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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.”

+3 Hot

+2 Warm

+1 Slightly warm

0 Neutral

−1 Slightly cool

−2 Cool

−3 Cold

This scale is the thermal sensation scale according to ISO 7730. It is useful to use standard scales as results can be compared directly with international standards assessments as well as with the results of other studies. The emphasis to the subject (person providing the rating) is how he/she, him/herself (“YOU”) — not another person or a general view of the group — feels (how the person actually feels, not how the environment seems to be) *NOW* (at that particular time). The form of the scale is in discrete intervals; although, by joining with a line, a continuous form of the scale can be used. For example, a rating of between +1 and +2 (indicated by a mark on the line between +1 and +2) will indicate that the subject felt between “slightly warm” and “warm” and be given a numerical value, such as “+1,3”. Continuous forms also apply to the uncomfortable and stickiness scales. An extension of the scale, if required, would be to use the terms “Very hot” and “Extremely hot”, and “Very cold” and “Extremely cold” (see ISO 10551).

Uncomfortable scale

4 Very uncomfortable

3 Uncomfortable

2 Slightly uncomfortable

1 Not uncomfortable

Stickiness scale

4 Very sticky

3 Sticky

2 Slightly sticky

1 Not sticky

These two scales have a similar form, with an absence of effect at the base of the scale and increasing strength of effect up the scale. An important point is that a consistent word — uncomfortable or sticky — is used for each rating. This presents the specific psychological continuum as well as ensuring that the scale is unidimensional. The description *uncomfortable* is a negative effect of the environment, as is *stickiness*. It is unlikely that the scales are independent dimensions and they shall be used to complement each other. It may be that people can be slightly warm and not uncomfortable, but it is unlikely that a sedentary, clothed subject would feel cold, very sticky, and not uncomfortable.

Preference scale

“Please rate on the following scale how YOU would like to be NOW.”

7. Much warmer

6. Warmer

5. Slightly warmer

4. No change

3. Slightly cooler

2. Cooler

1. Much cooler

Preference scales are used in assessment, as they provide a “value” judgement from subjects. If a subject rates a sensation of “slightly warm”, for example, this 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 will indicate 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 shall choose) yes or no response to “Are you satisfied?” would give a direct measure. Ratings of pleasure may be of interest. These can be confounded with visual stimuli such as those experienced when driving through the countryside on a sunny day, but solar radiation can elicit pleasant and unpleasant responses and shall be considered if relevant. Ratings of acceptability will be useful to vehicle manufacturers. They require a sophisticated level of judgement based upon what a subject feels is acceptable in that context. A combination of scales integrated into a questionnaire provides a useful measurement tool. The scales will complement each other and give a detailed profile of comfort. Subjective ratings from individual parts of the body will provide some indication of why subjects gave their “overall” rating.

Draughtiness scale

4. Very draughty

3. Draughty

2. Slightly draughty

1. Not draughty

Dryness scale

4. Very dry

3. Dry

2. Slightly dry

1. Not dry

Satisfaction scale

Satisfied Not satisfied

Acceptability scale

Acceptable Not acceptable

5.3 Observation/assessment

The person conducting the survey shall note the general impression of the thermal environment (hot, comfortable, cold, draughty, etc.) and, in particular, local discomfort factors. Consideration shall be given to the dynamics of how the room is heated and cooled and how this will affect the occupants. Are there aspects of an occupant’s behaviour that can be identified with the influence of the thermal environment? What can occupants do to avoid being too hot or too cold (adaptive opportunity)? Can they move around, adjust clothing, vary

activity, close windows, adjust the thermostat, and so on? The risk assessment forms for thermal environments provided in ISO 15265 shall be used.

6 Measurement of the acoustical environment

6.1 Physical measures

6.1.1 Parameters

— A-weighted sound pressure level

— Equivalent continuous A-weighted sound pressure level

6.1.2 Instruments

Sound level meters for measuring A-weighted sound pressure and equivalent continuous A-weighted sound pressure levels, as specified in IEC 61672-1.

6.1.3 Application

The method specified in ISO 9612 for determining occupational noise exposure using sound level meters shall be used. The survey requires that the acoustical environment to which people are exposed be quantified. The sound level will have both spatial and temporal variations. A number of measures over different conditions will give a sound level profile (people in a room, equipment on or off, etc.). The equivalent continuous A-weighted sound pressure level will give an overall average value of the sound levels over a longer period of time.

6.2 Subjective measures

Psychological continua (subjective terms): *annoyance*, *preference*, *satisfaction* and *acceptability*.

Subjective scales for acoustics typically use the scales of annoyance specified in ISO/TS 15666, but other generic terms may also be used. The following are examples of scales.

Annoyance scale

4. Very annoying

3. Annoying

2. Slightly annoying

1. Not annoying

Preference scale

“Please rate on the following scale how YOU would like it to be NOW.”

4. Much quieter

3. Quieter

2. Slightly quieter

1. No change

Preference scales shall be used in the assessment, as they evoke a “value” judgement from subjects. If a subject rates a sensation as “loud”, for example, this does not indicate whether or not he or she *wishes* that it were quieter. The preference rating compares how the subject’s environment *is*, with how he or she would *like it to be*. No change will indicate a form of acceptability, preference and satisfaction. It could be that a person would prefer different aspects of the acoustic environment to change. In that case, the subjective scale can

be used for each different aspect. For example, a person may wish the background sound, but not the other sounds in the space, to be quieter.

Acceptability scale

Acceptable Not acceptable

Satisfaction scale

Satisfied Not satisfied

Sources of noise

“Please indicate any sources of noise YOU can hear in your environment NOW.”

6.3 Observation/assessment

The person conducting the survey shall note the general impression of the acoustic environment, including background noise levels and the general ability of the occupants to conduct any tasks. Particular noise sources such as machines, printers, footfalls, people talking, ventilation fans or telephones, shall be noted. Frequency and duration of noise may be noted for particular causes of annoyance, as well as intermittent or impulsive noise or pure tones that may lead to annoyance. The change of noise sources throughout the day shall be noted.

7 Measurement of the visual and lighting environment

7.1 Physical measures

7.1.1 Parameter

— Horizontal illuminance

7.1.2 Instrument

Iluminance meter, as specified in CIE 69.

7.1.3 Application

Horizontal illuminance shall be measured such that the level available in the visual scene of the person is quantified. It may also be appropriate to take specific task-related measurements. The level can vary depending on the location of people and objects between the lighting source and the surface. Where lighting levels vary, a number of readings may be necessary to quantify the lighting profile; light levels can vary in space and time, and can be influenced by the time of day, as outside conditions will often influence lighting levels. The person conducting the measurement shall take care not to interfere with the lighting levels received by the sensor.

NOTE General guidance on the lighting of indoor workplaces can be found in ISO 8995-1.

7.2 Subjective measures

Psychological continua (subjective terms): *visual discomfort*, *preference*, *acceptability* and *satisfaction*.

Visual discomfort scale

“Please rate on the following scale YOUR visual discomfort NOW.”

4. Much discomfort

3. Discomfort

2. Slight discomfort

1. No discomfort

Preference scale

“Please rate on the following scale how YOU would like your visual environment to be NOW.”

7. Much lighter

6. Lighter

5. Slightly lighter

4. No change

3. Slightly darker

2. Darker

1. Much darker

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

Acceptability scale

Acceptable Not acceptable

Satisfaction scale

Satisfied Not satisfied

Sources of glare

“Please indicate if you are experiencing any glare NOW.”

7.3 Observation assessment

The person conducting the survey shall note the general impression of the visual environment including background lighting levels and general ability of the occupants to conduct any tasks. Particular light sources that cause visual discomfort shall be noted, as well as the change of visual environment, including light levels and sources throughout the day. A general impression of mood and aesthetics can be recorded, as this will relate to overall satisfaction. An impression shall be taken as to whether the lighting and general visual environment is complementary to the purpose of the space — for example, does the general colour or level of the lighting fit with the purpose of the space such as, formal for an office or warm and intimate for a social space.

8 Measurement of the air quality environment

8.1 Physical measures

8.1.1 Parameter

— Level of CO_2

8.1.2 Instrumentation

Suitable instruments for measuring CO_2 **levels**, as specified by the manufacturers.

8.1.3 Application

The level of CO_2 shall be representative of levels to which people are exposed. In a closed environment, this may be homogeneous in distribution; however, people nearer windows or doors may have different values. CO_2 levels will build up during the day in an insufficiently ventilated space and shall therefore be measured throughout the day. CO_2 levels indicate ventilation and the degree of fresh air as well as general air quality (even though CO_2 itself does not smell), as levels will correlate with the build-up of other gases and odours within a space.

NOTE In particular contexts, it can be of advantage to measure specific gases or particulate levels such as carbon monoxide, formaldehyde, particulates and others.

8.2 Subjective measures

The psychological continuum (subjective term) is *smelly*.

Smelliness scale

4. Very smelly

3. Smelly

2. Slightly smelly

1. Not smelly

Preference scale

It can be reasonably assumed that if a person rates an environment as “smelly” then they would prefer no smell at all. The term itself is assumed to be negative. Pleasant smells would therefore not be rated as “smelly”.

Acceptability scale

Acceptable Not acceptable

Satisfaction scale

Satisfied Not satisfied

Sources of smells

“Please indicate any sources of smell in your environment NOW.”

8.3 Observation assessment

The person conducting the survey shall note the general impression of the air quality, including any sources of smells. Inputs and outputs of air shall be noted, as well as circulation patterns, dead spots and the type of ventilation system(s). In buildings, inputs and exhaust systems shall be identified for the whole building, with

particular attention paid to pollution sources. The change of air quality levels and sources throughout the day shall be noted. Particular attention shall be paid to the fact that people adapt to smells. It is important, therefore, to gain an impression when an occupant first enters a space as well as for prolonged exposure.

9 Measurement of the vibration environment

9.1 Physical measures

9.1.1 Parameters

Acceleration in the vertical, horizontal and fore-and-aft directions with respect to a person, sometimes also in roll, pitch and yaw.

9.1.2 Instruments

The performance specifications and tolerance limits for instruments designed to measure vibration values for the purpose of assessing human response to vibration shall be in accordance with ISO 8041.

NOTE ISO 2631-1 provides general guidance on measurement, evaluation and assessment of whole-body vibration and shock: for the evaluation of motion with respect to comfort, ISO 2631-1 recommends that the overall frequency-weighted root-mean-square acceleration or vibration dose value be determined.

9.1.3 Application

Accelerometers are to be situated orthogonally so as to measure in all directions of interest and at the point of entry to the body. This attempts to quantify the acceleration to which the person is exposed.

9.2 Subjective measures

Psychological continua (subjective terms): *uncomfortable; annoying.*

NOTE Terms used are those generally used in vibration assessment. The term *unpleasant* could be regarded as a negative experience and an expression of dislike by the person experiencing the vibration. *Uncomfortable* is more an expression of lack of contentment. They are likely to be closely correlated in many applications.

Uncomfortable scale

6. Extremely uncomfortable
5. Very uncomfortable
4. Uncomfortable
3. Fairly uncomfortable
2. A little uncomfortable
1. Not uncomfortable

Annoyance scale

4. Very annoying
3. Annoying
2. Slightly annoying
1. Not annoying

Acceptability scale

Acceptable Not acceptable

Satisfaction scale

Satisfied Not satisfied

Sources of vibration

“Please indicate any sources of vibration in your environment NOW.”

9.3 Observation/assessment

The person conducting the survey shall observe how the motion is affecting a person’s attention, behaviour and ability to carry out tasks. In a vehicle, motion will be expected but could interfere with driving or the ability to read or drink. In a building, vibration can be distracting or cause alarm or annoyance.

10 Other environmental factors

The main components of the physical environment that influence human responses are presented in the preceding clauses. Other factors that can be of influence include the tactile environment and the general aesthetics of the environment. The general disposition of those experiencing an environment will also be influential. The person conducting the survey shall note the general atmosphere in the space in terms of social interaction. It is possible that complaints about the environment are fundamentally caused by general dissatisfaction at work. Management styles and worker relations are often influential. It is important when conducting a survey to take this into account. The person conducting the survey becomes part of the social environment him or herself and shall recognize that he or she can influence subjective responses.

Annex A
(informative)

Example of an environmental survey in a building

A.1 General

The following is a practical example of an environmental survey and an actual case. It describes what was done and found, and the actual materials that were used.

A.2 The problem

The consulting ergonomist received a request for assistance from managers of an office complex where in a particular large open plan office, workers were refusing to work and some were refusing to enter the room. The workers complained of feeling unwell and of unusual odours, tastes, facial tensions, headaches and lethargy. Medical opinion had recommended tests for carbon monoxide build-up which had proven negative. Due to the seriousness of the case, the manager had been directed to seek expert assistance. Did they have a sick building?

A.3 The environmental ergonomics survey

It was agreed that the ergonomist would undertake a “first shot” environmental ergonomics survey and make recommendations for a solution and further action. The ergonomist conducted a one-day assessment that included arrival and briefing by the managers, observation and measurements in the office, assessment form completion by the ergonomist, completion of stand-alone questionnaires by the staff, interviews with individual workers and a de-briefing of managers. A report and recommendations were provided soon after the assessment.

A.4 The “expert” assessment form

The form used by the ergonomist is shown in Table A.1. It is designed to “force” the expert to systematically address important questions and provide direct views concerning what is significant (e.g. the “best” aspect and the “worst” aspect).

Table A.1 — "Expert" assessment form used by ergonomists as part of environmental ergonomics survey

PHYSICAL ENVIRONMENT AND HUMAN PERFORMANCE ASSESSMENT FORM Complete this form in the context of the organizational culture and mission, the job requirements of the staff and how the physical environment may affect their performance and productivity.	
Category	**Comments**
General impression (one sentence and one word descriptors)	
Good points (include what the best aspect is)	
Bad points (include what the worst aspect is)	
Air quality (immediate impression on entering: stuffy, smelly, dusty?)	
Thermal environment (hot, cold, humid, draughty, hot/cold surfaces, sweaty)	
Lighting and visual environment (easy to see? lighting levels, clean windows and lights, glare, general appearance)	
Noise and vibration (detect vibration, footfall, background noise level, interruptions, interference with task, annoying, noise sources, echoes)	
Furniture (appearance and condition, fit for purpose, fit to person's size, telephone, chair)	
Computer equipment (correctly positioned and adjusted, glare on screen, reflections, orientation)	
Overall layout (storage space, organization of work, filing system, coats and accessories)	
Adaptive opportunity (clothing adjustment, move around, open window, control over conditions, level of activity, take breaks)	
Distraction (sources of distraction from task that cease work or interfere with performance)	
Overall conclusion: Environment optimum for performance?	Yes or No:
Recommendations:	

From the assessment form it was considered that the office appeared well-equipped with a good layout and modern workstations. The fabric of the building was poor and there was a fusty smell. The best aspect was the modern and attractive equipment, good layout and the quietness of the room. The worst aspect was that there was poor building fabric and the smell. Air quality seemed poor with some dampness. The thermal environment was acceptable, although a supplementary heater was noted. Daylight was present, but when dull outside, the lights provided poor colour rendering and the strip light was not working. It was possible to open windows. Although caution is always needed concerning expert subjective opinion, it was evident that air quality was a problem.

A.5 Questionnaire

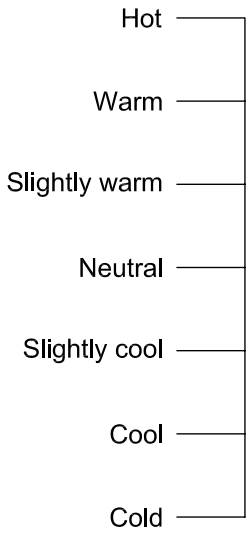
The following simple questionnaire was completed by each of the workers at his/her workplace.

"What do YOU think of your workplace environment?

Please answer the following questions concerning YOUR COMFORT and SATISFACTION with your environment.

Thermal environment

a) Please indicate on the scale below how YOU feel NOW.



b) Please indicate how YOU would like to be NOW.

Warmer No change Cooler

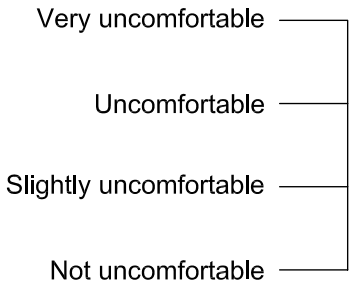
c) Are you generally satisfied with your thermal environment at work?

Yes No

d) Please give any additional information or comments which you think are relevant to the assessment of your THERMAL environment at work (draughts, dryness, clothing, suggested improvements, etc.)

Lighting and visual environment

e) Please indicate on the following scale how YOU find your VISUAL environment NOW.



f) Please indicate any sources of glare YOU can see in your VISUAL environment NOW.

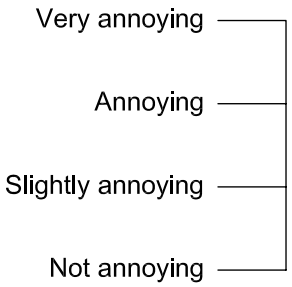
g) Are you generally satisfied with your LIGHTING AND VISUAL environment at work?

Yes No

h) Please give any additional information or comments which you think are relevant to the assessment of your VISUAL environment at work (e.g. glare, visual scene and view, general visual impression, flicker, colour).

Noise

i) Please indicate on the following scale how YOU find the NOISE in your environment NOW.



j) Please indicate any particular sources of NOISE that YOU can hear in your environment NOW.

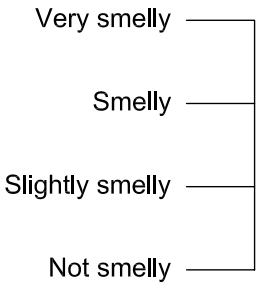
k) Are you generally satisfied with the NOISE level in your environment at work?

Yes No

l) Please give any additional information or comments which you think are relevant to the assessment of the NOISE in your environment at work (machines, talking, outside noise, reverberation and echoes, speech communication and listening difficulty, etc.).

Air quality

m) Please indicate on the following scale how YOU find the AIR QUALITY in your environment NOW.



n) Please indicate any particular sources of pollution that contribute to the AIR QUALITY in your environment NOW.

o) Are you generally satisfied with the AIR QUALITY in your environment at work?

Yes No

p) Please give any additional information or comments which YOU think are relevant to the assessment of the AIR QUALITY in your environment at work (e.g. smells from smoke, chemicals, machines, etc.)

General

q) Do you suffer from persistent symptoms at work such as dry lips, eyes and throat, runny nose or others?

Yes No

r) Are you generally satisfied with your environment at work?

Yes No

s) Please give any additional information or comments which YOU think are relevant to the assessment of your environment at work including suggestions for improvement."

Overall, the workers were generally satisfied with their thermal, lighting and acoustic environments. They found the room very smelly, they were not satisfied with the air quality and identified "musty", "damp" and chemical smells. Some workers reported feeling dizzy, headaches, tiredness with irritation to the eyes and throat. Symptoms persisted when away from work and led to absenteeism.

One of the workers had been greatly troubled by the problem and had kept a diary of her experiences while working in the room. This included periods of illness attributed to working in the office.

A.6 Interviews with staff

Individual interviews with staff confirmed the subjective reports. Some staff had been moved to the new office from what had previously been a better social environment. The problem had been ongoing for a number of months and unions and medical personnel had become involved. Some staff felt that they had been identified as "complaining about nothing". The interview detected a genuine interest in solving the problem and a genuine level of illness and frustration.

A.7 Environmental measurements

The air temperature and humidity were measured at each workplace with a whirling hygrometer. The air movement was observed by blowing (children's) bubbles at the workplaces. Horizontal illuminance was recorded with a light meter and noise levels with a sound level meter. The air temperature was around 21 °C with 50 % RH (relative humidity). There was very low air movement apart from when the windows were open. The light levels were around 300 lx on the workspaces (500 lx near windows) and A-weighted noise levels were around 55 dB. None of these values would be expected to cause severe discomfort, although the lack of air movement was noted.

A.8 Wrap-up meeting

As the problem appeared to be one of air quality, an inspection of the building and building services was made with the health and safety and building services managers. A final discussion was then held with the managers. They were uncertain as to whether they had an environmental or organizational problem. In any event, the situation had persisted sufficiently long for a managerial solution to be essential. Calling in experts had helped the situation and the assessment was sufficiently clear to conclude that there was an air quality issue.

A.9 Report and conclusion

A full environmental survey was not necessary, as the problem was focussed around air quality. Lighting maintenance and better colour rendering would provide some improvement. The findings were presented to the management and advice was given about further action.

This example describes an actual case where air quality was a problem. The assessment form and questionnaire approach would also have identified other problems in the environment had they occurred. Simple on-the-spot solutions might then have been possible. If solutions were not then obvious, a more detailed investigation of the thermal environment, noise, vibration and lighting would be recommended.

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