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Ergonomics of the physical environment — Assessment of environments by means of an environmental survey involving physical measurements of the environment and subjective responses of people

Ergonomie de l'environnement physique — Évaluation au moyen d'une enquête environnementale comprenant des mesurages physiques et des réponses humaines subjectives

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 28802 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 5, *Ergonomics of the physical environment*.

Introduction

This is one of a series of International Standards concerned with the ergonomics of the physical environment. It provides a method for conducting an environmental survey. It complements other International Standards in the series concerned with specific components of the environment such as thermal, acoustic, lighting and air quality environments. It builds upon those standards to allow the assessment of human response to the total environment.

This International Standard presents methods for the evaluation of comfort using physical measures of the environment and subjective measures from people. It provides methods for the assessment of thermal, acoustic, visual and lighting, and air quality environments, as well as other relevant environmental components. For each environmental component, methods are provided for measuring the physical environment and subjective responses to the environment. An assessment form for use as an environmental assessment tool by the person conducting the survey is also included.

Measurement of the physical environment is conducted using relevant instrumentation such as a thermometer, sound level meter or illuminance meter. Where appropriate, reference to the relevant International Standard is provided for the specification of the instruments. Subjective methods quantify the responses of people to an environment using subjective scales. For each environmental component, examples of subjective scales are provided. The third part of the assessment is concerned with observation. For each environmental component, advice on what may be included in an observation assessment form is provided. An example of an assessment form is provided in Annex A.

Each of these methods has been developed according to basic principles. The most appropriate form of the method or combination of methods used in concert, for the determination of environmental comfort, will depend upon the context and environment of interest. This International Standard provides both principles and application of methods for the assessment of environments using an environmental survey, and complements standards concerned with the ergonomics of the physical environment. In particular, it can be used together with environmental indices that are valid for use in those environments.

Ergonomics of the physical environment — Assessment of environments by means of an environmental survey involving physical measurements of the environment and subjective responses of people

1 Scope

This International Standard provides an environmental survey method for the assessment of the comfort and well-being of occupants of indoor and outdoor environments. It is not restricted to any particular environment, but provides the general principles that allow assessment and evaluation.

It presents the principles for conducting an environmental survey to assess the comfort and well-being of people in environments. It gives guidance on the design of the survey, as well as on the environmental measurements used to quantify the environment and the subjective assessment methods used to quantify the occupants' responses to that environment. It does not provide guidance on the design of subjective scales.

It is applicable to built as well as other environments, including vehicle and outdoor environments, and to all the occupants of those environments who can be considered as providing valid responses to an environmental survey. There may be specific features of certain types of environment that have to be taken into account; however, the general principles it outlines will apply.

This International Standard is not restricted to specific environmental components. It includes assessment of thermal environments, the acoustic environment, the visual and lit environment, air quality and other environmental factors that could be considered to influence the comfort and well-being of the occupants of an environment.

It is a basic ergonomics standard which can contribute to the development of standards concerned with specific environments such as those found in buildings. It is intended to be used by people involved in the general assessment and evaluation of physical environments, including general ergonomics practitioners as well as those who develop standards and guidelines for specific applications.

NOTE The results of the environmental survey produced by the application of this International Standard may identify specific problems that require expert advice.

2 Normative references

The following referenced documents are indispensable for the application 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 7726, *Ergonomics of the thermal environment — Instruments for measuring physical quantities*

ISO 7730, *Ergonomics of the thermal environment — Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria*

ISO 8041, *Human response to vibration — Measuring instrumentation*

ISO 8996, *Ergonomics of the thermal environment — Determination of metabolic rate*

ISO 9612, *Acoustics — Determination of occupational noise exposure — Engineering method*

ISO 9920, *Ergonomics of the thermal environment — Estimation of thermal insulation and water vapour resistance of a clothing ensemble*

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

ISO 15265, *Ergonomics of the thermal environment — Risk assessment strategy for the prevention of stress or discomfort in thermal working conditions*

IEC 61672-1, *Electroacoustics — Sound level meters — Part 1: Specifications*

CIE 69, *Methods of Characterizing Illuminance Meters and Luminance Meters: Performance, characteristics and specifications*

3 Terms, definitions and symbols

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

3.1
adaptive opportunity
opportunity for a person to alter the environment to which he or she is exposed by behavioural (move away, adjust posture, adjust clothing, etc.) or other means (e.g. open window, close door, adjust environmental controls)

3.2
behavioural method
method that quantifies or represents human behaviour in response to an environment

3.3
objective method
method that quantifies the physical, physiological or psychological condition of a person by the use of instrumentation or measures of output such as performance measures

3.4
subjective method
method that quantifies the responses of people to an environment using subjective scales

4 Designing an environmental survey

4.1 Aim of survey

The design of any environmental survey will depend upon the specific aims of that survey. It is necessary, therefore, to be specific about the aims of the survey.

Two general principles are

— a typical environmental survey involves measuring the *physical* environmental conditions and also the *subjective* responses of people exposed to the environment, and

— an optimum survey will achieve its aim with efficient use of resources.

4.2 Measurement of the physical environment

Instruments shall be selected according to the appropriate specifications and standards as presented in the following subclauses under each environmental component. Particular considerations will include range, accuracy, sensitivity and physical robustness. Calibration procedures will be necessary to ensure that the instruments measure according to the specification. Depending on the instrument, it is recommended to calibrate both before and after an environmental survey to check for “drift”. Practical use of instruments is important and there are many pitfalls. It is important to remember that the objective of the measurement is to quantify the physical environment to which people are exposed. “Experimenter” interference by leaning over a light meter, talking when taking noise measurements, or an equipment case shading a globe thermometer, are all examples of practical errors that shall be avoided.

4.3 Measurement of subjective responses

IMPORTANT — The subjective scales presented are those typically used in the investigation of the environment under consideration. The scales used may differ depending upon context.

Subjective methods quantify the responses of people to an environment using subjective scales. Such scales are based upon psychological continua (or constructs) that are relevant to the psychological phenomenon of interest. It is important to know the properties of the scales in order to correctly interpret the results. Scales of sensation (e.g. hot or cold), preference, comfort, annoyance, smell and stickiness are often used in comfort assessment. Advantages of subjective methods are that they are simple to administer and are directly related to the psychological phenomenon. Disadvantages are that the subjective methods may interfere with what they are measuring, some groups may not be able to perform the subjective task (e.g. babies, children, people with disabilities) and there is no reason given as to why such a response is provided.

ISO 10551 provides guidance on the construction of subjective scales. Five types of scales are identified:

— perceptual (How do you feel now? e.g. hot);

— affective (How do you find it? e.g. comfortable);

— preference (How would you prefer to be? e.g. cooler);

— acceptance (acceptable/unacceptable);

— tolerance (Is the environment tolerable?).

From these basic subjective dimensions, questionnaires of subjective scales can be developed.

The responses of people that will be measured are to be selected according to the aims of the survey. Typically subjective responses are taken to quantify comfort. Objective measures are sometimes used, for example in the thermal environment, mean skin temperature (and sometimes sweat loss) to complement subjective measures. In a novel situation, subjective scales shall be established from "first principles" by establishing subjective continua using psychological techniques. Subjective scales for assessing environmental comfort have, however, become established. Examples are provided in Clauses 5, 6, 7 and 8. It is important to note that the way in which a scale is presented and administered can influence results. A single-sheet questionnaire, for example, may be preferable to a number of pages. The exact question asked shall be established. The frequency of completion of the questionnaire should be balanced with the overall aim of design. Translation of scales (from English, for example) as well as cultural aspects of the subject sample will be issues. Providing knowledge to people of their previous ratings or of those from other subjects' responses shall be avoided. Subject training and instruction will be necessary to ensure that the subjects have a correct understanding of what is required. Some scales are used for ratings of overall "comfort" as well as for comfort ratings for specific areas of the body.

It is important to avoid leading questions when developing scales (e.g. 'You are uncomfortable aren't you?'). For newly-constructed scales, expert advice might be necessary. Pilot testing of newly-constructed surveys will be necessary.

4.4 Where to measure?

Where to measure the environment will be determined by the aim of the survey; typically, the intention will be to quantify the environment to which people are exposed, and this will then be their physical location. If people are static then this is clear. For environments where people move around or for large groups of people, a representative sample of spaces will be required for measurement. Environments vary continuously in space, and it may be useful to identify measurement points in three dimensions. This will depend upon how homogeneous the environment is and how homogeneously spaced people are. Where people are evenly spread about a room, a simple grid system can be identified. Of note is that where one component of an environment may be homogeneous (e.g. temperature) another may not (e.g. light level).

For subjective measures it will be important, where possible, to ask how subjects feel *now* and in the exact space to be assessed. Measurements based upon memory or general impression are not as reliable as those obtained when the person is directly exposed to that environment.

4.5 What to measure?

What needs to be measured will depend upon the context. It is usual to measure thermal, visual and acoustic environments. Air quality in indoor environments would also be typically measured, but vibration would usually be measured only where present at perceptible levels (e.g. in vehicles and some buildings). Important parameters for the assessment of each environmental component are provided later in this International Standard. Typical physical measurements include air temperature, humidity, air velocity, radiant temperature, noise levels and illuminance. Additional physical measures may be included as appropriate.

Subjective measures can often be used to complement physical measures and analysis. They may be used to provide an indication of possible problems (e.g. annoyance) before physical measures are taken. The range of the subjective scales and type used will depend upon the context and may have to be extended for more extreme environments.

4.6 When to measure?

Environments vary in space and time and the objective of the survey is to quantify the environment and the subjective response to it. It is important, therefore, to measure at times of the day when conditions are representative of the environments to which people are exposed. Conditions to which people are exposed can be influenced by outside weather and it could be necessary to measure throughout the day or to carry out a long-term survey across the year. Temperatures can "build up" in a room throughout the day due to the heat produced by machines and people. Carbon dioxide can also accumulate during the day and air quality can be reduced. It may be useful to continuously record physical measures or take readings at a number of different times. Subjective measures may also be taken — for example, in the morning and in the afternoon towards the end of a shift. If only one set of measurements is possible, then it is recommended to conduct the survey at a time when most dissatisfaction is expected, based upon preliminary information. When people move from one environment to another, short-term effects caused by such movements shall be taken into account.

4.7 How many people and who?

A valid method of evaluating environments is to use a panel of experts. This technique is used in wine tasting, for example, where acknowledged experts give opinions concerning the quality of wines. This technique depends upon identifying unbiased acknowledged experts. This is not usually possible in the area of environmental comfort and the environmental survey design shall specifically avoid bias. It is usual to survey all the occupants of a space or, if that is impractical, to identify a "random" sample of human subjects as representatives of the population of interest. This is a question of statistical sampling and relevant factors such as age, gender, experience, and anthropometry could be identified and could influence subject selection. The number of subjects selected will depend upon the aim.

4.8 Adaptive opportunities

When conducting a practical survey, it is important to recognize that people will behave in such a way as to avoid discomfort or dissatisfaction. In using an observation assessment form, where the person conducting the survey makes general observations concerning the environment, it is useful to identify the opportunity people have to do this (see Annex A). This will be determined by the organizational and social environment as well as the environmental design. An environment where people can move around, adjust clothing and/or have the ability to change environmental conditions (thermostat, light levels, open a window, etc.) can be more satisfactory than one where people have restricted opportunity. Restrictions can be caused by the task (e.g. emergency telephone operator who cannot leave the workplace), the character of the organization (e.g. strict dress code, obligation to wear a uniform) or the building (e.g. sealed windows), to take some examples. It can also be caused by the characteristics of the person him or herself (e.g. a person with a disability/restricted movement). In any environmental survey, such adaptive opportunities shall be considered.

5 Measurement of the thermal environment

5.1 Physical measures

5.1.1 Parameters

— Air temperature

— Radiant temperature

— Air velocity

— Humidity

These are normally used with estimates of the clothing insulation worn and the activity level of the people in the environment.

5.1.2 Instruments

Instruments for measuring a thermal environment in accordance with ISO 7726.

Estimation of the metabolic heat production of people conducting different activities shall be in accordance with ISO 8996.

Estimation of the thermal insulation of clothing worn by people in an environment shall be in accordance with ISO 9920.

5.1.3 Application

The instruments shall be placed such that they measure the environment that would be experienced by the occupant of the space (e.g. at the workstation or on the desk where the person works). They shall provide minimum interference with the environment and shall not influence the subjective judgements or observation assessment form part of the survey. The time of day is important when assessing thermal environments. It is also important to ensure that a sufficient measurement duration is provided, both to take account of the time constant of the instruments (e.g. globe thermometer) and to quantify any variation in the environment. In heterogeneous environments or when local discomfort occurs, it is recommended that measurements be made at three different heights: ankle, abdomen and head.

5.2 Subjective measures

Psychological continua (subjective terms): *thermal sensation*, *uncomfortable*, *stickiness*, *preference*, *acceptability*, *satisfaction*, *draughtiness* and *dryness*.

Guidance on the construction of subjective scales for the assessment of the influence of the thermal environment is provided in ISO 10551. The following are typical scales used in the assessment of thermal environments.

Sensation scale

"Please rate on the following scale how YOU feel NOW."