias;

— embarrassing questions;

— hypothetical questions; and

— impersonal questions.

Other issues include whether knowledge of the results is given. For example, if responses are requested over time, is the subject informed of previous ratings that he or she made, and whether the ratings are given in the presence of others? In some circumstances, people can avoid extremes such as end points on scales or be influenced by the range presented.

Although subjective measurement techniques can be useful for measuring extreme environments, they should not be used as a primary measure in health and safety. In these conditions, the ability of a person to make a "rational" subjective judgement can be impaired. While a subject shall always be allowed to withdraw from an investigation, he or she does not have the overriding right to remain in it. It is the investigator's judgement as to whether he or she should remain exposed (based on physiological responses, etc.) even if the subject is willing (enthusiastic) to do so.

The three judgement scales should be applied in the following order: perceptual scale, evaluative scale, scale of preference. The combination of possible replies provides all the required information.

The following introductory questions should be posed:

— before applying the perceptual scale: "How are you feeling (at this precise moment)?" (followed by the replies from the scale);

— after the response given on the perceptual scale, and immediately before applying the evaluative scale: "Do you find this... ?" (followed by the replies from the scale);

— after the response given on the evaluative scale, and immediately before the application of the preference scale: "Please state how you would prefer to be now" (followed by the replies from the scale).

A 7-degree scale should be applied in the case of environments judged to be close to neutrality; a 9-degree scale should be applied in the case of environments judged to be more intense.

Full scales are presented, even in cases of surroundings located only in a limited range of conditions. The wording of all the degrees of a scale provides a frame of reference useful to those asked to verbalize their instantaneous experience.

There is utility to the investigator to consider a large number of environmental impacts and a variety of scales. However, the desire for data shall be balanced with the willingness of the participants to provide accurate perceptions, and the management's tolerance for the use of the time required. The survey is most acceptable if it is focused on legitimate environmental concerns specific to the environment in question. The scales used and the ergonomic aspect assessed shall get to the point and provide actionable data.

5.2 Scale of perception of the personal state

5.2.1 Structure of the scale

Scales can be unipolar or bipolar.

For a unipolar scale, a 4-degree one-pole scale, which can be extended to 5 degrees, with a point of origin indicating the absence of the effect, and 3 (or 4) degrees of increasing intensity of the effect.

Point of origin	Degrees of intensity	
0	1 2 3 (4)	Unique pole

For bipolar scales, a symmetrical 7-degree two-pole scale, which can be extended to 9 degrees, comprising a central indifference point and two times 3 (or 4) degrees of increasing intensity.

	Degrees of intensity	Point of indifference	Degrees of intensity	
Pole A	(–4) –3 –2 –1	0	+1 +2 +3 (+4)	Pole B

5.2.2 Wording of the degrees

Poles A and B are at either end of the scale. The central point of indifference corresponds to absence of sensation. The wording of the degrees depends on the vocabulary choices in each language. The selection of the terms should be carried out carefully and tested beforehand on a representative number of persons who are native speakers of the given language.

The following wordings should be taken as an example:

— for languages which have several (at least two) distinct terms to denote different degrees of intensity, these terms are used along the lines of the English wording;

— for languages which do not have two terms for denoting different degrees of intensity for each of the poles, a single term is used for each pole and its intensity modulated by the use of adverbs along the lines of the French wording.

NOTE Tables A.1 and C.1 give examples for each case.

5.3 Evaluative scale

5.3.1 Structure of the scale

A 4-degree one-pole scale, which can be extended to 5 degrees, with a point of origin indicating the absence of the effect, and 3 (or 4) degrees of increasing intensity of the effect.

Point of origin	Degrees of intensity	
0	1 2 3 (4)	Unique pole

5.3.2 Wording of the points

The unique pole devoted to the evaluation of the load denotes a negative effect: DISPLEASURE, DISSATISFACTION or DISCOMFORT. Its intensity can be modulated by adverbs. COMFORT, located at the point of origin, and ABSENCE OF DISCOMFORT, are also classed as positive evaluations (pleasure, satisfaction).

NOTE Tables A.2, C.2, D.1, and E.1 give examples for each case.

5.4 Preference scale

5.4.1 Structure of the scale

A symmetrical 7-degree bipolar scale comprises a central point of indecision and two times 3 degrees of increasing intensity.

	Degrees of intensity	Point of indecision	Degrees of intensity	
Pole A	–3 –2 –1	0	+1 +2 +3	Pole B

5.4.2 Wording of the degrees

Poles A and B are at either end of the scale. The central point of indecision corresponds to the ABSENCE OF CHANGE.

The degrees should be worded using, for each pole, a comparative term which can be modulated in intensity by means of adverbs. It is possible to reduce the three degrees of each of the poles to a single degree worded by means of an unmodulated comparative term.

NOTE Tables A.3, B.2, and C.3 give examples for each case.

6 Personal acceptability statement and tolerance scale

6.1 General

In addition to the previous judgements, information should be obtained indicating how the workers personally feel toward their situation.

This assessment would be in terms of rejection or acceptance on a personal level, complemented in any case by a relative judgement of the degree of personal tolerance. Rejection or acceptance is expressed on a personal level, i.e. out of context, the judgement being based purely on personal preference. The expression of rejection on a personal level (unacceptability) is therefore not incompatible with actual acceptance, which takes into account other contextual motivations (instructions, job requirement, short duration of exposure, remuneration).

In contrast to the three preceding scales, the personal acceptability statement and the tolerance scale consist of judgements made about the surroundings.

6.2 Instructions for using the judgement expression forms

The acceptability statement form and tolerance scale should be applied after the perception and assessment scales described above, and should be in the following order: acceptability statement form, then tolerance scale.

The following introductory questions should be posed:

— before application of the acceptability statement form:

1) in explicit terms: “How do you judge this environment on a personal level?”;

2) with the initial statement: “Taking into account only your personal preference,” either:

a) “... would you rather accept this environment than reject it?”; or

b) “... would you rather reject this environment than accept it?”;

— before the application of the tolerance scale: “In your opinion, is the environment ...?”.

6.3 Description of the forms of judgement expression

6.3.1 Structure of the forms of judgement expression

The form of the personal acceptability statement will be a binary structure of the type: PERSONAL ACCEPTANCE (GENERALLY ACCEPTABLE) — PERSONAL REJECTION (GENERALLY UNACCEPTABLE).

The personal tolerance scale has a unipolar 5-degree structure, the single pole expressing DIFFICULTY IN TOLERATING, with a point of origin indicating no difficulty in tolerating and with 4 degrees of increasing difficulty in tolerating, the 4th degree expressing intolerable.

Point of origin	Degrees of intensity	
0	1 2 3 4	Unique pole

6.3.2 Wording of the degrees

The wording of the two categories on the personal acceptability statement form can consist of either:

a) a clarification of the judgement of the person questioned;

A.1.1.1.1 Categories	A.1.1.1.2 Wording	A.1.1.1.3 Response
ACCEPTABLE	Environment acceptable rather than unacceptable	
UNACCEPTABLE	Environment unacceptable rather than acceptable	

b) or the expression of agreement or disagreement of the person questioned with the initial statement.

Initial statement	Category ACCEPTABLE	Category UNACCEPTABLE
Either “personal acceptance”	Yes (agreement)	No (disagreement)
Or “personal rejection.”	No (disagreement)	Yes (agreement)

NOTE The degrees on the personal tolerance scale can be worded in terms of difficulty in tolerating (or bearing). An example is given in Table A.5.

7 Instructions for repeat enquiries

Persons submitted to repeated application of the same judgement scales should be informed beforehand, in order to avoid undesired reactions and to present arguments justifying the application of the procedure. The following instructions can be issued:

> “As you usually stay several hours at this workplace, you will be asked several times, at regular intervals, by means of the same scales, to judge the physical conditions; indicate your actual

experience at that moment. You will, thus, be in a position to express (more) accurately the possible changes in the physical conditions you may experience over a longer period of exposure".

8 Summary of the scales

Table 1 summarizes the various judgements which are recommended for an assessment of comfort or stress based on subjective data.

Table 1 — Stress assessment

	1	2	3	4	5
Subject under judgement	Personal state			Physical ambience	
Type of judgement	Perception	Evaluation	Preference	Personal acceptability	Personal tolerance
Wording	"How do you feel (at this precise moment)?" 7 or 9 degrees	"Do you find it ...?" 4 or 5 degrees, from COMFORTABLE to very (or extremely), UNCOMFORTABLE	"Please state how you would prefer to be now." 7 (or 3) degrees	"How do you judge this environment on a personal level?" 2 degrees, GENERALLY ACCEPTABLE, GENERALLY UNACCEPTABLE	"In your opinion is the environment...?" 5 degrees, from perfectly TOLERABLE to INTOLERABLE

9 Format and method of presentations of the scales

Scales with more than two degrees can be presented in a discontinuous format: 3, 4, 7 or 9 separate degrees at equal intervals; the response consists of ticking the degree corresponding to the judgement.

The same scales can also be presented using a continuous format, e.g. a segment of a straight line or curve comprising 3, 4, 5, 7 or 9 equally spaced marks with the corresponding wording next to them. This format not only makes it possible to indicate the mark corresponding to the judgement, but also to locate the response anywhere within the intervals between marks.

Normally presented in written form to be completed manually, these scales can also be presented on a video display unit and the responses given using a keyboard, or other equivalent, and an appropriate code.

10 Data analysis and application of the results

The numerical properties (i.e. in terms of mathematical structure) of the data collected by applying the judgement scales above, and the statistical characteristics of the distributions of these data dictate the type of quantitative analysis that can legitimately be applied to them.

The example given in Annex F illustrates a number of treatments and the results that can be obtained: indices of central tendency, of scatter and of association in particular, or statistical tests for significance of difference, of effects of factors or of association.

NOTE This document encourages practitioners and researchers with sufficient data, or those who are able to collect data, to publish studies on the statistical characteristics of the sample distributions of such data.

Annex A
(informative)

Commonly used scales for assessing thermal environments

Table A.1 — Scale of perceptual judgements on personal thermal state

(after the question "How are you feeling now?")

Poles	Degrees	English
HOT	(+5)	Extremely hot
	(+4)	Very hot
	+3	Hot
	+2	Warm
	+1	Slightly warm
INDIFFERENCE	0	Neutral
COLD	−1	Slightly cool
	−2	Cool
	−3	Cold
	(−4)	Very cold
	(−5)	Extremely cold
Common introductory term(s)		I am feeling/I am
NOTE The central tendency of the perceptual judgements obtained by applying one of the above-mentioned scales (in continuous form) yields an observed mean vote which can be compared with the Predicted Mean Vote (PMV index) determined according to ISO 7730[2].		

Table A.2 — Scale of evaluative judgements on personal thermal state

(after the question "Do you find this....?")

Pole	Degree	Wording of degrees
	0	Comfortable
	1	Slightly uncomfortable
DISCOMFORT	2	Uncomfortable
	3	Very uncomfortable
	4	Extremely uncomfortable
Common introductory terms		I find the thermal environment....
NOTE By summing up the judgements which express discomfort, one obtains an observed percentage of dissatisfied people, which can be compared with the Predicted Percentage of Dissatisfied (PPD index) determined according to ISO 7730.		

Table A.3 — Thermal preference scale

(after the instruction "Please state how you would prefer to be now.")

Poles	Degrees	Wording of degrees for 7-degree scale	Equivalent for 3-degree scale
WARMER	+3	Much warmer	Warmer
	+2	Warmer	
	+1	A little warmer	
	0	Neither warmer nor cooler (no change)	
COOLER	−1	Slightly cooler	Cooler
	−2	Cooler	
	−3	Much cooler	
Common introductory terms		I would prefer to be...	

Preference scales are used in assessment as they provide a "value" judgement from subjects. If a subject rates a sensation as "slightly warm" for example, it does not indicate whether or not he or she *wishes* to be "slightly warm". The preference rating compares how the subject is with how he or she would like to be. "No change" indicates a form of acceptability, preference, and satisfaction. Other scales can be useful depending upon the aims of the experiment. If a percentage of satisfaction is required then a "forced" (the subject must choose) yes or no response to "Are you satisfied?" would give a direct measure. Ratings of pleasure can be of interest. These can be confounded with visual stimuli (for example, driving through the countryside on a sunny day) but solar radiation can elicit pleasant and unpleasant responses and should be considered. Ratings of acceptability are useful to vehicle manufacturers. They require a sophisticated judgement based on what a subject would feel is acceptable in that context. A combination of scales integrated into a questionnaire provides a useful measurement tool. The scales complement each other and give a detailed profile of comfort. Subjective ratings from individual parts of the body provide some indication of why subjects gave their "overall" rating.

Table A.4 — Personal acceptability statement form

Categories	a) Explicit wording of the degrees	b) Wording of degrees after initial statement 1) or 2)	
	After the question: "How do you judge this environment (local climate) on a personal level?"	After the common instructions: "Taking into account only your personal preference, ..."	
		Initial statement 1): "... would you accept this environment (local climate) rather than reject it?"	Initial statement 2): "... would you reject this environment (local climate) rather than accept it?"
	"On a personal level, this environment is for me.....		
0	....acceptable rather than unacceptable."	Yes	No
1	....unacceptable rather than acceptable."	No	Yes

Instead of using a two-category statement form, personal acceptability may be expressed on a continuous scale, such as the following:

Clearly acceptable	Just acceptable	Just unacceptable	Clearly unacceptable

The preliminary instructions would be as follows [after the question "How do you judge this environment (local climate) on a personal level?" or after instruction "Taking into account only your

personal preference"]: "Please mark the appropriate place on the scale to express your acceptance of the environment (local climate). Do not mark the middle of the scale, but express either acceptance or unacceptance".

NOTE In addition to the same information obtained by applying the two-category statement form, a more gradual judgement can be expressed which can show a linear relationship with the "observed percentage of dissatisfied" people, as defined in the evaluative judgement scale in Table A.2 (see also Annex G, Example A).

Table A.5 — Personal tolerance scale

(after the question: "Is it……?")

Pole	Degree	Wording of degrees
DIFFICULTY IN TOLERATING	0	bearable/tolerable
	1	slightly difficult to bear/tolerate
	2	fairly difficult to bear/tolerate
	3	very difficult to bear/tolerate
	4	unbearable/intolerable
Common introductory terms		I find the thermal environment …..

Annex B
(informative)

Commonly used scales for assessing acoustic environments

Loudness is a perceptual term for the acoustic environment. However, it is not normally considered in assessment.

Table B.1 — Personal annoyance scale

(after the question: "Is it……?")

Pole	Degree	Wording of degrees
Annoyance	1	Not annoying
	2	Slightly annoying
	3	Annoying
	4	Very annoying
Common introductory terms		I find the acoustic environment to be …..

A widely used scale for noise annoyance which is available in a number of languages can be found in References [4] and [9].

Table B.2 — Preference scale

(after the instruction "Please state how you would prefer to be now.")

Pole	Degree	Wording of degrees
Preference	1	No change
	2	Slightly quieter
	3	Quieter
	4	Much quieter
Common introductory terms		I would prefer to be…

Table B.3 — Personal acceptability statement form

Categories	a) Explicit wording of the degrees	b) Wording of degrees after initial statement 1) or 2)	
	After the question: "How do you judge this environment on a personal level?"	After the common instructions: "Taking into account only your personal preference, …"	
		Initial statement 1): "… would you accept this environment rather than reject it?"	Initial statement 2): "… would you reject this environment rather than accept it?"
	"On a personal level, this environment is for me…..		
0	….acceptable rather than unacceptable."	Yes	No
1	….unacceptable rather than acceptable."	No	Yes

Instead of using a two-category statement form, personal acceptability can be expressed on a continuous scale, such as the following:

Clearly acceptable	Just acceptable	Just unacceptable	Clearly unacceptable

The preliminary instructions would be as follows [after the question "How do you judge this environment on a personal level?" or after instruction "Taking into account only your personal preference"]: "Please mark the appropriate place on the scale to express your acceptance of the environment. Do not mark the middle of the scale, but express either acceptance or unacceptance".

NOTE In addition to the same information obtained by applying the two-category statement form, a more gradual judgement can be expressed which can show a linear relationship with the "observed percentage of dissatisfied" people, as defined in the evaluative judgement scale in Table B.2 (see also Annex F, Example A).

Annex C
(informative)

Commonly used scales for assessing visual environments

Table C.1 — Scale of perceptual judgements on personal state

(after the question "The lighting environment now is…?")

Extremely dark ——————————————————— Extremely light

Table C.2 — Scale of evaluative judgements on personal state

(after the question "Do you find this….?")

Pole	Degree	Wording of degrees
Visual comfort	1	No discomfort
	2	Slightly discomfort
	3	Discomfort
	4	Much discomfort
Common introductory terms		This visual environment causes me …..

Table C.3 — Preference scale

(after the instruction "Please state how you would prefer to be now."
I would prefer a lighting environment to be:)

Pole	Degree	Wording of degrees
Preference	1	Much darker
	2	Darker
	3	Slightly darker
	4	No change
	5	Slightly lighter
	6	Lighter
	7	Much lighter
Common introductory terms		I would prefer the visual environment to be…

Preference scales are used in assessment as they provide a "value" judgement from subjects. If a subject rates a sensation of "bright" for example, it does not indicate whether or not he or she *wishes it* to be "darker". The preference rating compares how the subject is with how he or she would like to be. "No change" indicates a form of acceptability, preference, and satisfaction. It can be that a person prefers different aspects of the visual environment to change. In this case, the subjective scale can be used for each different aspect. For example, a person can wish the background to be brighter but not the other aspects of the visual environment.

Table C.4 — Personal acceptability statement form

Categories	a) Explicit wording of the degrees	b) Wording of degrees after initial statement 1) or 2)	
	After the question: "How do you judge this environment on a personal level?"	After the common instructions: "Taking into account only your personal preference, …"	
		Initial statement 1): "… would you accept this environment rather than reject it?"	Initial statement 2): "… would you reject this environment rather than accept it?"
	"On a personal level, this environment is for me…		
0	… acceptable rather than unacceptable."	Yes	No
1	… unacceptable rather than acceptable."	No	Yes

Instead of using a two-category statement form, personal acceptability can be expressed on a continuous scale, such as the following:

Clearly acceptable	Just acceptable	Just unacceptable	Clearly unacceptable

Annex D
(informative)

Commonly used scales for assessing vibration environments

Table D.1 — Scale of perceptual judgements on personal state

Pole	Degree	Wording of degrees
Perceptible	1	Not perceptible
	2	Just perceptible
	3	perceptible
	4	Very perceptible
Common introductory terms		I find the vibration to be …

Table D.2 — Scale of evaluative judgements on personal state

(after the question "Do you find this…?")

Pole	Degree	Wording of degrees
Comfort	1	Not uncomfortable
	2	A little uncomfortable
	3	Fairly uncomfortable
	4	Uncomfortable
	5	Very uncomfortable
	6	Extremely uncomfortable
Common introductory terms		I find the vibration to be …

Table D.3 — Personal annoyance scale

(after the question: "Is it …?")

Pole	Degree	Wording of degrees
Annoyance	1	Not annoying
	2	Slightly annoying
	3	Annoying
	4	Very annoying
Common introductory terms		I find the vibration to be …

Table D.4 — Personal acceptability statement form

Categories	a) Explicit wording of the degrees	b) Wording of degrees after initial statement 1) or 2)	
	After the question: "How do you judge this environment on a personal level?"	After the common instructions: "Taking into account only your personal preference …"	
		Initial statement 1): "… would you accept this environment rather than reject it?"	Initial statement 2): "… would you reject this environment rather than accept it?"
	"On a personal level, this environment is for me…		
0	… acceptable rather than unacceptable."	Yes	No
1	… unacceptable rather than acceptable."	No	Yes

Instead of using a two-category statement form, personal acceptability can be expressed on a continuous scale, such as the following:

Clearly acceptable	Just acceptable	Just unacceptable	Clearly unacceptable

Annex E
(informative)

Commonly used scales for assessing air quality environments

Intensity of odour is a perceptual term for air quality which can be assessed using the scales[5][12][13].

Table E.1 — Scale of evaluative judgements on personal state

(after the question "Do you find the air to be ...?")

Pole	Degree	Wording of degrees
Smelliness	1	Not smelly
	2	Slightly Smelly
	3	Smelly
	4	Very smelly
Common introductory terms		I find the air to be ...

Table E.2 — Personal acceptability statement form

Categories	a) Explicit wording of the degrees	b) Wording of degrees after initial statement 1) or 2)	
	After the question: "How do you judge this environment on a personal level?"	After the common instructions: "Taking into account only your personal preference, ..."	
		Initial statement 1): "... would you accept this environment rather than reject it?"	Initial statement 2): "... would you reject this environment rather than accept it?"
	"On a personal level, this environment is for me...		
0	... acceptable rather than unacceptable."	Yes	No
1	... unacceptable rather than acceptable."	No	Yes

Instead of using a two-category statement form, personal acceptability can be expressed on a continuous scale, such as the following:

Clearly acceptable	Just acceptable	Just unacceptable	Clearly unacceptable

Annex F
(informative)

Application of assessment procedure and judgement scales: Examples, including data analysis

F.1 General

Three examples are given in the area of the thermal environment. The first is the most extensive, in order to illustrate the procedure and a more detailed data analysis. It concerns the application of the judgement scales in a working situation where somewhat cool conditions prevailed, creating slight discomfort. The other two examples are more specific; one concerns a laboratory setting providing thermal comfort, in which repeated assessments were carried out. The last example is related to a public transport situation in which the climatic conditions corresponded to slight thermal stress.

NOTE The examples provided in this annex demonstrate the application of this document in the construction and use of subjective scales. ISO 28802 describes how to integrate scales and other requirements to provide an environmental ergonomics survey.

F.2 Example A: Working places with slight cool discomfort

F.2.1 An ergonomist decided to gather the judgements of 40 workers on the thermal conditions they actually encountered at work. The estimated PMV values (see ISO 7730) at the workplaces were between −1,0 and +0,9 for various combinations of physical activity and thermal insulation of clothing, observed under measured climatic conditions.

F.2.2 The aim of the inquiry was explained to the workers: it was intended to establish how they felt with regard to their own thermal state and to the climatic environment, by means of a standardized questionnaire.

While the workers responded to the questions, the climatic parameters of the 40 workplaces were measured and estimates made of metabolic heat production and clothing insulation.

Each worker received a form containing the following questions:

1. How do you feel at this precise moment? (mark appropriate box): I am...

Very cold	Cold	Cool	Slightly cool	Neither hot nor cold	Slightly warm	Warm	Hot	Very hot
☐	☐	☐	☐	☐	☐	☐	☐	☐

2. Do you find this...?

Comfortable	Slightly uncomfortable	Uncomfortable	Very uncomfortable	Extremely uncomfortable
☐	☐	☐	☐	☐

3. At this moment, would you prefer to be...?

Much cooler	Cooler	Slightly cooler	Without change	Slightly warmer	Warmer	Much warmer
☐	☐	☐	☐	☐	☐	☐

4. Taking into account your personal preference only, would you accept rather than reject this climatic environment?

Yes ☐ No ☐

5. Is this environment, in your opinion...?

Perfectly bearable	Slightly difficult to bear	Fairly difficult to bear	Very difficult to bear	Unbearable
☐	☐	☐	☐	☐

F.2.3 The pooling of the results provided the following distribution of replies (n = number of replies of a given category):

F.2.3.1 Thermal perception

	Very cold	Cold	Cool	Slightly cool	Neutral	Slightly warm	Warm	Hot	Very hot	No reply
	−4	−3	−2	−1	0	+1	+2	+3	+4	
n			8	12	10	2	7			1

F.2.3.2 Affective assessment

	Comfortable	Slightly uncomfortable	Uncomfortable	Very uncomfortable	No reply
	0	1	2	3	
n	22	4	10	2	2

F.2.3.3 Thermal preference

	Much cooler	Cooler	Slightly cooler	No change	Slightly warmer	Warmer	Much warmer	No reply
	−3	−2	−1	0	+1	+2	+3	
n			4	18	14	4		0

F.2.3.4 Personal acceptability

	Yes	No	No reply
n	22	14	4

F.2.3.5 Personal tolerance

	Perfectly bearable	Slightly difficult to bear	Fairly difficult to bear	Very difficult to bear	Unbearable	No reply
	0	1	2	3	4	
n	5	0	15	7	0	2

F.2.4 Analysis of the data took into account the numerical properties of the data and the known statistical characteristics of their distributions.

The degrees on the scales of perception, affective assessment, preference and tolerance are ranked as classes of observable data which correspond to a totally ordered finite mathematical set (ordinal data or scales). The relevant statistics are the following:

— for the central tendency, the median (second quartile);

— for the scatter, the semi-interquartile distance (half the difference between the first and third quartiles);

— for the association in probability, the rank coefficients (Spearman's rho, Kendall's tau) or the coefficient of concordance (Kendall's W).

The appropriate statistical tests of the null hypothesis are of the nonparametric type (e.g. sign test, median test or certain types or variance analysis).

The replies on the acceptability statement form fall into two distinct categories of data, which correspond to two equivalence classes (nominal or categorical data). The relevant statistics are the following:

— for the central tendency, the mode (point of maximum frequency);

— for the scatter: the entropy of the distribution;

— for the probability association, various coefficients such as the coefficient of association or the contingency coefficient.

The appropriate statistical tests of the null hypothesis are also of the nonparametric type (e.g. binomial test or chi-squared test).

The statistics and null hypothesis tests relevant to nominal data are also relevant to ordinal data.

The only study devoted to the statistical characteristics of data distributions concerns those obtained by applying two 7-degree scales: the ASHRAE thermal perception scale and the Bedford mixed scale combining thermal perception and evaluation[6]. It was shown that degrees other than the two extreme ones are psychologically located at equivalent distances and can, thus, be treated as continuous data whose differences are defined numerically (interval scale); they approximate normal distributions, so it is quite legitimate to calculate the mean and standard deviation, and to submit them to calculations of correlations and regression applied to continuous variables. The appropriate statistical tests of the null hypothesis are the parametric type (e.g. t or F tests, variance and covariance analyses).

There appears to be no published material regarding the statistical characteristics of data from preference and tolerance scales, and from acceptability statement forms.

F.2.5 Results

F.2.5.1 General

The following results relate to the data reported in F.2.3.

F.2.5.2 Thermal perception (n = 39)

Central tendency (mean: $\overline{Y}$): −0,31

Scatter (standard deviation): 1,36

Significance of the difference between observed $\overline{Y}$ and $\overline{Y}$ = 0 (t test for n < 60): t = 1,42, p > 0,05

Conclusion: not significant

F.2.5.3 Affective assessment (n = 38)

Central tendency (median point): comfortable scatter (semi-interquartile distance): 1 interval between successive degrees

Dissatisfaction index (observed percentage of judgements expressing discomfort, or observed percentage of dissatisfied): 42 %

Significance of the difference between the observed percentage of dissatisfied (dissatisfaction index) and the predicted percentage of dissatisfied (PPD) corresponding to a predicted mean vote (PMV) equal to −0,31 PPD corresponding to PMV = −0,31: 7 % (ISO 7730:2005, Figure 1). This defines a theoretical two-category population consisting of "discomfort" judgements in the proportion p = 0,07 and of "comfort" judgements in a complementary proportion Q = 0,93.

The probability of obtaining 16 "discomfort" judgements (the observed number) or more in a sample of 38 judgements drawn from the theoretical population defined above. The sampling distribution of the numbers (or proportions) of events (here, the judgements) of one category that can be observed in random samples drawn from theoretical two-category populations such as that defined above is known: it is the so-called binomial distribution. It specifies that the exact probability of obtaining x events of one category (and $n–x$ events of the other category) is as Formula (F.1):

$$p(x) = \{n! / [(x!\ (n - x)!]\} \cdot P^x \cdot Q^{(n-x)} \quad \text{(F.1)}$$

where

n is the total number of events in the sample;

x is the number of events of a certain category ($0 \le x \le n$);

P is the probability of events of this category in the theoretical two-category population $Q = 1 - P$.

By summing up the probabilities of obtaining samples with x and more (up to $x = n$) events of this category drawn from the same theoretical two-category population, one obtains the probability $\sum_{i=n}^{x} p(i) =$ which will be examined from the statistical point of view[8].

In the present case, with n = 38, x = 16, P = 0,07 and Q = 0,93, one has $\sum_{i=38}^{16} p(i) = 4{,}365 \times 10^{-9}$.

In the case of samples with $n > 25$ and probabilities P and Q close to 0,5, the binomial distribution tends towards the normal distribution, which can then be used as an appropriate approximation of the statistical binomial test X is transformed into $z = (x - nP) / \sqrt{nPQ}$; z is approximately normally distributed with a mean equal to zero and a variance equal to one. A rule of thumb is that nPQ needs to equal at least 9 before the statistical test based on the normal distribution is applicable. This is obviously not the case in the present example (nPQ = 2,47). Therefore, the binomial distribution formula needs to be used.

In conclusion, the probability of obtaining a dissatisfaction index of 42 % is very low if one assumes that the population of judgements is that which corresponds to PMV = −0,31.

F.2.5.4 Thermal preference

Central tendency (median point): no change

Scatter (semi-interquartile distance): 0,5 interval between successive degrees

Preference index (percentage of judgements expressing a preference for change): 55 %

In contrast to the hypothesis of an equally probable distribution of the preference judgements among the three categories "cooler", "no change" and "warmer", the observed distribution of the preference judgements is significantly different ($\chi^2 = 10{,}1$, with two degrees of freedom: $p < 0{,}01$). The frequency of "cooler" preferences is lower, whereas those of the judgements of both other categories are higher than assumed.

F.2.5.5 Acceptability (n = 36)

central tendency (modal judgement): acceptable rather than unacceptable

unacceptability index (percentage of judgements expressing unacceptability "on a personal level"): 40 %

F.2.5.6 Tolerance (n = 36)

central tendency (median point): fairly difficult to bear

scatter (semi-interquartile distance): 0,5 interval between successive degrees

painfulness index (percentage of judgements expressing difficulty to bear): 86 %

F.2.6 Conclusion

On average, the workers judged their own thermal state as being close to thermal neutrality ($\overline{Y} = -0{,}31$) and the median of their corresponding evaluative judgements was "comfortable".

Nevertheless, the percentage of "discomfort" judgements amounted to 42, which is significantly different from random occurrence in a sample of judgements drawn from a population with only 7 % "discomfort" judgements (this would correspond to a PMV = −0,31). The frequency of judgements preferring "cooler" was significantly lower than that to be expected if the distribution of judgements among the three possible categories had been equally probable. 40 % of the persons judged the thermal ambience as being "unacceptable on a personal level", and 86 % among them judged it as being more or less difficult to tolerate.

It can be concluded that the climatic conditions in this workplace are not optimal for thermal comfort, apparently due to insufficient heating.

F.3 Example B: Repeated comfort assessment in a laboratory setting

F.3.1 Twelve young healthy adults (18 to 28 years old), six men and six women, remained seated at rest from 08:25 a.m. until 12:00 p.m. in a climatic chamber. They were lightly clad (Icl = 0,6 clo) and exposed to a uniform ambient temperature of 25 °C. They performed office tasks for 185 min, after a short 30-min adaptation period. The same subjective assessment scales used in Example A (see F.2) were applied at 08:55, 09:40 and 09:55, 10:40 and 10:55, 11:40 and 11:55, i.e. every hour. Except for the first one, each inquiry was carried out twice, with a 15-min interval, and the replies were pooled.

F.3.2 Results

Table F.1 gives the main statistics for the successive samples of data which were collected. The judgements are recorded according to the code numbers used for each scale, as shown in Annex A.