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Ergonomics of the physical environment — Application of International Standards to people with special requirements

Ergonomie de l'environnement physique — Application des Normes internationales aux personnes ayant des exigences particulières

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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 28803 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. This International Standard complements others in the series concerned with specific components of the environment, such as thermal environments, acoustics, lighting or air quality, building upon them to allow an assessment of human response to the total environment. This International Standard is particularly concerned with extending the scopes of other International Standards — see 5.2.2, 5.3.2 to 5.3.5, 5.4.2, 5.5, 6.2 to 6.6, 7.3 and 9.2 — so that they can be applied to as wide a range of people as possible. The background information it provides on the responses and needs of groups of persons with special requirements will contribute to accessible environmental designs that will complement other activities in the field of ergonomics.

This International Standard includes a description of the range and variety of responses and adaptations to physical environments of people with special requirements, and the consequences for measuring and evaluating those environments. It considers the application of indices and methods for people with special requirements where health and safety, comfort and well-being are considerations. It provides a description of the nature of the particular characteristics of people with special requirements in the context of their responses to environments (e.g. restricted sensation, reduced perception or ability to respond). It is not a database of characteristics of people with special requirements, but uses data from ISO/TR 22411 to provide methods and criteria that will in turn provide accessible environments.

Ergonomics of the physical environment — Application of International Standards to people with special requirements

1 Scope

This International Standard describes how International Standards concerned with the ergonomics of the physical environment can be applied for people with special requirements, who would otherwise be considered to be beyond the scope of those standards. It has been produced according to the principles of accessible design provided in ISO/IEC Guide 71 and using the data provided in ISO/TR 22411.

It is not restricted to any specific environment but provides the general principles that allow assessment and evaluation, and can contribute to the development of standards concerned with specific environments. It is applicable to built environments as well as to other indoor, vehicle and outdoor environments. Nor is it restricted to specific environmental components; it includes assessment of acoustic environments, thermal environments, lighting, air quality and other environmental factors that could be considered to influence the health, comfort and performance of people with special requirements in an environment.

It is applicable to all occupants of such environments who can be considered to have special requirements.

NOTE This will depend upon context and can, for example, include babies, infants, men or women, people with disabilities, older or ill people. A person could have a special requirement in one type of environment but not in another.

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 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 and the following apply.

3.1
accessible design
design focussed on principles of extending standard design to people with some type of performance limitation to maximize the number of potential customers who can readily use a product, building or service which may be achieved by

— designing products, services and environments that are readily usable by most users without any modification,

— making products or services adaptable to different users (adapting user interfaces), and

— having standardized interfaces to be compatible with special products for persons with disabilities

NOTE 1 Terms such as design for all, barrier-free design, inclusive design and transgenerational design are used similarly but in different contexts.

NOTE 2 Accessible design is a subset of universal design where products and environments are usable by all people, to the greatest extent possible, without the need for adaptation or specialized design.

[ISO/IEC Guide 71:2001, definition 3.2]

3.2
assistive technology
technology that is used to increase, maintain or improve functional capabilities of individuals with disabilities

3.3
assistive device
piece of equipment, product system, hardware, software or service that is used to increase, maintain or improve functional capabilities of individuals with disabilities

3.4
user
person who interacts with the product, service or environment

3.5
alternative format
different realization or presentation which may make products and services accessible by the use of another modality or sensory ability

3.6
impairment
limitation in body function or structure, such as a significant deviation or loss of capability, which can be temporary (for example, due to injury) or permanent (slight or severe and can fluctuate over time)

EXAMPLE Deterioration due to aging.

3.7
standard
document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context

NOTE Standards should be based on the consolidated results of science, technology and experience, and aimed at the promotion of optimum community benefits.

[ISO/IEC Guide 2:2004, definition 3.2]

3.8
international standard
standard that is adopted by an international standardizing/standards organization and made available to the public

[ISO/IEC Guide 2:2004, definition 3.2.1.1]

3.9
International Standard
international standard where the International Standards organization is ISO or IEC

3.10
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 (open window, close door, adjust environmental controls etc.)

4 General factors requiring consideration when designing or evaluating environments for people with special requirements

People with special requirements are people who generally fall outside the scope of most International Standards. Standards for environmental design and assessment are often valid only for people with specific characteristics who are frequently referred to as “normal” or “typical”. Environmental design for a wider

population can require different conditions from those given in a standard, in order to provide comfort or avoid unacceptable stress on the body.

NOTE Existing thermal International Standards cover a range of conditions, types of people and so on, which are identified in the scope of those documents, thereby providing information for people who fall outside the scope and who should be treated as people with special requirements.

One reason for standards to have a restricted scope in terms of user population, is that knowledge is incomplete for people who might have special requirements in environmental design. These people often include children, people with disabilities and older people. Although knowledge about such populations is incomplete, advice can still be provided to ensure accessible design of environments.

Clauses 5 to 9 describe the assessment of the thermal, acoustic, visual, lighting, air quality and other environments. For each environmental component, guidance is provided on how to apply the relevant International Standards for people with special requirements.

General considerations include factors which affect a person's response to the particular environmental component. For example, body size and shape or the ability to move around can be important. The relevant International Standards are then considered in terms of these general considerations. For example, if someone with a spinal injury cannot sweat below the lesion, then a heat stress standard based upon sweat rate will require appropriate modification. General advice can then be provided in terms of modifications to the relevant International Standard in order to make it more valid for a wider range of people.

A characteristic of people who are not "normal" or "typical" is the wide variation in response across the population; often, individual characteristics would have to be considered. In such cases, or where unacceptable strain or threat to health are involved, then medical advice needs to be sought. In such cases, the information provided in Clauses 5 to 9 should be brought to the attention of the medical advisor.

One particular consideration is the degree to which a person can modify exposure to environments by behavioural measures. People with special requirements could have restricted behavioural opportunities (to move around, change clothing, control the environment, etc.) and this will be important for all environmental components.

5 Considerations related to design and evaluation of the thermal environment

5.1 Factors requiring special consideration for design and evaluation

The following factors shall be considered when assessing the thermal environment.

a) **Sensory impairment and paralysis**

Some physical disabilities and methods of treatment (e.g. drugs) affect thermal sensation and requirements for thermal comfort and health. Examples of drugs that can affect body temperature regulation are beta blockers, diuretics, laxatives, anticholinergics, antihistamines, neuroleptics, methydopa, MAO inhibitors, tricyclic antidepressants, serotoninergic agonists, phenothiazines and vasoconstrictors.

Additional issues include methods for collecting valid and reliable data on the responses of people with special requirements, e.g. pregnant women, older people or babies.

b) **Difference in the shape of the body**

The loss or atrophying of a limb makes the application of the Dubois' surface area formula difficult and prone to error. Consequently, it will have some influence on the concept of mean skin temperature. Infants and babies will have somewhat different body proportions compared to average adults. This influences the projected surface area available for heat exchange from different parts of the body and hence the impact of thermal radiation, convection and evaporation.

c) **Impairment of sweat secretion**

It is not uncommon for more than 80 % of the sweat-secreting skin area to be impaired in quadriplegic persons (high-level spinal cord injured persons) and some other paralytic diseases. This will affect the

interpretation of thermal environment indices for hot environments, especially rational ones in which a "normal" level of sweating is assumed and the concept of *wettedness* plays an important role.

d) **Impairment of vasomotor control**

Impairment of peripheral vasomotor control, often found in such groups as the aged, spinal-cord injured or persons taking vasodilator drugs, affects adaptability to both cold and hot environments and often requires special consideration when considering thermal conditions.

e) **Differences in metabolic rate**

People with physical disabilities who use technical aids such as wheelchairs often have low metabolic rates due to their sedentary activity level. Conversely, others (such as those suffering athetosic cerebral palsy) require greater energy to perform tasks and hence have a higher metabolic rate due to the greater effort involved. Older persons are often less active and have a lower metabolic rate than average adults but there are large individual differences.

f) **Influence of thermal stress on other physiological functions**

Cerebral apoplexy and cardiovascular attacks are often evoked by thermal stress in (cold) winters and unusually hot summers. Sweat secretion can cause some cutaneous chronic diseases such as epidermolysis bullosa hereditaria. Cold environments may cause frequent urination. Strain is greater after exhaustive work, night work, "jet lag", etc.

5.2 Moderate thermal environments and people with special requirements

5.2.1 General considerations

Thermal conditions that are "normally" considered as moderate and providing thermal comfort, may not be moderate or acceptable to people with disabilities. People with paralysis due to injury to the spinal cord, for example, may report thermal sensation even on the paralyzed part of the body, which will also affect overall body sensation and comfort. Peripheral vasomotor disorders will affect heat exchange with the environment and studies have reported deterioration of thermal sensation and slow thermoregulatory responses in older people.

To evaluate whether an environment is acceptable or not, in addition to taking sensation votes, some simple physiological measurement (of oral temperature, using a clinical thermometer, heart rate, etc.) can be necessary on a regular basis. When at work, most people with special requirements are likely to be in what are, for the average healthy person, moderate thermal environments.

5.2.2 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*

The PMV (predicted mean vote) and PPD (predicted percentage of dissatisfied) indices were statistically derived from a theoretical comfort equation and experimental data obtained from a large number of subjects, mainly healthy young adults, although some older persons were considered. The method given in ISO 7730 could require modification for adequate prediction of the thermal sensation or dissatisfaction of people with disabilities and older people with thermoregulatory impairments. The method given is not intended for predicting the thermal sensation of persons, but rather to predict which thermal conditions (temperature, humidity, air velocity, clothing, activity) are acceptable or preferred. Both laboratory and field studies suggest that the PMV/PPD indices may adequately predict mean thermal responses for the majority of people with disabilities; however, they also show a wide variation in responses, demonstrating that consideration of individual requirements is necessary.

The PMV comfort equation seems to be useful for evaluating moderate thermal environments, i.e. the effect of the thermal environment on various persons with and without special requirements.

One problem with the structure of the comfort equation is the physiological background of the comfortable evaporative heat loss related to activity level. Further examination is necessary to determine if the equation for comfortable evaporation is appropriate for people with disabilities with impaired nervous control of sweating.

When estimating the mean radiant temperature, differences in body shape can be taken into account, but this is only of importance in environments with large directional differences in radiant temperature.

Persons with physical disabilities (e.g. spinal cord injury) often have vasoconstriction disorder and impaired sweating. This means their thermoregulation system does not compensate well if the ambient temperature deviates from the neutral temperature. Therefore, it is important for people with disabilities that the ambient temperature be close to the neutral temperature. Most studies show that the preferred neutral ambient temperature is the same as for people without disabilities and so the method in ISO 7730 can be used. People with physical disabilities often also have lower activity levels. They may not easily be able to change their activity or clothing level. Furthermore, the insulation of a wheelchair (0,1 to 0,2 clo) must be taken into account.

Under the same clothing and activity conditions, older persons may prefer the same neutral temperature as younger people. Nevertheless, many older people have a lower activity level (spending more hours of each day seated) than younger persons with a corresponding elevation in the neutral temperature. Due to lack of vasoconstriction and decreased thermal sensation, ambient temperatures on the cool side of thermal neutrality should be avoided. The designer should select an acceptable temperature range corresponding to $0 < \text{PMV} < +0{,}5$.

Many of the above factors will be taken into account in the PMV/PPD method, as they affect estimates of the six basic parameters (inputs to the method). Additional modification is often required, however, especially when deviating from thermal neutrality and where individual characteristics are important.

5.3 Hot environments and people with special requirements

5.3.1 General considerations

Except in tropical countries, normally only a limited number of people with special requirements will work in hot environments. But they may be exposed to severe conditions in their home, during outdoor activities, sport activities or traveling. ISO 12894 provides a list of contraindications that would make people particularly vulnerable to exposure to heat and hence require special consideration. See also Table 1.

5.3.2 ISO 7243, *Hot environments — Estimation of the heat stress on working man, based on the WBGT-index (wet bulb globe temperature)*

ISO 7243 was developed for estimating heat stress during work in hot environments based on the WBGT-index.

Reference values should naturally be re-established to allow for a maximum rectal temperature but taking into consideration the physiological tolerance and reactions of the persons with special requirements concerned.

The WBGT-index may underestimate the effects of heat stress on persons with disorders of sweat secretion because of their reduced ability to cool themselves by evaporation of sweat.

The effects of age on responses to heat stress are varied and directly relate to fitness. Fit, healthy and thin older people will have similar tolerance levels when compared to younger people. However, older people are often not as fit as younger people and reduced limits for unacceptable heat stress will be required.

5.3.3 ISO 7933, *Ergonomics of the thermal environment — Analytical determination and interpretation of heat stress using calculation of the predicted heat strain*

The required sweat rate may be used as an index for hot environments for people with special requirements but it will require careful modification and application. Impairments of sweat secretion must be considered when applying ISO 7933 to older adults and people with disabilities and comparing estimated and measured values for sweat rate.

For several types of the disabled, such as spinal-cord-injured persons whose sweat-secreting skin areas are reduced, the formula for calculating the maximum evaporation rate should be modified to take account of the reduced surface area for sweating. For example, for a spinal cord injury in the mid-spine region, the maximum capacity to cool by sweating should be halved.

Using ISO 7933, heat balance and heat content of the body may be calculated by using individual parameters for the estimation of body surface and body mass. The taking account of, and adjusting for, slow and dull thermoregulatory responses , which are often found in older persons or persons with disabilities, is not straightforward and would require detailed investigation of an individual's condition.

5.3.4 ISO 9886, *Ergonomics — Evaluation of thermal strain by physiological measurements*

The selection of measurement methods should be carefully considered for people with special requirements due to, for example, abnormal action like athetosic motion and paralyzed sensations.

Some of the limit values should be modified corresponding to the types of disability. For example, maximum heart rate can be lower for disorders of circulatory organs and allowable body mass loss smaller for impaired kidney function.

Measurement of blood pressure should be added for persons with circulatory disorder.

5.3.5 ISO 13732, *Ergonomics of the thermal environment — Methods for the assessment of human responses to contact with surfaces*

ISO 13732-1 and ISO 13732-3 address temperatures that will cause damage to skin on contact with hot or cold surfaces. Increased reaction times and longer contact times are specified for people with special requirements.

Reduced temperature sensitivity should be considered when specifying surface temperatures if it is possible for the surfaces to be touched by older adults and people with some types of disability. Special considerations can also be required for babies and children. Lower temperature limits can be necessary. Not only hot and cold surfaces, but those with higher moderate temperature might be dangerous, as they can cause so-called "low temperature burn" after long contact, owing to lost or deteriorated sensation and decreased skin blood flow. This must be considered when using heated surfaces like radiators, convectors and wall heating for space-heating purposes.

NOTE A maximum surface temperature of 41 °C is specified in EN 12182[31].

5.4 Cold environments and people with special requirements

5.4.1 General considerations

Normally, only a limited number of people with special requirements work in cold environments. Nevertheless, they can be exposed to severe conditions in their homes, during outdoor activities, sporting activities or transport.

5.4.2 ISO 11079, *Ergonomics of the thermal environment — Determination and interpretation of cold stress when using required clothing insulation (IREQ) and local cooling effects*

Physiological factors such as metabolic rate, sweating and heat loss should be considered when applying ISO 11079 to certain kinds of people with special requirements. It is recommended that the neutral IREQ be used which might differ according to the disorders of the circulatory system.

5.5 Supporting standards for evaluation of thermal environments

5.5.1 ISO 7726, *Ergonomics of the thermal environment — Instruments for measuring physical quantities*

ISO 7726 is concerned with instruments and methods for measuring the physical quantities of thermal environments and therefore requires only limited modification.

For selecting measuring points, the size and posture of the person should be considered. It should be noted that the projected area factors used in ISO 7726 for calculation of mean radiant temperature are based on the data from adults with symmetrical body shapes.

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

As the insulation values are given per square metre of body surface area, the values in ISO 9920 can also be used for persons whose body surface area differs from that of a “standard” person.

As many persons with special requirements are sedentary, it is important to take into account the insulation of chairs (0,1–0,3 clo) and especially wheelchairs (0,1–0,2 clo).

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

For the athetosic disabled, such as those suffering from cerebral palsy and the metabolic disability Basedow disease (thyreotoxicosis), the tables in the annexes of ISO 8996 for levels 1 and 2 estimation cannot be used, as the efficiency of consumed energy for useful work is considerably lower for people with these disabilities than for most people. Only the measured metabolic rate is applicable for such people who are working today and for whom the above-mentioned consideration is necessary for both their work and rest environments.

Many other persons with special requirements, including people with physical disabilities, older people, pregnant women and infants, etc., have a different size, shape and/or posture of the body from that of the standard person. The surface area might then not always be calculated with sufficient accuracy using Dubois’ surface area formula.

5.5.4 ISO 10551, *Ergonomics of the thermal environment — Assessment of the influence of the thermal environment using subjective judgement scales*

ISO 10551 will be useful for all people, including those with special requirements. Nonetheless, when analysing the responses, special requirements such as a disorder of thermal sensation should be considered. Additional considerations for the collection of subjective data could be required.

5.6 Thermal disabilities

5.6.1 Outline

Table 1 presents a list of significant thermal disabilities, together with their corresponding primary disabilities and thermal conditions. Various diseases also show disorder in body temperature control, thermal sensation and other thermo-physiological homeostasis, as well as the influences of the thermal environment on the deterioration caused by the disease, recovery and/or control of pain. However, only a few examples of chronic diseases where patients seek social integration outside hospitals are given in Table 1.

5.6.2 Important disabilities and diseases accompanying thermo-physiological disabilities

a) **Spinal-cord injury**

This includes paraplegia and quadriplegia. In many cases of this type of disability, sweat secretion and thermal vasomotor control, as well as thermal sensation, are lost at the skin surfaces of the paralyzed parts of the body, i.e. that part of the body governed by the spinal cord below the point of injury. For a person with paraplegia, when the position of the spinal cord injury is relatively low, the thermal responses of the upper part of the body surfaces remain healthy and the disorder of thermo-regulation is generally not very severe. Even so, a disorder of micturition is often serious (cooler environments should be avoided) and many hot and cold materials are dangerous because of lost sensation.

People with severe quadriplegia have significant disorders to their thermo-regulatory and thermal sensation systems. Disorder of micturition is common to all levels of spinal-cord injury. Even a person with partial quadriplegia whose spinal cord is injured at the neck but retains some sensation and mobility of the hands and feet, has some loss of sweat secretion and peripheral vasomotor control which is often complete. This might in some cases cause heat disorders (heat stroke, heat exhaustion) in summer and hypothermia in winter.

Spinal cord injuries are common among people with disabilities in modern society as this kind of disability is caused by accidents from traffic, labour, sports, etc. Many people with paraplegia and some partially

quadriplegic persons do mental and light physical work. Even people with severe quadriplegia perform mental work aided by technical aids.

b) **Cerebral palsy**

People with cerebral palsy are often wheelchair users and are also often able to walk to various levels of walking handicap. Many people with cerebral palsy are athetosic and use much more energy for certain working tasks (including daily behaviour) than an average person. They usually eat more, sweat more and prefer cooler environments because of a higher metabolic rate.

A too-low temperature is also unsuitable for people with cerebral palsy as the palsy grows worse in such environments. Dry and/or dusty air is more harmful to many of them who are forced to breathe through the mouth deeply because of a disorder of the breathing motion. Thermal sensation and thermo-regulation are not usually impaired. However, spinal-cord injury occurs in some cerebral palsy sufferers of above-middle age, caused by the repetition of strong convulsions.

Cerebral palsy is not progressive and many disabled persons of this type are working and want to work. Modern developments in electronics make the integration of severer cerebral palsy sufferers into various work markets easier. Many people with disabilities wish to be integrated into normal social life (going out shopping, to restaurants, concerts, the theatre, etc.) whether they are working or not.

c) **Aftereffects of acute anterior poliomyelitis**

The thermo-regulating function is usually retained in this type of disability; however, as the original disease is a kind of infectious diseases with intestinal viruses, the intestines are still weak even after its acute period. Persons with this condition easily suffer from diarrhoea and often have an abnormal cold sensation over the lower half of their body. Cooler environments should be avoided, particularly for the lower part of the body.

For people with severe poliomyelitis, the use of respiratory aids such as iron lungs or exposure to dry and/or dusty air is harmful.

Although, owing to advances in disease control, only a few new poliomyelitis cases appear each year, there are still many people with acute anterior poliomyelitis living in the world who work, want to work, and who want to join in social activities.

d) **Diseases of circulatory organs**

Hemiplegia is a major disability caused by cerebral infarction, cerebral haemorrhage and other cerebrovascular diseases. Myocardial infarction causes permanent deterioration of heart capacity and hence work capacity. There is usually a high risk of another (often fatal) attack of the disease, which can easily be caused by too-cold or extremely hot environments, as well as by exposure to rapid changes of temperature.

Some other diseases of the circulatory organs, such as chronic nephritis, also grow worse in cooler environments. Persons who have hypertension and/or arteriosclerosis are more vulnerable to such diseases and also have a high risk of attacks under cold, hot and changing environments.

Vasodilating drugs are often prescribed for hypertension and/or coronary diseases and these sometimes cause hypothermia because of their side effect of suppression of thermal vasoconstriction.

e) **Normal aging**

Even among healthy older persons, shifts of thermal circadian rhythms, and hence body temperature, are frequently found. Vasoconstriction against cold environments, and vasodilatation and sweat secretion against hot environments, are weaker and start later in an older person than young adults. Thermal sensations become dulled in older persons. Many cases of spontaneous hypothermia are reported in older adults.

Table 1 — Significant thermal disabilities and their primary disabilities

Thermal disabilities	Thermal effect of disabilities	Thermal environment of concern	Original disabilities, diseases and health conditions
Disorder of body temperature regulation	Impairment of sweating(heat congestion)	High temperature	Spinal cord injury, aging, Hansen disease, etc.
	Higher heat production (kinetic)	High temperature	Cerebral palsy, etc.
	Higher heat production (endogenous)	High temperature	Basedow disease, etc.
	Lower heat production (endogenous and/or kinetic)	Low temperature	Aging paralytic diseases
	Peripheral vasomotor disorder including side effect of medicine (excessive heat loss)	Low temperature/ high air flow	Spinal cord injury, aging, etc. Effect of medicine for hypertension, coronary diseases, diabetes mellitus, Raynaud's phenomenon, peripheral vascular diseases
Disorder of temperature sensation	Paralysis of temperature sensation	High and low temperatures	Spinal cord injury, aging, Hansen disease, etc.
	Nervous temperature sensation	Low temperature	Cold injuries, polio aftereffect, etc.
Worsening of other disabilities	Worsening of palsy, convulsion and pain	Low temperature/ high humidity	Cerebral palsy, spinal cord injury, rheumatism, etc.
	Effect on renal function	Low temperature	Chronic nephritis, aging, hypertension, etc.
	Infarctive fits	High and low temperatures, fluctuation of temperature	Myocardial infarction, cerebral infarction, etc.
	Effect on blood pressure	High and low temperatures, fluctuation of temperature	Hypertensive disabilities
	Worsening of respiratory functions	Low temperature, low humidity	Asthma, cerebral palsy, chronic bronchitis, etc.
	Worsening of skin condition by sweating	High temperature	Epidermolysis bullosa hereditaria, etc.
Burden on other disabilities	Pollakisuria (on disorder of micturition)	Low temperature	Spinal cord injury, etc.
	Heavy clothing (on physical disabilities)	Low temperature	Various types of kinetic paralysis
	Diarrhoea	Low temperature	Sequelae of poliomyelitis, spinal cord injury, etc.
Interruption of substitute	Decrease of finger sense	Low temperature	Difficulty the visually impaired have reading Braille

6 Considerations related to design and evaluation of the acoustic environment

6.1 General factors requiring consideration when designing and evaluating environments for people with special requirements

6.1.1 Hearing impairments, aging effects and hearing aids

Although hearing impairments are innate or acquired, they are generally classified into two categories, depending on the affected region(s) in the ear: conductive hearing loss and sensorineural hearing loss. Each shows a different profile of hearing ability.

Conductive hearing loss results from deficits in the outer and/or middle ear. Decreased hearing sensitivity is observed for the entire range of clinical measurement frequencies, 125 Hz to 8 000 Hz. The amount of hearing loss does not depend strongly on frequency. Hence, simple amplification of auditory signals or spoken announcements is helpful for people with conductive hearing loss receiving auditory information.

Sensorineural hearing loss results from impairments in the inner ear, the vestibulocochlear nerve and/or the auditory nervous system. The affected frequency range depends on the cause of the hearing impairment: most people with impairment have a hearing loss at high frequencies, whereas others have hearing loss at low frequencies.

Noise-induced hearing loss (NIHL) is a sensory-neural loss caused by exposure to high-intensity sounds. Hearing sensitivity decrease is typically initially observed at 4 000 Hz or around that frequency, the decrease at other frequencies being relatively small. It can be temporary or permanent.

Sensorineural hearing loss involves not only the decrease of sensitivity but also that of frequency selectivity and temporal resolution. Frequency selectivity refers to the ability to resolve a mixture of frequency components and is related to the ability to extract a target sound from others (e.g. differentiating a speaker's voice from background noise). People with sensorineural hearing loss often have difficulty with auditory communication in noisy environments.

The temporal resolution refers to the ability to follow time-related changes of sound. People with sensorineural hearing loss have difficulty in detecting a small and rapid change of sound. Long reverberation times in a room have an adverse effect on their speech perception.

Some people have both conductive hearing loss and sensorineural hearing loss and show a combined profile of both.

Aging is another factor that affects hearing ability. It creates another form of sensorineural hearing loss. Typically, the decline of hearing sensitivity starts to appear at very high frequencies and the affected frequency region then gradually extends downward as people become older (see ISO 7029 and ISO/TR 22411). Concomitant degradation of both frequency selectivity and temporal resolution is also observed.

Aging slows auditory processing in the sensory nervous system. Sometimes older people have difficulty in understanding quickly spoken speech even though they can hear it clearly.

Hearing aids are generally helpful for people with conductive hearing loss, but they have a limited effect for those with sensorineural hearing loss. That is because hearing aids can compensate for the hearing sensitivity decrease, but cannot completely compensate for the deficits in frequency selectivity and temporal resolution. Cochlear implants and hearing-aid systems that have as their function the slowing of speaking rates are beneficial for some people with hearing loss, including older people.

Table 2 presents significant kinds of hearing impairments with their corresponding primary impairments.

Table 2 — Significant hearing disabilities and their primary disabilities

Hearing impairments	Hearing effect of disabilities	Acoustic environment of concern	Original disabilities, diseases and health conditions
Conductive hearing loss	Threshold elevation for a wide frequency range	Quiet and noisy environments	— Otosclerosis — Otitis media — Acoustic trauma — Mechanical injury
Sensory neural hearing loss	Threshold elevation, usually at high frequencies	Quiet and noisy environments	— Aging — Ototoxication — Ménière disease — Hereditary hearing loss
	Decrease of frequency selectivity	Noisy environments	
	Decrease of temporal resolution	Indoor environments with long reverberation	
Noise-induced hearing loss	Threshold elevation around 4 000 Hz	Quiet and noisy environments	Acoustic trauma
Tardiness of auditory processing	Difficulty in understanding fast speeches	Listening to spoken announcement	Aging

6.1.2 Acoustic environmental cues

People with visual disabilities often use the sound of a walking stick or footsteps to detect surrounding obstacles and surfaces (e.g. walls, windows, open doors). The sounds reflected from those objects and/or interference of the reflected sound with the direct sound can be used as acoustic cues.

Because other noises can partially or totally mask such cues, the noise level in the environment should be minimized to the greatest extent possible.

Sound-absorbing materials on the floor (e.g. thick carpets) and walls (e.g. thick curtains) can also hinder visually impaired people from using acoustic cues. It is preferable that floor and walls be finished with hard materials that reflect the sound of a stick or footsteps. Rooms with hard surfaces, however, tend to have long reverberation times, which can present disadvantages for people with sensorineural hearing loss, including older people (see 6.1.1).

6.1.3 Information transmission through other sensory modalities

People who are deaf cannot receive information through the auditory channel. To address this, auditory information shall always be accompanied by visual (e.g. pictorial or written instructions) or tactile information (e.g. vibrations, coded surfaces, Braille), so that information equivalent to the auditory information is conveyed to the recipient.

6.2 ISO 7731, *Ergonomics — Danger signals for public and work areas — Auditory danger signals*

As stated in ISO 7731, care should be taken to determine acoustic characteristics of danger signals if persons with hearing impairment are likely to be present in the public and work areas concerned. It is strongly recommended that the probability of hearing loss in the recipient population be assessed. ISO 7029 may be used for the assessment in terms of age-related hearing loss.

Because some people have hearing loss in the middle frequency range of 500 Hz to 1 500 Hz, danger signals having dominant components within that range are not always recommended. Instead, frequency-sweeping signals that cover a wider range of frequencies assure audibility for those with hearing loss at specific frequencies.

It must be emphasized that the audibility of a danger signal against an ambient noise is solely determined by the difference in sound level between the signal and the noise, not by the absolute signal level. Hence,

although older people with normal hearing could have hearing loss of a few tens of decibels, it is not necessary to raise the sound pressure level accordingly; an additional increment of sound level of only 5 dB to 10 dB is required in typical cases in order to assure the same audibility as young people with normal hearing.

Because the hearing profile differs to a large degree among people with hearing loss, a listening test (see ISO 7731) should be conducted, even when an objective acoustic measurement for checking the audibility of a danger signal is possible.

Some people exhibit extraordinary reactions to sudden sounds, leading to distracted behaviour. Care should therefore be taken in determining the characteristics of a signal. Where practicable, extremely loud sounds should not be used and an abrupt onset should be eliminated.

Auditory danger signals shall not be used alone (see 6.1.3), but shall be accompanied by a visual and/or vibrotactile signal, so that information equivalent to the auditory danger signal is conveyed to the recipient. When a visual signal is used, another type of intense flash or flashing signal should be used to attract the attention of the recipient of the visual signal.

6.3 ISO 11429, *Ergonomics — System of auditory and visual danger and information signals*

Because ISO 11429 refers to ISO 7731 for the design of auditory signals, the recommendations given in 6.2 are applicable to both.

Auditory danger and information signals shall be used with specified visual signals (see 6.1.3). Another type of intense flash or flashing signal should be used to attract attention to the visual signal.

6.4 ISO 9355-2, *Ergonomic requirements for the design of displays and control actuators — Part 2: Displays*

The audibility of a danger signal against an ambient noise is solely determined by the difference in sound level between the signal and the noise, not by the absolute signal level (see 6.2).

ISO 9355-2 states that “The sensitivity of human hearing is ... most sensitive to signals in the range 500 Hz to 3 000 Hz.” But this is not always true: some people have hearing loss in that frequency range and older people have a substantial age-related hearing loss at 2 000 Hz and over. Hence, it is recommended that auditory displays contain multiple components over a wider frequency range or a temporal variation in frequency such as a sweeping sound. A “melodic” sound may also be used for this purpose, and not only for making the identification of auditory displays easier (ISO 9355-2).

Some people exhibit extraordinary reactions to sudden sounds, leading to distracted behaviour. Care should therefore be taken in determining the characteristics of a signal. Extremely loud sounds should not be used and an abrupt onset should be eliminated.

6.5 ISO 9921, *Ergonomics — Assessment of speech communication*

ISO 9921 specifies requirements for the performance of speech communication for verbal alert and danger signals, information messages and speech communication in general. The requirements are qualified by *intelligibility ratings* which consist of five categories: “Excellent”, “Good”, “Fair”, “Poor” and “Bad.” The relation between the ratings and the speech intelligibility score obtained by (younger) listeners with normal hearing, is presented in an annex. The relation is also applicable for older listeners with moderate hearing loss due to aging. To achieve the same intelligibility ratings for older listeners, a better acoustic environment is necessary. People with a slight hearing disorder or non-native language listeners require a higher signal-to-noise ratio — approximately 3 dB, according to ISO 9921. However, in many cases, 5 dB would be more appropriate for word recognition.

To predict speech intelligibility in an environment, an objective index such as the speech transmission index (STI) measure may be used. ISO 9921 presents the relationship between intelligibility ratings and STI. Table 3

gives the relationship between intelligibility ratings and STI value for normal listeners as given in ISO 9921 and that for older listeners given in ISO/TR 22411.

NOTE STI is a single value that measures the physical quality of speech transmission channels. The STI values vary between 0,0 (unintelligible) and 1,0 (perfectly intelligible). The STI measurement method is presented in IEC 60268-16.

Table 3 — Intelligibility ratings and relation between STI for persons with normal hearing and older listeners and phonetically balanced-word/PB-word score for people with normal hearing

Intelligibility rating (ISO 9921)	STI for normal hearing persons (ISO 9921)	STI for older listeners (23 dB HL of PTA of 0,5 kHz to 2 kHz)	Meaningful PB-word score for normal hearing persons (ISO 9921)
Excellent	>0,75	>0,8	>98
Good	0,60 to 0,75	0,75 to 0,8	93 to 98
Fair	0,45 to 0,60	0,60 to 0,75	80 to 93
Poor	0,30 to 0,45	0,45 to 0,60	60 to 80
Bad	<0,30	<0,45	<60
NOTE STI values for older listeners were estimated based on the comparison between the word recognition score for listeners with normal hearing and those of older listeners.			

6.6 IEC 60268-16, *Sound system equipment — Part 16: Objective rating of speech intelligibility by speech transmission index*

Because ISO 9921 refers to IEC 60268-16 for the measurement of speech transmission performance of the environment, the same considerations as those described in 6.5 are applicable to IEC 60268-16 in the evaluation of the sound environment.

7 Assessment of visual and lighting environments

7.1 General

Good lighting will create a visual environment that enables people to see, move about safely and perform visual tasks efficiently, accurately and safely, without causing undue visual fatigue.

For people with visual disorders, an increase in the illumination of their environment can increase their perception of the objects and their ability to undertake tasks within it.

Visual disorders can be broadly categorized as follows.

Partially sighted — the field of vision is impaired because of an illness, a degenerative syndrome, or trauma.

Low vision — a severe visual impairment, not necessarily limited to distance vision. Low vision applies to all individuals with sight who are unable to read the newspaper at a normal viewing distance, even with the aid of eyeglasses or contact lenses.

Legally blind — a person who has less than 6/60 vision in the better eye or a very limited field of vision (20° at its widest point).

Totally blind — the inability to tell light from dark.

Those with vision disorders can have them from birth, or have them develop during their lifetime through diseases/conditions such as glaucoma, retinal detachment, cataracts and diabetes-related eye conditions.

Aging brings about a level of visual impairment in almost all people, a reduction in visual acuity, a reduction in the field of view and a susceptibility to glare.

Glare is a particularly common problem in work places. There are two primary types of glare:

a) ***Disability glare*** is a degradation of visual performance caused by a reduction of contrast. It can occur directly, by reducing the contrast between an object and its background, or indirectly, by affecting the eye. Indirect disability glare affects the eye and not the object being viewed. It is seen, for example, when a car approaches at night with its headlights on full beam, causing the eyes to be dazzled. In this scenario, the disability is caused by a reduction of retinal image contrast caused by light scattering within the eye and also by the raised adaptation level of the eye as the car approaches. Disability is prolonged because the eye takes time to re-adapt to the ambient light level when the car has passed. Disability glare can be reduced by lowering the luminance of the glare source.

b) ***Discomfort glare*** at low levels can often induce annoyance rather than discomfort. At higher levels of glare, physical discomfort is reported, rather than simply annoyance, and this can be accompanied by disablement (disability glare). There is a large variation in the level of discomfort reported by different people exposed to the same physical stimulus. This range is further extended when people with clinical conditions are included.

Furthermore, not only will different people report different amounts of discomfort for the same configuration of light, but the same person will sometimes report different amounts of discomfort for the same light configuration at different times.

7.2 Contrast sensitivity

Discomfort can be reduced by decreasing the contrast between the light source and the background (by either lowering the source luminance or by raising the background luminance), by reducing the size of the glare source, or by moving the glare source away from the line of sight.

7.3 ISO 8995, *Lighting of indoor work places*

In addition to the general considerations for illuminated environments, users of the environment, particularly those with visual impairment, should have the ability to control the level of illumination and shading to maximize their performance and minimize their discomfort.

7.4 Lighting for older people

As people age their ability to focus on close objects decreases, light is more scattered in the eye, less light reaches the retina and there are changes in the spectral quality of light reaching the retina. These changes reduce sensitivity to light, reduce visual acuity, reduce contrast sensitivity, reduce colour discrimination and cause an increased sensitivity to glare. In particular, the elderly have difficulty seeing in dim light, when moving from bright to dark conditions, in reading small print and in distinguishing between colours. There can also be pathological changes leading to low vision and even blindness. Where pathological factors occur, they will have been identified through medical advice and individual requirements will have been identified. Deterioration of the visual system is diagnosed using eye and eyesight tests. Care should be taken when designing work to consider the use of aids such as *reading* glasses. Specific advice on lighting appropriate for different activities by older people is presented in CIE Technical Report 1234[30].

8 Considerations related to air quality

Air quality is influenced by the chemical and particulate content of air. This can have direct effects on the health of a person due to the reaction between the physiological systems of the body and the “contaminated” air. Breathing *poisonous* gases, for example, is a threat to health and can cause death. Threshold limits for particulates and gas concentration that influence health is related to the characteristics of the people receiving them. However, this is beyond the scope of this International Standard, in which air quality is considered in terms of comfort and satisfaction.

Data concerning satisfaction related to air quality are often obtained from the responses of large samples or panels (expert testers) of people who smell the air and rate dissatisfaction. The results of user performance tests can be related to the “normal” responses of people (normative data). People with special requirements

will include those whose olfactory system is impaired or modified. People with a common cold, for example, will have impaired perception. Older people have lower sensitivity to smells. Where odours provide information or pleasure, then this will be impeded. It may be that dissatisfaction from smells will be reduced; however, there is little systematic data to support this.

A particular consideration can be that people with disabilities, for example, will not be able to move out of a poor air quality environment, and so it is particularly important to maintain good air quality.

9 Considerations related to assessment of other environmental components

9.1 General

This International Standard considers environmental components. However, people occupy *total* environments, and additional components can also be influential in determining human response as well as their interactions. Vehicles, fans, electric tools, kitchen appliances, traffic, building services, etc., will expose people to vibration. There is a lack of data concerning human response to vibration for people with disabilities. The effects of age, body shape and size, illness, drugs and aids such as wheelchairs or balancing aids could be important. It seems reasonable to predict significant effects, but each context must be judged individually as no general guidance exists.

Whole-body vibration is vibration transmitted to the entire body via the seat or the feet, or both, often through driving or riding in motor vehicles (including forklift trucks and off-road vehicles), or through standing on vibrating floors. Hand and arm vibration, on the other hand, is limited to the hands and arms and usually results from the use of power hand tools (e.g. screwdrivers, nut runners, grinders, jackhammers, and chippers) or from vehicle controls.

9.2 Vibration environments

9.2.1 ISO 2631-1, *Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration — Part 1: General requirements*

Vehicles and machines, and some buildings, expose people to vibration. ISO 2631-1 defines methods of quantifying whole-body vibration with respect to human health, comfort, perception and the incidence of motion sickness. ISO 2631-1 provides frequency weightings for the different axes of vibration derived from studies involving normal healthy subjects. Laboratory studies have not shown any age-dependence in sensitivity to different frequencies of whole-body vibration. Frequency weightings have not been determined for people with specific disabilities. However, people with some disabilities may have sensitivity to vibration that differs from healthy people. The frequency dependence of the effects of vibration on discomfort and health depend on many factors, including seat configuration, body shape and posture, as well as other sources of individual variability. Posture is especially influential in the transmission of vibration from seats, depending on spinal posture and limb positions. Persons with disabilities may adopt unusual postures and require different seat configurations than able people. Although the effects may be large, there is currently little information on the variations in sensitivity to vibration in specific postures and seat configurations. The prediction of the influence of vibration on the discomfort and health of people with disabilities therefore currently employs the basic standards, without adjusting for factors that could alter their sensitivity.

ISO 2631-1 gives the magnitudes of various frequencies, directions, and durations of whole-body vibration associated with risks to people in normal health, as implied by biodynamic research and epidemiological studies of long-term exposure to whole-body vibration. For those with disabilities affecting the lumbar spine or the connected nervous system, there may be increased risk to health, and so minimization of exposure to vibration can be especially important. Disabilities affecting the metabolism and internal disorders can have additional effects on the degeneration of discs and vertebrae caused by exposure to vibration. Prior to exposure to potentially harmful whole-body vibration, health screening should be conducted. ISO 2631-1 provides information on the screening of people to be exposed to whole-body vibration environments.

When standing or walking in transport (e.g. rail, air or marine travel), low-frequency motions can impair postural stability. There is potential for greater problems in older passengers who are more likely to have postural control or vestibular deficits, or abnormalities of proprioception or muscle activity. Furthermore, falls in older

people are more likely to result in injury than those in younger persons. Currently, there are no standards that predict the loss of balance due to motion in either healthy people or those with disabilities.

9.2.2 ISO 2631-2, *Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration — Part 2: Vibration in buildings (1 Hz to 80 Hz)*

Guidance on the measurement and evaluation of whole-body vibration and shock with respect to comfort and annoyance in buildings is provided in ISO 2631-2. No specific advice is provided on acceptable magnitudes of building vibration. However, it is stated that adverse comments can arise in residential situations at vibration magnitudes only slightly in excess of perception levels.

Reactions of residents to vibration depend on many factors, such as expectations of vibration exposure, activities being undertaken and acoustic noise. Building vibration often occurs simultaneously with noise exposure. It has been found that assessments of vibration can be either increased or decreased by noise, depending on the relative magnitudes of the two stimuli. In combined noise and vibration environments, those with hearing impairments can judge the relative annoyance caused by the two stimuli differently from those with normal hearing due to differences in perceived relative magnitudes of the two stimuli. For example, hearing-impaired residents could rate the vibration as more annoying than the noise, while masking of vibration by a noise stimulus could be more likely for those with normal hearing.

9.2.3 ISO 5349-1, *Mechanical vibration — Measurement and evaluation of human exposure to hand-transmitted vibration — Part 1: General requirements*

ISO 5349-1 specifies general requirements for the measurement and evaluation of hand-transmitted vibration. A frequency weighting is defined and information on health effects of hand-transmitted vibration and preventive measures is provided.

Exposure of the hands of workers to vibratory tools, machinery or work-pieces can induce disturbances in finger blood flow (vibration-induced white finger), and neurological and motor functions of the hand and arm. The term *hand-arm vibration syndrome* (HAVS) is commonly used to refer to peripheral vascular, neurological and musculoskeletal disorders associated with exposure to hand-transmitted vibration. ISO 5349-1 provides a method of predicting the exposure to hand-transmitted vibration required for 10 % of exposed persons to develop vibration-induced white finger. The probability and severity of vibration-induced disorders of the hand can be influenced by several factors: the characteristics of the vibration, the type of tool and work process, environmental conditions, ergonomic factors (e.g. posture and grip). Medical conditions that can predispose workers to the effects of hand-transmitted vibration include primary Raynaud's disease, disorders associated with impairment of blood circulation to the hands and fingers, past injuries to the hand causing circulatory defects or bone and joint deformity, and disorders of the peripheral nervous system. Those taking medicines affecting the peripheral circulation can also be predisposed to the effects of hand-transmitted vibration. It is appropriate to give warnings of the risk of exposure to workers with such medical conditions. Prior to regular exposure to potentially harmful hand-transmitted vibration, workers should be medically screened.

9.3 Interaction of environmental components

Interaction of environmental components is sparsely researched, even for those people typically considered by standards. Questions such as whether thermal comfort conditions depend upon levels of noise or lighting or the equivalence in dissatisfaction between noise and vibration level cannot be fully answered. It is reasonable to assume that, for people with special requirements, interactions will occur and that they could be different from those typically considered in standards. No guidance beyond this is presently available.

NOTE People with disabilities or a lack of ability to respond to environmental conditions can feel more threatened by environments than others.

10 Environmental design and adaptive opportunity

People behave such that they seek comfort and avoid discomfort, dissatisfaction and loss of performance. International Standards provide the relationship between environmental conditions (light, noise, temperature etc.) and human response. When considering environmental design the "adaptive opportunity" for people to

alter their exposure to the environment is important. This can be achieved by moving away from the source of discomfort (out of the room, to another visual scene, etc.), changing posture, wearing ear-muffs, adjusting clothing. It can also be achieved by adjusting the environmental level (turning down lights, lowering temperature settings on a thermostat, etc.). It is clear that the ability to “adapt” in this way to an environment will depend upon the environmental design. For people with special requirements, this opportunity might be restricted. For example, people with restricted movement may not be able to move away from an environment. Levels of air quality, glare, temperature and so on will then become more critical and the application of International Standards should take this into account.

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