TECHNICAL REPORT

ISO/TR 22411

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Ergonomics data and guidelines for the application of ISO/IEC Guide 71 to products and services to address the needs of older persons and persons with disabilities

Données d'ergonomie et lignes directrices pour l'application du Guide ISO/CEI 71 aux produits et services afin de répondre aux besoins des personnes âgées et de celles ayant des incapacités

Reference number
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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.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard (“state of the art”, for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

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/TR 22411 was prepared by Technical Committee ISO/TC 159, *Ergonomics*.

Introduction

This Technical Report is intended to help standards developers understand the accessible design principles of ISO/IEC Guide 71 and implement them into individual standards by providing design considerations and ergonomic data related to human abilities. While this Technical Report was written primarily for standards developers, it is recognized that much of the information is technical in form and committees are advised to seek technical advice on the interpretation of such data where relevant expertise is not available within the committee. In addition to its application by standards developers, this Technical Report could also be useful to manufacturers, designers, service providers, educators and others.

ISO/IEC Guide 71 stresses the concept that taking care of the needs of older persons and persons with disabilities is important in developing relevant International Standards. The underlying idea is that products, services and environments encountered in all aspects of daily life and intended for the consumer market and the workplace should be designed to be accessible for all people including those with special requirements, such as older persons and persons with disabilities. This idea, called accessible design, has been spreading all over the world. Some regional and national standard bodies have adopted the ISO/IEC Guide 71 as their own standard or guidance.

ISO/IEC Guide 71 has successfully addressed the importance of being aware of the needs of older persons and persons with disabilities. For seven design fields it provides structured tables of factors and human abilities that need to be considered in designing products and services. Its tables are intended to also direct the attention of standards developers to these factors when they draft or revise standards. However, ISO/IEC Guide 71 does not exhaustively describe how to consider those factors or how to find solutions for them. What is required is to establish design methods for implementing the concept of accessible design into individual standards. The methods demand a wider range of knowledge on properties and ergonomic data of human abilities. Without such knowledge, better design for persons with special requirements will not be realized.

Social and economic effects are expected from accessible design. In the social dimension, a greater number of individuals — including older persons and persons with disabilities — will be able to be involved in social activities without any restriction in using products or enjoying services and environments. The economic effect is that products developed using accessible design can be purchased by a wider range of people, including older persons and those with disabilities, who are now a significant proportion of consumers with buying power.

ISO/TC 159, *Ergonomics*, has been involved in this challenging work, firstly with an ad hoc group and then with Working Group WG 2, *Ergonomics for persons with special requirements,* the result of which has been the development of this Technical Report, which also incorporates factors that do not appear in ISO/IEC Guide 71 where considered necessary. Nevertheless, these design considerations and human ability data are arranged in accordance with the structure of ISO/IEC Guide 71, for ease of reference.

This Technical Report widens the scope of users as far as possible and is not limited to the 5th to 95th percentiles of working populations[1)]. It constitutes a starting point from which to offer technical information for accessible design. It is not exhaustive and does not fully reflect the present state of knowledge and data for accessible design: while some of the design considerations are well established, others are still under development.

1) A percentile describes the percentage of people in a population group (e.g. 5 % or 95 %) for which the relation to a certain body size is greater or smaller than the value given in each case. For more details, see ISO 7250.

Ergonomics data and guidelines for the application of ISO/IEC Guide 71 to products and services to address the needs of older persons and persons with disabilities

1 Scope

This Technical Report presents ergonomics data and guidelines for applying ISO/IEC Guide 71 in addressing the needs of older persons and persons with disabilities in standards development.

It provides:

— ergonomics data and knowledge about human abilities — sensory, physical, cognitive abilities — and allergies;

— guidance on the accessible design of products, services and environments.

Each of its design considerations or recommendations is based on ergonomic principles that are necessary for making products, services and environments accessible to older persons and those with disabilities. It is applicable to products, services and environments encountered in all aspects of daily life, as well as in the consumer market and workplace (herein, the term “products and services” is used to cover all these areas). While it does not provide techniques for designing assistive devices, some of its provisions do, however, support interoperability with assistive technology. Conformity assessment of any international, regional or domestic standards is outside its scope.

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/IEC Guide 71:2001, *Guidelines for standards developers to address the needs of older persons and persons with disabilities*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
accessible design
design focused on principles of extending standard design to persons 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 persons, to the greatest extent possible, without the need for adaptation or specialized design.

[ISO/IEC Guide 71:2001, 3.2]

3.2
assistive technology
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

NOTE This can be acquired commercially off-the-shelf, modified or customized. The term includes technical aids for persons with disabilities. Assistive devices do not eliminate impairment but may lessen the difficulty an individual has in carrying out a task or activity in specific environments.

[ISO/IEC Guide 71:2001, 3.3]

3.3
user
person who interacts with the product, service or environment

NOTE Adapted from ISO 9241-11:1998.

[ISO/IEC Guide 71:2001, 3.6]

3.4
alternative format
different presentation which may make products and services accessible by the use of another mobility or sensory ability

[ISO/IEC Guide 71:2001, 3.8]

3.5
impairment
problem in body function or structure such as a significant deviation or loss which can be temporary due, for example, to injury, or permanent, slight or severe, and which can fluctuate over time, in particular, deterioration due to ageing

NOTE 1 Body function can be a physiological or psychological function of a body system; body structure refers to an anatomic part of the body such as organs, limbs and their components, as defined by the World Health Organization (WHO), see Reference [42].

NOTE 2 This definition differs from that in ISO 9999:2002 and, slightly, from the WHO definition, see Reference [43].

[ISO/IEC Guide 71:2001, 3.4]

3.6
accessibility
extent to which products, systems, services, environments or facilities can be used by people from a population with the widest range of capabilities to achieve a specified goal in a specified context of use

NOTE 1 Context of use includes direct use or use supported by assistive technology.

NOTE 2 Term and definition adopted by TC 159 and first published in 2007.

4 General considerations

4.1 Need for technical guidance in implementing ISO/IEC Guide 71 in individual standards

ISO/IEC Guide 71 provides standards developers with guidance on taking into account the needs of older persons and persons with disabilities when developing new standards or revising existing ones. It defines seven design fields and human abilities and summarizes ergonomic factors to be considered in the form of tables. These are followed by possible solutions with some practical examples.

However, ISO/IEC Guide 71 neither fully describes methods for realizing its principles nor shows ways to consider the factors in developing standards, and the examples and possible solutions explained therein are not exhaustive. Standards developers need to interpret the principles of ISO/IEC Guide 71 and find their own technical solutions, applicable to individual standards. To achieve this, ergonomic data on human abilities as a function of age and impairment (grouped by their nature) are necessary. This technical information is currently distributed across multiple standards and documents. Therefore, it would be preferable and helpful for users of ISO/IEC Guide 71 to have common technical guidance that they could consult during their drafting work from time to time. This technical guidance, provided by this Technical Report, is intended to bridge ISO/IEC Guide 71 and other, individual standards, as shown in Figure 1. Furthermore, standards for different products or services can become inconsistent or contradictory if they lack common data sources on accessible design.

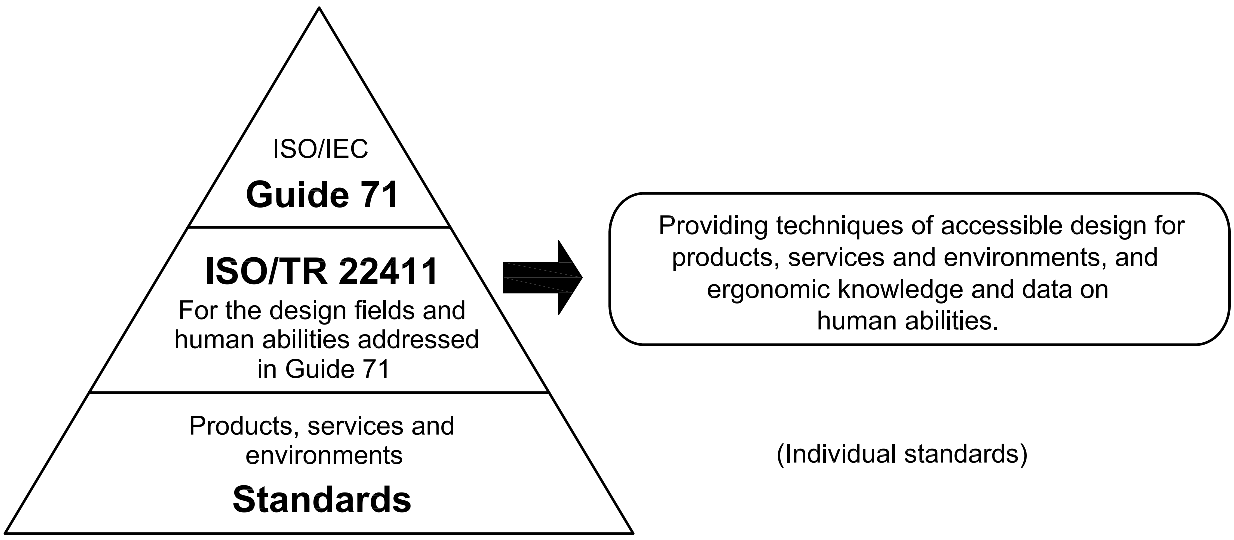


Figure 1 — ISO/TR 22411 in relation to ISO/IEC Guide 71 and individual standards

4.2 Approaches for achieving accessibility

This Technical Report describes two different approaches.

The first is concerned with compensation for impaired abilities with alternative modalities. An example of this is providing visual information for visually impaired persons by means of other sensory modalities such as hearing and/or tactile sense(s). This approach is called the *alternative format* in ISO/IEC Guide 71. Although this method is primarily intended to compensate for serious impairments, it is also helpful for persons when one of their modalities is occupied by another busy task, such as using auditory information for a person who is involved in tasks with visual displays.

The second approach is to design products and services taking into account the extent of impairments, including those related to ageing. Impairments occur in every aspect of sensory, physical, and cognitive abilities. Many can be compensated for by ergonomic design methods provided the impairment is not serious. Giving auditory information at a higher sound level for persons with hearing impairment is an example of this approach, which relies on sets of data derived from knowledge on human abilities.

Some design methods extend over both approaches.

4.3 Human abilities data

In addition to design considerations, this Technical Report supplies human ability data relevant to the accessible design of products and services. The data were adopted from scientific journals or publicly available sources such as international or domestic standards and academic books. When ergonomic data were not available, recommended, *de facto*, values have been described.

5 Using this Technical Report

This Technical Report follows the same structure as that of ISO/IEC Guide 71, for easy reference.

Clause 6 describes additional issues to consider when standards developers draft or revise a standard.

Clause 7 briefly mentions the present status of knowledge pertaining to the factors adopted in this Technical Report. It also addresses the need to cope with competing requirements in standards which can arise in drafting or revising a standard.

Clause 8 provides design considerations for each factor described in ISO/IEC Guide 71. Each subclause begins with a citation from ISO/IEC Guide 71 (in a box) relevant to the subclause. Then design considerations about the factors follow, where available. The subclauses are linked to the rows in the tables of ISO/IEC Guide 71, Clause 7. When no information is given, none was available at the time of writing: further research is necessary.

Clause 9 provides basic knowledge of and reference data for human abilities. Some are directly related to the design considerations in Clause 8 to supplement them with human ability data, where available. The subclauses are linked to the columns in the tables of ISO/IEC Guide 71, Clause 7.

Annex A introduces some guiding principles of accessible design to supplement the descriptions in ISO/IEC Guide 71. Annexes B to D describe visual ability data which supplement the relevant descriptions in Clause 9. Annex E shows a case report on cases of allergy.

6 Developing standards — Issues to consider during the standards developing process

6.1 General

ISO/IEC Guide 71:2001, Clause 6, describes a helpful process for ensuring that the needs of older persons and persons with disabilities are included when standards developers draft a new standard or revise an existing standard. Users of this Technical Report are advised to refer to ISO/IEC Guide 71 for an overview. Additional guidance is provided below.

6.2 Definition of the standardization project

While the standards project is being defined and the purpose clarified, it is important to identify the end-users of the product or service being standardized. Various standards, such as ISO 20282-1:2006 (for everyday products), provide methods for identifying important user characteristics.

During this process, the following fundamental design recommendations apply. See Annex A.

— Accessible products and services should find acceptance with as many persons as possible.

— Accessible design should not have adverse effects on the functionality of the product or service or on the usability for any user.

— Accessible design should not impact the privacy of the users.

EXAMPLE 1 The voice output of cash dispensers is not audible to a third party.

— Products and services should not discriminate against, stigmatize or disadvantage users in any other way.

EXAMPLE 2 A separate entrance for wheelchair users that takes the occupant to a back corridor rather than into the main foyer.

EXAMPLE 3 Voice output or key tones that can be switched off so as not to disadvantage users who are sensitive to noise.

— Products and services should pose no safety risk to their users and should comply with the relevant International Standards under the technical safety laws of the respective countries.

— Products and services should be designed for the intended environment and context of use.

6.3 Composition of the drafting committee

The members of the committee drafting the standard should be aware of ageing and disability issues. Data on issues affecting older persons and persons with disabilities should be collected. This Technical Report can serve as a starting point for that information. However, experts in the subject should be consulted or placed on the committee so that appropriate use of the data can be made within the context of the specific standard being developed. The following considerations concerning the committee composition are also relevant.

— Experts in ergonomics or human factors can help to interpret data on human physical, sensory, perceptual and cognitive abilities. They have the skills necessary to apply the data for the intended user groups that will be affected by the standard.

— Older persons and persons with disabilities should be included for their first-hand experience.

— Accessibility experts can provide a more general knowledge on accessibility requirements.

6.4 Content of the standard

To keep the needs of older persons and persons with disabilities in mind during the writing of the standard, it is beneficial to consult, for example, the principles of universal design (see Annex A) [44].

It is presupposed that a product or service complies with the relevant International Standards under the technical safety laws of the respective countries. However, persons with certain impairments have requirements that differ from, and may run counter to, safety regulations. For example, someone with one hand could wish to disengage a control which requires two-handed operation, for safety reasons, or to de-activate the child-safety mode.

It is also prerequisite that the surroundings (such as the lighting conditions, climate and noise level) promote the accessibility of the product or at least in no way restrict it.

However, there can be situations where, despite following the guidelines and recommendations of this Technical Report and other standards, the product or service is not equally usable by all persons to the greatest extent possible. In those cases, the following measures can be taken to prevent the exclusion of users.

a) Provide instructions and recommendations specific to users with special requirements to help them adapt the product to their needs.

b) Ensure compatibility with assistive technology.

EXAMPLE 1 Mobile telephones can be fitted with an interface (i.e. according to the ETSI standards) which enables connection to voice output or a Braille display.

c) Offer supplementary aids.

EXAMPLE 2 Supplementary modules or templates.

d) If accessibility of the product or service is affected by its installation or configuration, provide information to the user or service provider to help him or her optimize the product or service use during this first assembly.

e) In certain cases, train users with special requirements to facilitate the use of the product or service.

EXAMPLE 3 Accessible design can promote activities of specialists for adapting aids to the product, for preparing special instructions and for training users.

f) Provide appropriate information on product properties that allows users to determine whether the product

1) is appropriate for their abilities to the full extent,

2) can be re-equipped and adapted so that they are able to benefit from the expected use, or

3) cannot be used by them.

6.5 Review process

During the standardization process, existing ergonomic data and design guidelines can help to guide the product or service standard definition. When possible, this information should be further validated with members of the intended user groups. This step is especially important when considering the needs of older persons and persons with disabilities. This validation includes verifying the physical, sensory and cognitive requirements, including the understanding of how to use the product or service. Various standards, such as ISO 13407:1999, provide processes for human-centred design and evaluation activities.

EXAMPLE A new standard is being drafted to define graphical symbols for medicine prescription bottles. Existing data helped identify the possible colours and sizes for the symbols. As a check on the requirements identified for the graphical symbols, they are tested with a representative sample of the target user group (50 % of which is over the age of 65) to determine whether the symbols can be visually identified and whether they are correctly understood.

Just as it is important to review the standard definition of the product or service, it is also worthwhile reviewing the actual standard document itself from the standpoint of (or with) older persons and persons with disabilities.

6.6 Publication of the standard

The standard should be available in alternative formats that meet the needs of older persons and persons with disabilities. See 8.2.

EXAMPLE A standard is made available in large print, Braille or in an accessible electronic format, which allows users to adapt the documents to their needs.

7 Resolution of contradictory requirements

The accessibility of a product is perceived very differently by individuals depending on their experience, training and/or type or degree of impairment. In order to resolve conflicts between competing requirements that can arise from different types of impairment, these should be weighed against each other using the following criteria.

a) Number of potential users

The decision about what is readily achievable and what would be acceptable to the user should be oriented towards the alternative which would address as many additional potential users as possible.

b) **Application areas for the product**

When designing products and services for the public sector, it is particularly important to take into consideration as many requirements and recommendations as possible since, in contrast to the private sector, the user is usually not in a position to choose from several alternatives the product or service that would be most appropriate for his or her personal abilities. Until fully accessible products and services are available, accessibility can be secured by the installation of several supplementary units (such as machines for wheelchair users and blind persons). These can be conventional products or services or products or services designed for persons with a specific impairment (if necessary with adaptation).

c) **Economic appropriateness**

Accessibility should not result in an inappropriately high cost of the product or service. Therefore, the considerations and recommendations of this Technical Report can already be taken into account or followed during the early design stages of new products and services. Economic appropriateness may also be achieved by making only intended product or service functions or only certain products in a product line or services in a service line accessible.

Accessible products need to avoid the inappropriate implementation of recommendations that benefit a few to the disadvantage of many.

EXAMPLE 1 If the loudness of speech or a signal intended to assist a hearing-impaired user is set too high, it may disturb or be audible to others in the vicinity who do not need to hear.

Where a product or service appears to breach accessibility guidelines, compromise solutions are required.

EXAMPLE 2 If there is a demand for miniaturized products, the recommendations in this Technical Report could still be implemented to a reasonable extent when designing the product.

EXAMPLE 3 Where it is not possible to make all products in a product line fully accessible, accessible versions for certain impairments could be provided as part of the product range.

8 Factors to consider with design guidelines

8.1 General

This section is structured to present the relevant guidance from ISO/IEC Guide 71 first (in a box), followed by design considerations about the factors presented in Guide 71. The considerations are presented in the same structure as those of Guide 71. For some factors useful information is not currently available, therefore no extra considerations will be given in these cases.

8.2 Alternative format

8.2.1 General considerations

An alternative format (defined in 3.8) describes a different presentation or representation intended to make products and services accessible through a different modality or sensory ability. By providing all input and all output, i.e. information and functions, in at least one alternative format, for instance visual and tactile, more people, including some with language/literacy problems, may be helped. In terms of function for people with dexterity and strength impairment, alternative packaging solutions may need to be envisaged.

[ISO/IEC Guide 71:2001, 8.2.1]

Providing several alternative formats increases the probability of making a product or service accessible to the greatest number of people. There are two basic approaches (see also ISO 9241-20 and ISO 9241-171).

a) Presenting information via different senses

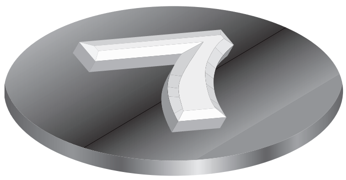
In this approach, the same information is provided through more than one sense, such as providing visual and auditory information for the same content.

EXAMPLE 1 Floor designation in an elevator is displayed in both visual and tactile format so that blind persons can identify the floor number by touch. See Figure 2 a).

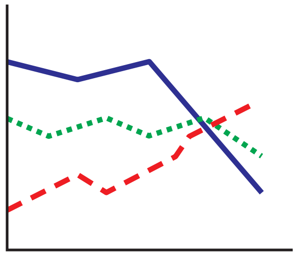
b) Presenting information via different aspects of the same sense

In this approach, additional cues are provided, such as showing two different visual implementations of the same content.

EXAMPLE 2 Lines in a graph are displayed in different colours and different patterns so that colour deficient persons can identify the lines by the patterns. Persons without colour deficiency can also identify the lines under low illuminance conditions. See Figure 2 b).



a) Raised sign for floor designation in elevator



b) Colour and line pattern in graph

Figure 2 — Examples of alternative format

8.2.2 Alternatives to visual information

> The type and texture of surface finishes can be important in providing tactile feedback which can reinforce instructions and warnings for those with visual impairment. Where the principal form of instruction on a product or in a building is written, alternatives would be voice (instructions "spoken" by a product or service), sound (feedback from clicks, bells and buzzers) or touch (tactile marking or grip).
>
> Wherever feasible, visual information which is presented on electronic products should be available from the product in audio or other sensory stimuli for those with a visual impairment including those who cannot read Braille, as well for those who have difficulty with reading or are unable to read. Printed visual information should be available in alternative formats (electronic audio, large raised letters or Braille, etc.) which are readable by individuals without vision and in large print for those with low vision.
>
> [ISO/IEC Guide 71:2001, 8.2.2]

8.2.2.1 Tactile markings

Tactile markings can be used as an alternative to visual information not only for persons with visual impairments but also for persons whose eyes are occupied with other tasks. In principle, tactile markings can be used anywhere visual information is needed. However, some persons with touch impairments (e.g. older persons or persons with diabetes) have difficulty sensing tactile information. Surface temperature is unsuitable for conveying precise information. See 9.2.3.4.

Tactile markings are useful for indicating locations, recognizing surface structure, perceiving shape of goods, and presenting information contained in characters, signs or plans.

EXAMPLE The distinction of a shampoo bottle with tactile grooves from a rinse bottle that has a smooth surface without grooves [45].

The following accessibility considerations are relevant to the use of tactile markings [46].

— The shape of the markings is designed to clearly correspond to the function assigned to it.

  EXAMPLE 1 Door handles, rocker switches, emergency stop switches.

— The surface is designed so that the function can be recognized.

  EXAMPLE 2 Walking areas, handle zones.

— A pyramid shaped cross section is preferred for raised letters and lines. See Figure 3.

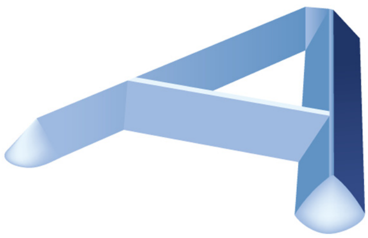


Figure 3 — Raised letter with pyramid shaped cross section

— Smoothing sharp edges increases accessibility.

— Dots with a convex shape (in contrast to cylindrical or peak form) and a sufficient amount of raised height above the surface increase accessibility.

— The dimensions like height and size are designed suitably to the spatial and temporal resolution of tactile sense. See 9.2.3.2 and 9.2.3.3.

— If there is sufficient space, Braille and raised characters can be provided additionally.

— Non-abbreviated Braille is preferred due to the international use and support of elderly blind users.

A large variety exists in the recommendations for spacial dimensions of tactile markings and Braille depending on, for example, material used, body dimensions (fingertips, feet, etc.) and environmental conditions. Table 1 summarizes them.

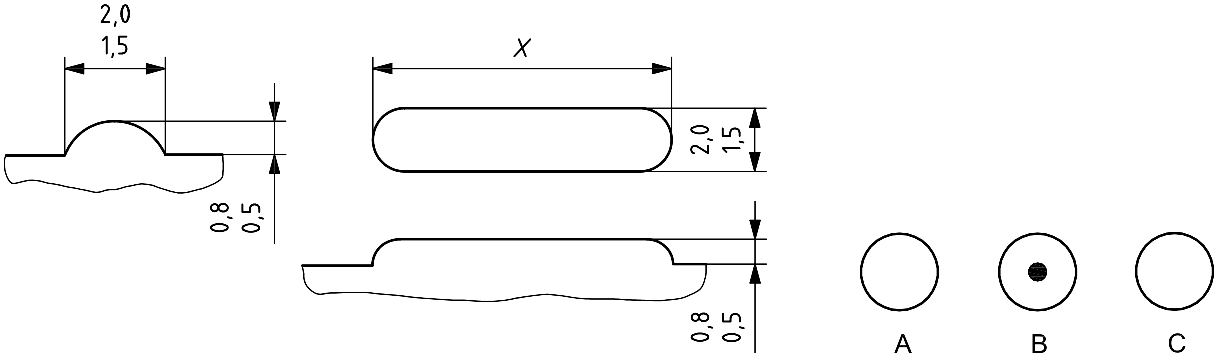
Table 1 — Dimensions of tactile markings used in applications (for fingers)

Unit: millimetres

Dimension		Tactile markings		Braille
		International Standard	**National standard**	
Raised height of dots, bars and symbols	Dots	0,6 ± 0,2 [47]	0,5 to 0,8 [48] 0,8 to 2,0 [46]	0,4 ± 0,1 [49] 0,7 to 1,3 [46]
	Bars	0,5 ± 0,1 [47]	0,5 to 0,8 [48]	
	Symbols	0,25 to 0,5 (ISO 11683:1997) 0,40 to 0,48 (for embossed characters) (ISO/IEC 7811-1:2002)	—	
Size dimensions of dots, bars and symbols	Dots (diameter)	1,5 ± 0,2 (ISO 11683:1997)	1,5 to 2,0 [48]	—
	Bars (length)	4,0 ± 1,0 [47]	—	
	Symbols (size)	3-4, 9 ± 1, 18 ± 2 (ISO 11683:1997)	10 to 25 [46]	
Inter-dot spacing (for Braille)		—	—	2,13 to 3,17 (depending on country)
Inter-character spacing (for Braille)		—	—	3,13 to 4,05 (depending on country)
Interline spacing (for Braille)		—	—	4,87 to 9,17 (depending on country)

EXAMPLE 3 Convex dots or bars used to show the centre of an operating part or the standard position of a consumer product. Figure 4 shows dimensions and positions of a tactile dot and a tactile bar.

Dimensions in millimetres



a) Tactile dot and tactile bar for selector switch indicating a centre

b) Selector switch using tactile dot

Key

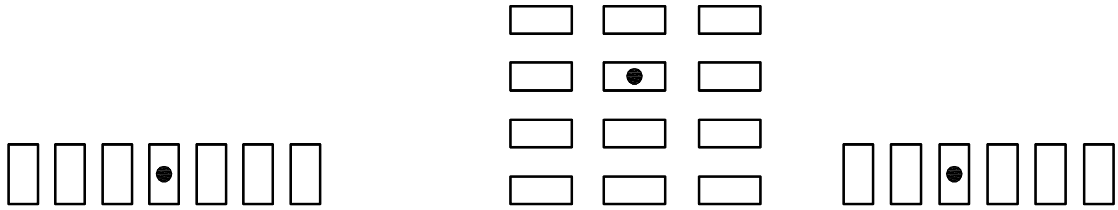
A slow

B standard

C fast

X longer than 5 × width of convex bar

Figure 4 — Examples of tactile dots and bars [48]



Centre of odd number of controlling part

Centre of controlling part

N/2th position from the left of even number of controlling parts

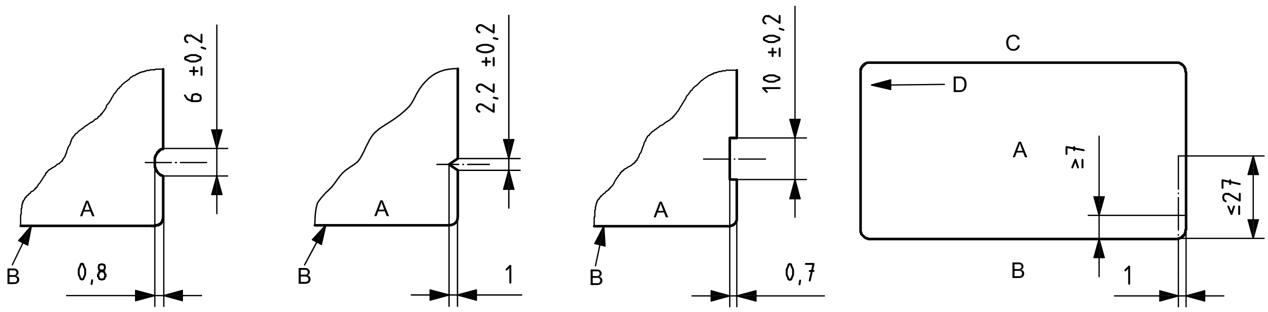
c) Tactile dots used for multiple controlling parts to show a centre

NOTE *N* is the number of controlling parts.

Figure 4 (*continued*)

EXAMPLE 4 Use notches with different shapes at the edge or on the corner of a card to identify the card type, indicate the direction of card insertion into a machine, or indicate the visual orientation of information presented on the card. Examples of dimensions and positions of notches are shown in Figure 5.

Dimensions in millimetres



For telephone

For transportation

For shopping

a) Shapes and dimensions of tactile notches on cards [50]

b) Location of notch on card

c) Mobile phone SIM card

Key

A front surface of card

B lower edge of card

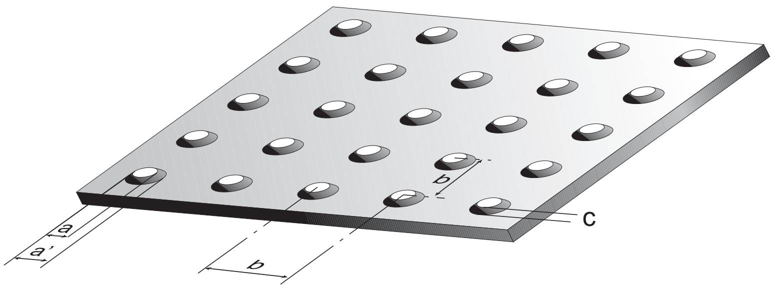
C upper edge of card

D direction of insertion

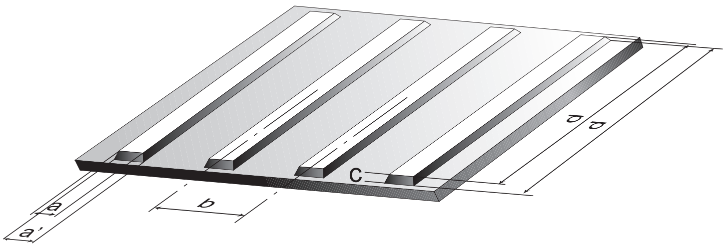
The corner part of the notch shall be adequately rounded at the time of processing for the benefit of card-handling by users.

Figure 5 — Examples of tactile notches

EXAMPLE 5 Use tactile bars or dots installed on the ground and floor surface to aid the mobility of persons with visual impairment. Two patterns of tactile ground/surface indicators are used: a) attention pattern used to call attention to decision points for direction, and b) guiding pattern to direct the direction. Figure 6 shows examples of the dimensions of these patterns.



a) Attention pattern (see Table 2)



b) Guiding pattern (see Table 3)

Figure 6 — Examples of tactile indicators on ground [51]

Table 2 — Dimension of attention pattern shown in Figure 6 a) [51]

Millimetres

Symbols	Dimensions	Tolerances
a	12	$^{+1,5}_{0}$
a′	a + 10	
b	55 to 60	
c	5	$^{+1}_{0}$
NOTE Within this range of dimensions, one dimension is set in proportion to the size of a block.		

Table 3 — Dimension of guiding pattern shown in Figure 6 b) [51]

Millimetres

<table>
<tr><th>Symbols</th><th>Dimensions</th><th>Tolerances</th></tr>
<tr><td>a</td><td>17</td><td rowspan="3">$^{+1,5}_{0}$</td></tr>
<tr><td>a′</td><td>a + 10</td></tr>
<tr><td>b</td><td>75</td></tr>
<tr><td>c</td><td>5</td><td>$^{+1}_{0}$</td></tr>
<tr><td>d</td><td colspan="2">⩾ 270</td></tr>
<tr><td>d′</td><td colspan="2">d + 10</td></tr>
<tr><td colspan="3">NOTE The distance between the upper surface of the raised parts at the joining part of the blocks (longitudinal direction of the raised part) is 30 mm maximum.</td></tr>
</table>

EXAMPLE 6 Tactile maps to show the routes or layouts of facilities. These include information of present location, tactile ground/surface indicators, stairs, escalators, elevators, entrances and exits, ticket machines, gateways, ticket gates, and information of maps for restrooms including toilet, hand basin, etc.

8.2.2.2 Auditory signals

Auditory signals can be used effectively as an alternative to visual information. They are especially useful for delivering information to visually impaired persons. Auditory signals have the advantage that information can be conveyed to persons who cannot see or whose eyes are already occupied with other tasks such that they cannot attend to a visual display.

Auditory signals used in human-machine interfaces are simple and easy to install, but are sometimes abstract in their meaning compared to spoken instructions. When two or more auditory signals are employed in a product and service or when two or more products and services with an auditory signal are used at the same time and at the same place, those signals are required to be clearly discriminable from each other. Temporal patterns are one of the most robust cues with which the listener discriminates different auditory signals.

The following accessibility considerations are relevant to the use of auditory signals.

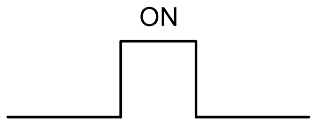
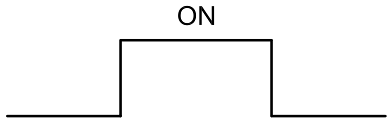
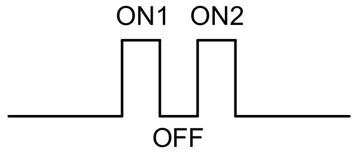
— The signals for the same purpose in all products and services have the same temporal pattern across different products and services.

— The signals for different purposes are clearly discriminable from each other.

— The auditory signals are designed functionally so that they can help the user handle the product when visual information is not available or restricted, as in dark conditions.

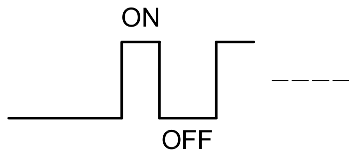
EXAMPLE 1 Table 4 shows an example of temporal patterns of operation confirmation signals [52]. The reception and start signal indicates the reception of the operation of the apparatus or the start of the action of the product. The stop signal indicates the stoppage of the action of the product. The base point signal indicates the reference position in the case where the plural settings are switched by pushing one button repeatedly.

Table 4 — Examples of temporal patterns of operation confirmation signals

Division	Pattern	Type	ON time (s)	OFF time (s)	Information auditory signal
Reception and start signal		Simple signal (one time)	0,1 to 0,15	—	Pip
Stop signal		Simple signal (one time)	0,5 to 0,6	—	Peep
Base point signal	 Remarks: ON time 1 = ON time 2 ON time ⩾ OFF time	Combined signal (one time)	0,05 to 0,075	0,05 to 0,075	Pip pip (quick)

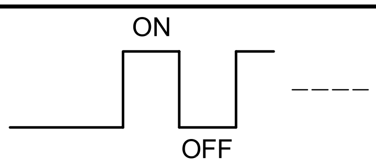
EXAMPLE 2 Table 5 shows an example of temporal patterns of end signals [52]. The end signal indicates the completion of the action after the product has continued the action for a specified time.

Table 5 — Example of temporal patterns of end signals

Division	Pattern	Type	ON time (s)	OFF time (s)	Information Auditory signal
Case of hearing at position distant from the instrument	 Remarks: 1 ON time ⩽ OFF time 2 The number of repetitions is optional.	Simple signal (Repetition)	0,3 to 0,8	0,5 to 1,0	Pip, Pip, pip, pip, … (specified times, slowly)

EXAMPLE 3 Table 6 shows an example of temporal patterns of caution signals [52]. The caution signal indicates that the product cannot be single-handedly in normal motion.

Table 6 — Example of temporal patterns of caution signals

Division	Pattern	Type	ON time (s)	OFF time (s)	Information Auditory signal
Strong caution signal	 Remark: ON time = OFF time	Simple signal (Repetition)	0,1	0,1	Pip, Pip, pi… (quick and consecutive)

8.2.3 Alternatives to auditory information

> Wherever feasible, sound signals should be supported by visual or other sensory stimuli for those with a hearing impairment (e.g. communication in writing, graphical symbols, vibration or sign language). In particular, audible warnings, such as fire alarms, should also activate, for example, visual stimuli, such as flashing lights that are well sited and clearly indicated.
>
> [ISO/IEC Guide 71:2001, 8.2.3]

8.2.3.1 Visual Information

Visual information is one possible alternative to auditory information. Temporal changes of brightness or colour, such as flashing lights, step-changed lights, blinking lights, and flickering lights, can also be used, like auditory signals, to indicate the state of controls such as start, termination and emergency.

The following accessibility considerations are relevant to the use of visual information for signalling.

— A flashing, blinking, and/or flickering light is effective in drawing attention and can be used for conveying task-relevant information to be discerned. However, light that is too bright and a certain range of repetition rates can be avoided to prevent photosensitive seizures. See 8.2.6.

— Choices of colour, colour combination, and intensity of coloured light are appropriately determined. Efficiency of coloured light for detection or discrimination can be taken into consideration for a better choice of visual signalling. See 8.2.5. Some colours have associated meanings such as those related to safety and this enhances the meaning of signs. See 8.8.

— Viewing conditions such as lighting level, brightness level, size, and viewing distance can critically affect the appearance of visual signals. Visual signals can be appropriately designed to consider those viewing factors. Special care can be taken for dark conditions to assure better visibility.

— Graphical symbols as well as text in displays can also be used to convey comprehensive meanings of sound signals. See 8.7 and 8.8.

8.2.3.2 Tactile information

Tactile information is also a useful alternative to auditory information, particularly when vibratory, as in alarm clocks.

The following accessibility considerations are relevant to the use of tactile vibratory signals.

— Human tactile sensitivity to vibratory stimuli depends on the frequency and the part of the body touched. The selection of an appropriate frequency depends on the part of the body with which it is intended to interact. See 9.3.3.2.

— Mode of touch (i.e. active or passive) and temperature of a tactile stimulator are critical for the recognition of tactile stimuli. When skin temperature is too low, the sensitivity to tactile stimuli decreases. See 9.2.3.1.

EXAMPLE Vibration signal used in a mobile phone to indicate receipt of a message.

8.2.4 Alternatives to voice input

> Where voice input is used to activate a process, for example, building entry security systems, alternatives such as keypads or the use of video monitoring should be considered.
>
> [ISO/IEC Guide 71:2001, 8.2.4]

A number of biometric and other measures can be used in security systems as alternatives to voice identification and verification. These include keypad or keyboard input of a password and/or username, retinal scanning and identification by fingerprints.

8.2.5 Biological identification and operation

> Where biometric forms of identification are intended, an alternative form of identification or activation should also be provided. For example, if systems require a retinal scan and a person does not have a retina, or the system requires a fingerprint and the person does not have hands or uses a prosthesis, such people are unable to operate the devices unless some alternative form of identification is substituted.
>
> [ISO/IEC Guide 71:2001, 8.2.5]

Voice identification and verification, keypad or keyboard input of a password and/or username, and traditional security measures such as photographic identification and signatures can be used as forms of identification. See ISO/IEC TR 24714-1.

8.2.6 Prevention of seizures

> Flicker rates, or flashing or blinking text, objects or video screens should avoid frequencies that are most likely to trigger visually induced seizures.
>
> [ISO/IEC Guide 71:2001, 8.2.6]

The use of blinking or flashing on computer and television screens induces undesirable biological effects, such as seizures, especially in persons who are photosensitive. The extent to which this is a problem depends on the size of the flashing area, the rate of the flashing, and the colour composition of the flashing material. Guidelines on the use of flashing/blinking and moving images so as to avoid such undesirable effects are under development (see also References [41] and [53]). The issue is considered to be applicable to all categories of self-luminous displays such as videos, DVD, computer/video games, movies, and any other form of electric display.

Moving or drifting images, even if they are not flashing or blinking, also cause undesirable feelings such as sickness in some cases. This is called visually-induced motion sickness. The extent of the effect is also a function of screen size, moving type and speed, and contents of the image as well.

The following accessibility considerations are relevant to the use of flashing/blinking and moving images so that these undesirable biological effects can be avoided.

— A sequence of flashes with more than three flashes within any 1 s period can cause undesirable biological effects such as seizures.

  NOTE There is no consensus for the upper limit in a number of flashes that can still cause photosensitive seizures even if it is beyond the frequency that the human visual system can critically see a flickering light [54].

— Rapidly changing image sequences are provocative if they result in flashes on the screen.

— Avoidance of the use of a transition to and from a saturated red, irrespective of luminance, can decrease the possibility of occurrence of seizures.

— Well-lit surroundings of the screen images and viewers can reduce undesirable biological effects.

8.2.7 Alternatives to visually displayed text or graphic information

8.2.7.1 General

Alternative information is “equivalent” to the original information when both fulfil essentially the same function or purpose. Thus, the equivalent fulfils essentially the same function for a person with a disability (at least insofar as is feasible, given the nature of the disability and the state of technology), as the primary information does for a person without any disability.

NOTE This factor has been newly introduced with this Technical Report.

8.2.7.2 Alternatives to textual information visually displayed

The following accessibility considerations are relevant to the use of textual information visually displayed:

- provision of non-textual information such as pictures, videos or pre-recorded audio as alternatives to textual information visually displayed increases accessibility for persons with cognitive or reading difficulties;
- pictures, videos, or pre-recorded audio that substitute visually displayed text can have information that is equivalent to the corresponding text, e.g. a picture or video of a full moon, or the spoken phrase, “full moon”, can be substituted for the text, “The Full Moon”;
- however, when selecting an alternative graphic, conflicts with common usage of visual signs is avoided, e.g. a graphic showing a full moon is used on heaters to indicate night mode of operation. See 8.8.

NOTE This factor has been newly introduced with this Technical Report.

8.2.7.3 Alternatives to graphical information

The following accessibility considerations are relevant to the use of graphical information:

- provision of textual or pre-recorded audio information as alternatives to graphical information can help persons with visual impairments or blind persons to understand the graphical information;
- text or pre-recorded audio that substitutes graphical information can have information that is equivalent to the information conveyed by the corresponding graphic.

  EXAMPLE A picture of a flag is described by text providing the function (e.g. language selection) rather than the visual properties (colour) that are unable to be perceived by a blind person: a picture of a German flag is described by the text “Germany or German” instead of “Flag: black, red, gold”.

NOTE This factor has been newly introduced with this Technical Report.

8.3 Location and layout of information and controls and positioning of handles

8.3.1 Location

The position of information and controls on a product, or in a building, or even the point at which information is available for a service (e.g. warnings about the terms on which dry-cleaners accept clothes for processing) are important. They need to be prominent for someone with a visual impairment or language/literacy disability, visible from the angle of view of someone standing and seated in a wheelchair, and easily accessed by seated or standing users without bending and stretching. This may mean that the positioning needs to be flexible or adjustable or duplicated. Information or controls should be located in a position where they will not be obstructed, for example when a product is held by either or both hands, or held in a different way by someone with manipulation or strength impairment. [ISO/IEC Guide 71:2001, 8.3.1]

8.3.1.1 Position of information

Detectability of visual information largely depends on its positioning when placed in the periphery of the sight of a person. The detectability depends on the size of the useful field of view, which in turn depends on the viewing condition.

The general shape of the useful visual field is an ellipsoid with the horizontal axis longer than the vertical. The effective range for presenting visual signs is larger in the horizontal direction than in the vertical. The size of the useful field of view becomes larger when the target size is larger, the contrast becomes higher and the colour difference between the target and the background becomes larger also.

The size of a person's useful field of view is reduced with age and tends to shift to a lower direction (relative to horizontal line), particularly when the person is walking [55]. The useful field of view is considerably limited for persons with low vision. It varies widely in size and shape depending on their impairments, such that persons with macular degeneration have only a limited visual area in the central part of the visual field. Special care needs to be taken for positioning of visual information for those persons. See 9.2.1.5.

The following accessibility considerations are relevant to the positioning of information:

— visual information is placed near the central part of field of view;

— higher contrast, larger size and larger colour difference of the target can increase detectability;

— visual information for older persons can be presented in the lower portion of the environment.

8.3.1.2 Location of controls

Controls are placed such that they can be operated easily by someone standing or seated in a wheelchair, without bending and stretching. The reach envelope of humans is affected by the length and the range of motion (RoM) of upper limbs of the human body. In general, RoM decreases with age, and the reach envelope also becomes smaller. See 8.12.1 and 9.3.2.1.

The following accessibility considerations are relevant to the easy operation of controls:

— controls are easy to reach (see 8.12);

— controls and displays and the way they are grouped together are easy to recognize and easy to assign;

— controls and displays are clearly and meaningfully arranged;

— adjustment steps are implemented logically;

— double- or multi-functional controls are avoided;

— the number of controls required is limited;

— the visibility of controls is considered so that they are placed in the visible range of the user (see 9.2.1.5).

8.3.2 Buildings

The design of buildings can incorporate simple measures that enable people to feel more confident in the physical environment, such as well placed, sturdy handrails. Controls and door handles within easy reach facilitate use by those with impairment in dexterity, manipulation, movement or strength. [ISO/IEC Guide 71:2001, 8.3.2]

Buildings are designed so that all people can use them without assistance and without restrictions, regardless of their age or their impairment. Accessibility considerations can be given to any building, but are especially important for public buildings and buildings open to the public, as follows:

— rail, road, sea and air travel buildings and associated concourses and car-parks;

— administrative and commercial buildings, e.g. courts, offices, banks, post offices, shops, department stores and shopping centres, and public service buildings, including police stations;

— health and welfare buildings, e.g. hospitals, health centres, surgeries and residential homes;

— refreshment, entertainment and recreation buildings, e.g. cafes, restaurants, public houses, concert halls, theatres, cinemas, conference centres, community buildings, swimming pools and sports centres;

— religious buildings;

— educational, cultural and scientific buildings, e.g. schools, universities, colleges, zoos, museums, art galleries, libraries and exhibition centres;

— residential buildings, e.g. hostels, hotels, residential clubs, university and college halls of residence, nursing homes and prisons.

In many countries, special laws, regulations, guidelines and standards are of relevance. Some such standards were considered in the preparation of this Technical Report. Detailed measures and illustrations for the construction of parts of buildings are provided via representative examples in 8.12.7 and 8.16. Only those dimensions and representations that are sufficient for the requirement of accessible design are considered.

8.3.3 Layout

The layout of information and controls will also determine how easy they are to read by someone with a visual or cognitive impairment. Factors to consider include logical grouping of information and controls, line length of text, relevance of information and relationship of controls to actions to be undertaken.

[ISO/IEC Guide 71:2001, 8.3.3]

The layout of controls can be determined considering logical grouping and relationships of controls based on cognitive abilities (see ISO 1503). For text design see 8.7.1, 8.7.2, and 8.7.6.1. For physical issues in layout, see 8.12.7.

Although the logical layout of controls and displays in a system or product is important for all users, it is especially critical for users with visual or cognitive impairment.

The following ergonomics principles and accessibility considerations are relevant to the layout of controls.

— Organize related information into groups and ensure that grouping is made obvious in the display itself.

— Maintain a consistent format from one display to another.

— Clearly label individual displays, so users can easily identify them and understand the relationships between them.

— If tactile markings are provided, ensure that controls are not triggered accidentally by a person feeling the tactile markings.

EXAMPLE 1 Buttons in lifts/elevators are sufficiently separated spatially to avoid misoperation.

— Position controls in a spatial layout on a display or product that corresponds with the layout of the objects they control.

EXAMPLE 2 Objects arranged horizontally are best adjusted by controls also arranged in a horizontal pattern.

— Position controls relative to their use or importance.

EXAMPLE 3 Frequently used controls or those that are safety-critical are placed in a more accessible/prominent location.

8.4 Lighting levels and glare

8.4.1 Provision of lighting

Appropriate lighting ensures that those with a visual impairment are better able to see instructions and controls. This should also be considered for those with a hearing impairment to assist with lip reading or sign language communication. [ISO/IEC Guide 71:2001, 8.4.1]

Provision of lighting depends largely on the visual task, environment and visual capabilities of the person. For example, reading small characters requires higher lighting levels to increase visibility, but a lower lighting level is sufficient for relaxing in a living room.

A sufficient lighting level is required to maintain safety, especially in transportation environments such as railway stations, subway stations, bus stops, busy roads and pedestrian areas. Entrances to buildings, stairs, elevators and escalators need also to be lit sufficiently to ensure safety.

For products, a sufficient illumination can be achieved by placing lamps outside (e.g. ticket vending machine, automated teller machine) or inside (e.g. oven, refrigerator). The level of illumination needs to be sufficiently high. Adjustable illumination (e.g. instrument panel) can be used if the product is used at different ambient conditions (e.g. day and night) or if visual capabilities are much different within the user population.

Polished or highly reflective surfaces, as well as glossy papers, can cause a glare from reflected light sources. See 8.18.4.

Appropriate lighting levels for older persons and for persons with visual impairments can be determined by taking into account their visual sensitivity. For many such people, an increased level of lighting may be required. It is noted, however, that there is a large variation in the extent of impairments, and the appropriate level of lighting depends largely on the type of impairment. For example, those who have opacification of the cornea or lens, or albinism, often find it difficult to see in bright light. Care needs to be taken not to cause glare when increasing the light level.

8.4.2 Consideration of ambient lighting

The likely lighting levels in typical use should be considered, for example television controls may be operated in a darkened room, and installation of a product may be in a dark space. [ISO/IEC Guide 71:2001, 8.4.2]

Lighting for tasks and surroundings can be appropriately designed so that there is no large brightness change between the task and the ambient lighting. Attention to ambient light level for walking areas is also important to ensure safety. This is particularly important for older persons and persons with low vision, because their peripheral vision, which plays an important role in walking, is often limited.

8.4.3 Buildings

Adjustability of lighting levels in a building is desirable to suit different needs but sudden changes in lighting levels should be avoided. [ISO/IEC Guide 71:2001, 8.4.3]

Appropriate lighting levels in buildings can be defined for each part of the building by taking into account the purpose of the place, such as entrance, living room, dining room, or working room, and the extent of visual impairment. Higher lighting levels may be required for visually impaired persons, depending on the type of impairment, as long as they do not have an effect of severe glare.

The appropriate lighting level can also be defined by taking into account the type of visual tasks involved. Visual tasks are categorized into the following groups: a) detection of objects, b) recognition of colour, c) reading characters and symbols, d) walking and other behaviour, and (e) relaxation and comfort. For each category, the lighting level can be defined appropriately. Producing a dark spot or bright-to-dark change in buildings causes accessibility problems, because persons with low vision often have difficulty seeing the details of the dark area due to their reduced ability to adapt to sudden changes of brightness.

Standard lighting levels required for various indoor workplaces are defined by the CIE (International Commission on Illumination), see Reference [56] and ISO/CIE 8995-1:2002. They can generally be used for younger and older people as well.

8.4.4 Avoidance of glare

Too high light levels and strong directional light can result in deep shadows or glare. Reflecting surfaces on information panels and glossy paper in instruction books or on packaging containing warnings should be avoided, to reduce the possibility of glare.

[ISO/IEC Guide 71:2001, 8.4.4]

Due to the increase of optical scatter in the eye, the effects of glare are exacerbated for older people and for people with some types of visual impairment (e.g. cataracts, corneal edema, vitreous opacities). Visual acuity decreases in the presence of glare for older people in particular [57]. Recovery from glare also takes more time for older adults, as do light and dark adaptation generally. Glare also causes discomfort and interferes with task performance by decreasing the perceived contrast in visual signs and displays (i.e. disability glare).

The age factor for glare is found in CIE Reference [58]. A unified glare index (UGR) for illumination is also defined by the CIE, and the index for various workplaces is recommended in the CIE Reference [56], although it assumes that light sources are uniform, bright and in the field of view. See 9.2.1.6.

Polished or high-reflection surfaces, as well as glossy papers, can cause glare by reflecting light sources. See 8.18.4.

General solutions to the problem of glare include shielding of bright light sources and the use of indirect lighting for illumination of tasks and workplaces. The following are some considerations for the solutions [59].

— Avoid placing very bright lights against dark ceilings or walls. Choose light-coloured walls and ceilings to soften the effects of bright light.

— Shield bright objects from usual lines of sight. For example, if a light bulb is seen when seated at a dining table, it is better to hide the direct view of the bulb by adjusting its shade or repositioning the fixture.

— Avoid clear lenses or shades on fixtures; they do not shield the light bulb from view.

— Spread light over large areas by lighting ceilings and walls, or by using fluorescent tubes shielded from direct view.

— Choose a deeply recessed fixture to minimize direct view of the bulb when recessed downlights or “cans” mounted in the ceiling are needed.

— Place task lights to the side of the viewer, not in front, to avoid reflected glare from shiny surfaces, like polished wood or glossy magazines.

— Use shades, blinds or curtains to minimize glare from windows.

8.5 Colour and contrast

8.5.1 Choice of colour

> This is important for ease of recognition and ease of seeing. Some colour combinations are also more effective. For example, some colours, such as red/green, are not distinguishable by a significant minority of the population (those with colour blindness).
>
> [ISO/IEC Guide 71:2001, 8.5.1]

Colour is used as a way of marking, distinguishing and drawing attention. The colour appearance of objects or light sources for older persons and for persons with visual impairments, including those with colour deficiencies and low vision, differs from normal colour appearance. Careful choice of colour or colour combinations for those persons increases accessibility.

Colour appearance also changes with luminance levels. At lower luminance levels, namely a few cd/m^2 or 10 lux, bluish colour looks relatively brighter and reddish colour on the contrary darker. Colour becomes more desaturated as luminance decreases. Care can be taken in choosing appropriate colours for use in low luminance. See Annex D.

Colour appearance also changes with age. A typical example of the change for older persons is that bluish colour looks darker due to the absorption of the short-wavelength (blue) component of light in the eye lens (yellowing of the eye lens). Letters coloured blue on a dark background are good examples difficult-to-see for older persons. White appears yellowish, also due to the yellowing of the eye lens, and this brings older people poor colour discrimination between white and yellow.

For the special use of colour for safety, a set of colours is defined in ISO 3864-1:2002.

The following accessibility considerations are relevant to the use of colours and colour combinations:

— Whenever colour is used to convey information, the information accompanied by other non-colour information such as figures or letters can increase accessibility. See 8.2.1.

— Use of too many colours can cause accessibility problems.

— When blue is used, higher luminance of the colour or higher illuminance than the moderate level can increase accessibility for older persons. See 9.2.1.1.

— The colour combinations of green/red and yellow/blue are used with significant luminance contrast for persons with colour deficiencies to avoid confusion of the colours.

— Persons with low vision have reduced discrimination and identification of colours. Care in the choice of colours can increase accessibility for those persons.

8.5.2 Colour combinations

> The best colour combinations depend on the purpose of information, whether it is for guidance or a hazard warning, and the lighting conditions under which it is most likely to be viewed. For example, black on yellow or light grey are general purpose combinations which provide strong definition without too much glare, pastel shades on pastel backgrounds or red lettering or symbols on light grey are difficult to see and should normally be avoided.
>
> [ISO/IEC Guide 71:2001, 8.5.2]

Colour combination is a useful tool for identifying and discriminating objects. Colour appearance changes with age, visual impairments, and luminance levels can be taken into account in creating colour combinations to increase visibility. See 8.5.1.

A conventional method of colour combination is to use opponent colours, such as red/green and yellow/blue. Some combinations of red and green, however, are difficult to discriminate by persons who have colour deficiency. Colour discrimination ability is reduced for people with low vision. Luminance contrast can help the discrimination of colours for those people.

Colours are perceived as a limited number of “similar-colour” groups, such as red, orange, yellow, green, etc. This is called categorical colour perception and is widely used in the application of colour and colour combinations. See 9.2.1.3.

The following accessibility considerations are relevant to the use of colour combinations.

— Large luminance contrast can greatly help persons with colour deficiency, as well as those with low vision, to discriminate colours.

— Colour combination by colours of different colour categories increases detectability. See 9.2.1.3.

Table 7 presents gives colour combinations that are recommended for signs and background in self-luminous displays [46].

Table 7 — Colour combinations for signs and backgrounds

Background colour	Sign colour							
	Black	**White**	**Purple**	**Blue**	**Cyan**	**Green**	**Yellow**	**Red**
Black		+	+	–	+	+	+	–
White	+		+	+	–	–	–	+
Purple	+	+		–	–	–	–	–
Blue	–	+	–		+	–	+	–
Cyan	+	–	–	+		–	–	–
Green	+	–	–	+	–		–	–
Yellow	+	–	+	+	–	–		–
Red	–	+	–	–	–	–	+	

\+ very suitable

– not suitable

NOTE The colour combination of black and purple in Table 7 usually does not appear well in high contrast of luminance due to the age-related sensitivity loss for blue and purple lights for older people. Purple can be used with higher luminance in this combination.

8.5.3 Colour coding of information

All information conveyed with colour should also be available without the perception of colour. Colour coding should not be used as the only means for conveying information, indicating a response or distinguishing a visual element.

[ISO/IEC Guide 71:2001, 8.5.3]

Coding of information by colour is a simple and useful way of making it easily perceivable, identifiable and distinguishable. Colours used for such purposes can be selected based on categorical colours as described in 8.5.2 and 9.2.1.3.

Under some viewing conditions, however, such as in low luminance, and for some persons with colour deficiencies, colours are difficult to discriminate. Accompanying the use of colours that are used for coding by other forms of coding (such as: textual, graphical, auditory and/or tactile information) increases accessibility for those with colour deficiencies and low vision. See 8.1.

Some colours have their special associated meanings. See 8.2.3 and 8.8.

8.5.4 Luminance contrast

Contrast of luminance is one of the most critical factors for visibility. The higher the contrast, the better the visibility. The sensitivity to contrast for fine images decreases with age due to optical scattering in the eye. The contrast sensitivity is much lower for persons with low vision due to various types of visual impairments. See 9.2.1.7.

Effective luminance for different colours changes with age and consequently the contrast of colours changes. See 8.5.1, 9.2.1.1 and Annex B.

The following accessibility considerations are relevant to the use of luminance contrast.

— High contrast is clearer in public signs or images and in characters of visual display terminals (VDT).

— Luminance contrast increases discrimination when colours are not well discriminated from each other.

— Extremely high contrast, such as black and white, can cause accessibility problems by generating glare for older persons and persons with low vision.

— Adjustable contrast can increase accessibility.

NOTE This factor has been newly introduced with this Technical Report.

8.6 Size and style of font and symbols in information, warnings and labelling of controls

> The required size of font for information, warnings and labelling of controls, relates to the probable viewing distance, level of illumination and colour contrast of the text against its background. The choice of font, whether with or without serif, in upright form or italics and light, medium or bold appearance also has a significant impact on legibility. Standards developers should also be aware that text written in CAPITAL letters is more difficult to read. This is significant for those with a visual impairment. Consideration should be given to specifying size and style of font and symbols for warnings.
>
> [ISO/IEC Guide 71:2001, 8.6]

8.6.1 General

With increasing age, the lens in the eye loses elasticity and the ability to focus clearly. The legibility of font and symbols is associated with the reader’s ability to visually discriminate one character from another, and is affected by the physical construction and properties of the font or symbol. Legibility is different from readability, which addresses the meaningful grouping of alphanumeric characters to form words or sentences. Readability is affected by grammar, writing style, or even the spacing between characters or sentences.

Persons with low vision tend to prefer light text on a darker background rather than darker text on a light background. See Figure 7.

Figure 7 — Examples of polarity

The following accessibility considerations are relevant to the use of style and size of fonts.

— The context in which the font is used can affect the combinations of sizes, styles and colours that can be used to improve accessibility.

— Appropriate font size and style for various presentation media, such as printed information and display screens, can increase accessibility.

NOTE Other International Standards provide additional guidelines for various situations (e.g. ISO 9241-303 for displays).

— Fonts in negative polarity can improve accessibility for persons with low vision.

For tactile characters, see 8.2.2.1. For graphical symbols see 8.8.

8.6.2 Font size

A reader's visual acuity is one of the critical parameters that affect the legibility of letters or symbols. The better the visual acuity he or she has, the smaller the legible font size he/she can see. Viewing contexts affect visual acuity. Visual acuity is a function of luminance and viewing distance. The acuity becomes worse as the luminance decreases. The acuity in near viewing distance (less than about 1 m) becomes worse with ageing. See 9.2.1.2.

The following accessibility considerations are relevant to font size.

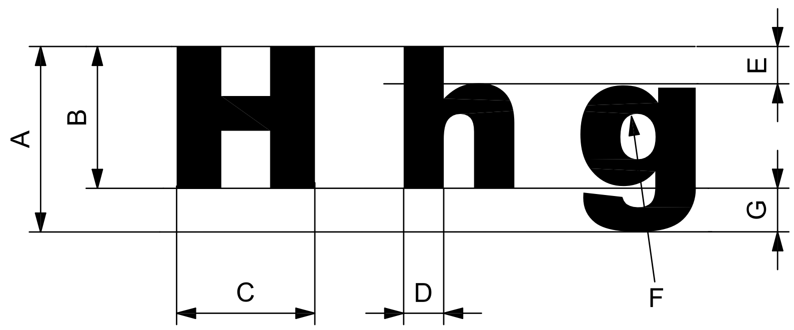
— A larger font size can improve accessibility under low luminance conditions.

— A larger font size can improve accessibility for older persons at near viewing distances.

NOTE "Luminance" here means the luminance of the background (brighter part) when positive picture polarity is used, or luminance of the letter (brighter part) when negative picture polarity is used.

8.6.3 Font style

Font style is also a factor affecting legibility. Figure 8 shows the characteristics concerning font style.



Key

A body height
B font height
C font (body) width
D stroke width
E ascender
F counterform
G descender

Figure 8 — Font characteristics

The following font design characteristics can improve accessibility for older persons and persons with low vision:

— consistent stroke widths;

— open counterforms (the open space in letters like “e” and “a”);

— clearly visible ascenders and descenders (such as tails on the lower case letters “b” and “j”);

— wider horizontal proportions;

— extended horizontal strokes for certain letterforms (such as the arm of the lower case “r” or the crossbar of the lower case letter “t”).

The fonts used in Figure 9 highlight the differences between several styles.

a) Poor legibility **b) Good legibility**

Figure 9 — Font style comparison

Figure 9 b), “Good Legibility”, uses a font created by the American Printing House for the Blind that is well suited for users with low vision. Other specially created fonts may also be investigated by standards developers.

For older persons, there is some evidence that serif fonts assist reading speed, while sans-serif fonts are actually preferred subjectively. With high resolution displays or printed hardcopy, it is preferable to focus on overall font design, and ensure that serifs, if present, do not negatively affect legibility. However, as Figure 10 shows, when the output resolution (either on paper or screen) is low, a sans-serif font can increase accessibility because there will not be enough dots or pixels to render the serifs clearly.

a) Serif font **b) Sans-serif fonts**

Key

A serif

Figure 10 — Serif and sans-serif fonts on low-resolution 5 × 7 dot-matrix display

The following are further accessibility considerations for font styles [46].

- Bold letters generally have better visibility than plain ones provided that the line width is not too great.
- The ascenders of lower case characters project above the type height by approximately 20 %.
- Lower case characters with descenders project below the line of text by approximately 20 %.
- Characters are designed to avoid confusion, e.g. between the number zero “0” and the letter “O”, between upper case “i” (“I”) and lower case “L”(“l”).

Font style is not only an issue for visual abilities, but guidance on font styles also exists in relation to the needs of persons with dyslexia. At the most basic level, the sans-serif fonts should be avoided, although a more complex recommendation is to enable the reader to choose his or her own font, as situations do vary between persons with dyslexia.

8.6.4 Special consideration for fonts used in display screens

Visual appearance of self-luminous screen displays is different from reflected images used in printed information (hardcopy documents, books), and the difference affects accessibility of display design. In particular, the appearance of contrast and colour in self-luminous displays differs from that of reflected images, even if the physical characteristics of the light are the same.

Contrast values for a certain range can increase accessibility of screens. See 8.5.4 and 9.2.1.6.

8.7 Clear language in written or spoken information

8.7.1 Information available as text

> Information should be made available in text format wherever possible, in addition to other forms, to facilitate recognition and translation into speech and other languages for those who have trouble seeing, recognizing or deciphering non-text information presentations.
>
> [ISO/IEC Guide 71:2001, 8.7.1]

Products comply with IEC 62079:2001 if the instructions are prepared in the languages of the country in which the product is to be marketed (see References [34] and [60]).

The following accessibility considerations are relevant to user instructions.

- All essential information can be presented in alternative formats so that it can be perceived and recognized unambiguously. Specialists are consulted when preparing user instructions in Braille or Braille shorthand. For essential information, the use of graphics and graphic elements can be supplemented by explanations in text (see 8.2.7), which also allow the preparation of audio user instructions.
- The user instructions can be structured both visually and logically.
- Audio user instructions (cassette, CD, MP3, Daisy Book, etc.) are usually preferable to a version in Braille. A point in their favour is that an audio version is also accessible to blind persons who are not familiar with Braille. At least with complex products such as telephone systems, a short instruction manual in Braille is preferable.
- Electronic user instructions (such as those on the Internet or on data media supplied with the product) can be prepared in an accessible format, e.g. HTML format according to the guidelines of the Web Accessibility Initiative (WAI) of the World Wide Web Consortium or accessible PDF. Accessible formats can be used in preference to graphical formats (e.g. PS, GIF and JPEG) or offered as an alternative.

8.7.2 Complexity of information

> Instructions or operations which are too complex will often deter older persons and persons with limited intellect from using a product or device. Simple written or spoken messages are also clearer to understand by someone with a visual or hearing impairment.
>
> [ISO/IEC Guide 71:2001, 8.7.2]

Effective communication is promoted by using clear and simple language. Persons with cognitive or learning impairment often have difficulties accessing written information. Using clear and simple language is also useful for persons with a different native language, including those who communicate primarily in sign language.

Keeping document layout consistent, designing apparent graphics and using easily understandable language benefits a wide range of users, especially persons with cognitive impairment and those who have difficulty reading.

The following accessibility considerations are relevant to communication with persons with cognitive impairment or learning disabilities and for those who have difficulty reading.

- Use the clearest sentences and simplest words appropriate for the content of the document.
- Supplement text with graphic or auditory presentations where they will facilitate comprehension of the document.
- Create a style of presentation that is consistent across the document.

8.7.3 Printed instructions

> These should use short sentences of simple, straightforward and non-technical language and may include simple illustrations.
>
> [ISO/IEC Guide 71:2001, 8.7.3]

No additional guidance is offered.

8.7.4 Spoken information

> Rules for spoken information are similar to those for printed information. The context should always be given to ensure that information is meaningful and instructions should be provided in a logical order. Key points should be reinforced by repetition. People with hearing loss are at an increased risk or disadvantage if spoken announcements are not loud enough, or if the pitch is too high or too low.
>
> [ISO/IEC Guide 71:2001, 8.7.4]

8.7.4.1 Sound level of spoken announcements

The sound level of announcements, or voice instructions, has a large influence on the comprehension of spoken information. Announcements are required to be comfortably loud for listeners; announcements that are too soft or too loud may not be fully understood. Spoken announcements sound comfortably loud when the listener can recognize them nearly 100 % without any special effort.

The comfortable sound level for announcements depends on the environment in which they are presented. In quiet environments, the absolute level of announcements is a key factor. Persons with age-related hearing loss prefer louder speech. However, the amount of increment required is not very large: a few decibels on average.

In noisy environments, the difference between the level of an announcement and that of the background noise determines the intelligibility of the announcement. When the noise level is low, the effect of noise is usually negligible. When the noise level is high, a constant signal-to-noise ratio is required to attain comfortable listening. Control systems that adjust sound level automatically are available to keep a certain signal-to-noise ratio, and are sometimes used for spoken announcements in public spaces as well as for acoustic traffic signals. When the noise level is even higher, people tend to have difficulty in speech communication. Provision of necessary information in an alternative form of instruction can increase accessibility. For more detailed descriptions of preferred speech levels in noisy conditions, see 9.2.2.3.

Some persons with severe hearing loss prefer an even higher speech level, depending on their hearing profile.

8.7.4.2 Cognitive aspects of voice instruction

Voice instructions are widely used, not only as an alternative format for visually impaired people but also for general information for all people in private as well as public spaces.

Cognitive aspects of auditory processing decline with age. Older people have more difficulty than younger ones in ignoring irrelevant information from one source when processing relevant information from another. They also require more time to switch their processing from one source of auditory input to another. Older people also have greater difficulty in perceiving auditory information via synthetic speech. They also learn new tasks and respond to instructions more slowly. For some persons who have faster processing ability, a slower speed of voice instruction does not necessarily improve their performance. If a task requires that older people simultaneously process or manipulate information, as well as remember it, performance also declines.

Many of the cognitive deficits that accompany increasing age are also seen in younger persons with cognitive disabilities.

The following is relevant to the accessibility of systems and products providing voice instructions.

— Minimize background noise and reverberation when recording voice instructions, and provide the user with the capability to adjust the volume of the presented instructions, where feasible.

— Consider using male voices for instructions, as these voices are sometimes better understood by users with high-frequency hearing impairments. This is especially desirable for voice instructions transmitted over telephone lines. However, there are other considerations relevant to determining the gender of a voice used for instructions (e.g. cultural issues), which can make the use of a female voice preferable.

— Because voice is a serial transient medium, design instructions that are simple to understand and minimize the number of responses a user has to make to a single instruction.

— Minimize requirements on short-term memory. See 9.4.3.

— To address slower processing speeds due to ageing or certain cognitive impairments, use repetitive voice instructions or descriptive information for some users. Provide systems that employ voice prompts or instructions with the capability of replaying instructions on request.

— Consider using a speech rate of approximately 140 words/min for voice instructions, and lengthen pauses between sentences (beyond that of normal speech) to allow more time for processing information. It is advisable to test the product or system with the intended users in order to determine the speech rate and pause length that yield the best performance and highest level of user acceptance.

— Provide users with sufficient time to respond to voice instructions. Older people need at least one and a half times as long to respond verbally to voice instructions, compared with younger ones. They often need considerably more time if a manual response is required (e.g. inputting a number via keypad) instead of, or in addition to, the vocal response. Thus, application response time allowances need to be determined through evaluation that includes older people and persons with physical, cognitive and sensory impairment, if they are members of the intended user group.

— If instructions are to be given in a public setting, consider providing wireless headsets for the benefit of older users, if appropriate to the task situation.

8.7.4.3 Voice warnings or alerts

Voice warnings and alerts differ somewhat from general voice instructions, in that attracting the attention of the user is a priority. Data suggest that female voices have a greater attention-getting ability than male voices. However, recommendations concerning the use of male vs. female voices are sometimes culture-dependent; for example, male voices are used in fire-alarm systems in Japan.

The appropriate sound pressure level and frequencies for warnings and alerts all differ generally somewhat from voice instructions. See 8.7.4.2.

8.7.4.4 Speech communication in noisy environment

A spoken announcement is understandable when the signal-to-noise ratio is above a certain level. It is comfortably audible for listeners when the signal-to-noise ratio is above a certain threshold (higher than that required for complete understanding).

The boundary of signal-to-noise ratio, both for understanding and comfortable listening, can be determined for young and older listeners. See Figure 43 and ISO 9921.

8.7.4.5 Speaking rate

The speaking rate is defined as the number of speech items uttered in a unit time period. The rate is expressed, for example, as the number of words per minute or the number of syllables per second. A normal rate is, for example, 140 to 170 words/min in English or 8 to 9 mora/s in Japanese. See 8.7.4.2 and 8.10.2.1.

NOTE *Mora* is a unit of sound related to pronunciation, while *syllable* is a unit of sound consisting of a vowel or of a vowel and a consonant or consonants.

8.7.5 Multiple languages

> Where instructions are to be provided in more than one language, written information in each language should be presented in separate sections of a manual rather than interleaved on a page; spoken information should be preceded by a clear statement in the language to be used.
>
> [ISO/IEC Guide 71:2001, 8.7.5]

Identification of the language used in a document and the meaning of abbreviations and acronyms is essential. This will improve the readability of the information for all persons.

If instructions are required in more than one language, the instructions for each language can be kept separate and not mixed. Spatial separation of the printed instructions in each language, if printed in the same document, or use of a separate document for the instructions for each language, facilitate accessibility. Identification of the language in the application content also facilitates accessibility.

EXAMPLE "Fine" in English and "fine" in Italian have different meanings, although their spellings are the same. If the language is not identified, they cannot possibly be distinguished.

In the case of abbreviations and acronyms, someone unfamiliar with a particular abbreviation or acronym will not understand what it means. An explanation of each abbreviation or acronym where it first appears in the text facilitates accessibility.

NOTE *Language* means spoken, written, or signed languages such as French, Japanese, American Sign Language and Braille.

8.7.6 Other factors

8.7.6.1 Document navigation mechanisms

Clear and consistent navigation mechanisms increase the likelihood that people will find what they are looking for in a document and improve readability for all people.

Provision of information about the document layout (e.g. a table of contents for documents or a site map of a Web site) can increase accessibility.

NOTE This factor has been newly introduced with this Technical Report.

8.7.6.2 Language support

Persons who have difficulty in reading, writing or speaking often also have difficulty in using products and services safely and effectively.

The following accessibility considerations are relevant to language support.

— For users who have difficulty reading or who are illiterate:

  1) consider using speech displays for instructions and prompting of actions, as well as the use of multi-media instructional material, including video instructions;

  2) consider the use of task-relevant graphics (e.g. illustrations or photographs) as a supplement or a substitute for text instructions.

— For users who have difficulty writing or typing, minimize the amount of writing or typing required, and consider substituting speech recognition as an input mechanism.

— Provide equivalent alternatives to speech input (e.g. use of keyboard) for users who have difficulty speaking or cannot speak.

— Provide multi-language user interfaces, if appropriate.

— Use simple, unambiguous and easy-to-understand language.

— Avoid difficult terms, complex grammatical structures and long sentences.

— Avoid use of the passive tense.

NOTE This factor has been newly introduced with this Technical Report.

8.8 Graphical symbols and illustration

> The use of meaningful graphical symbols or illustrations, in addition to text, should be considered in instructions and also on a product, for ease of assembly or use. For example the same symbol should be used on the respective ends of parts to be joined, when assembling a product, or in the labels on controls.
>
> [ISO/IEC Guide 71:2001, 8.8]

Graphical symbols as well as pictorial illustrations constitute useful tools that allow people to identify objects, convey meaning and communicate. The use of these symbols and illustrations in addition to text helps people understand the content of the text. International Standards on graphical symbols include ISO 7000, ISO 7001, ISO 7010, ISO 9186 and ISO/IEC TR 19766:2007, as well as References [61] and [62]).

The following are accessibility considerations relevant to the design and use of graphical symbols and illustrations.

— The same design principles and basic forms, as well as combinations of them, facilitate the understanding of the symbols.

— Special colours or forms are assigned to special attributes of objects, such as safety. For colour coding see ISO 3864-1.

— Some colours have their own special meanings that depend on the culture concerned.

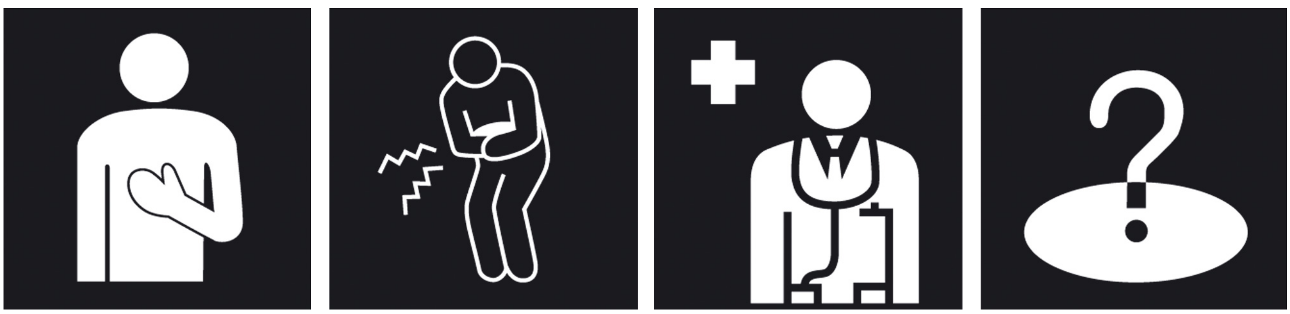
— Graphical symbols and illustrations in the standards cited above can be used.

— For tactile symbols see also 8.2.2.1.

For examples, see Figure 11, taken from ISO 7010 and ISO 7001, and Figure 12 [62].

Telephone | Fire extinguisher | Non-potable water

Figure 11 — Examples of graphical symbols



"I have a stomach-ache. Where is a doctor?"

NOTE ISO 7010:2003/Amd.1:2006 uses a symbol for a doctor different from the one used in Figure 12. See Figure 13.

Figure 12 — Example of communication using graphical symbols

Figure 13 — Doctor symbol as used in ISO 7010:2003/Amd.1:2006

8.9 Loudness and pitch of non-spoken communication

People with a hearing loss are at increased risk or are disadvantaged if warnings are not loud enough, or if the pitch is too high or too low. Where possible, volume should be adjustable over a wide range. Information should also be presented in multiple frequencies where possible (e.g. an alarm sign signal could consist of a strong component at multiple frequencies). Sudden changes in volume should also be avoided. [ISO/IEC Guide 71:2001, 8.9]

Sensitivity to higher-frequency sounds decreases with age. This is a key factor when determining a range of sound pressures and frequencies for auditory signals that are to be heard in a quiet environment. See 9.2.2.1 and 9.2.2.2.

When an auditory signal is used in a noisy environment, the sound pressure level difference between the signals and interfering noises becomes critical; a signal level higher by a certain amount than that of the noise can increase accessibility. Comfortable levels of auditory signals in quiet and noisy conditions, taking into account ageing effects, have been determined experimentally. See 9.2.2.2.

For alarms in work and public areas, a sound at an even much higher level is sometimes required to assure audibility. For details on the use of sound in warnings and danger signals, see ISO 7731.

8.10 Slow pace of information presentation

Announcements spoken at a slow measured pace allow listeners to pick out the message; pauses between instructions give time to understand and act on the information. If a message is delivered too rapidly, it is difficult to assimilate by someone with a hearing or vision impairment, or learning disability. Consideration should be given to the length of time information remains in view when presented on moving displays, or when information is temporarily displayed and then removed. [ISO/IEC Guide 71:2001, 8.10]

8.10.1 Operation not depending on user's memory

Persons with cognitive impairment and older persons tend to forget recently presented information or recently executed actions because of declines in short-term and working memory. Thus, minimizing the degree to which systems and products require memory of prior actions or operations facilitates accessibility. There is a variety of ways in which this can be accomplished, including the following:

— automated customer service applications over the phone can allow callers to pause or repeat messages;

— applications with visual displays can show a list of the most recent user actions or allow information that is referred to later to persist on the display;

— the appropriate pace of information presentation in electric marquee displays can facilitate comprehension of the users.

8.10.2 User control of time-sensitive content changes

8.10.2.1 Control of auditory information presentation

The following accessibility considerations are relevant to auditory information presentation, including prerecorded speech and synthetic speech.

— The comfortable speaking rate for broadcasting to older listeners is 6 to 7,2 mora/s. In contrast, the typical speaking rate in Japanese broadcasting is approximately 8 mora/s. Many blind persons prefer a faster speech rate, e.g. approximately two to four times the rate of normal speech. Adjustable speech rates covering the wide range of individual differences in preferred speech rate increases accessibility.

— Comprehension can be facilitated by lengthening the pauses between sentences, instead of or in addition to decreasing the rate of speech itself.

8.10.2.2 Control of visual information presentation

Some persons with cognitive or visual impairment are unable to read moving text quickly enough, if at all. Unnecessary movement of display content (e.g. non-task-relevant animation) distracts the user from task-relevant information and interferes with the task performance, particularly in the case of older users and those with cognitive impairment. In addition, assistive technology relies on a certain amount of stability of displayed content.

The following accessibility considerations are relevant to visual information presentation with respect to user control of time-sensitive visual content.

— Avoid causing the screen to flicker. See 8.2.6.

— Avoid causing the content to blink, or else allow users to control blinking. See 8.2.6.

— Allow users to freeze or slow moving content, and avoid unnecessary movement of the content of visual displays.

— Provide the capability to interrupt changes in displayed information until the current information is dealt with.

— Provide the ability to control the rate of speech, if speech output is included in an application or product. See 8.7.4.5 and 8.10.2.1.

8.10.3 Time-constrained task design

Older persons and persons with cognitive impairments often cannot complete tasks or respond to stimuli in a specified or limited amount of time. If systems place limits on the time required for responses, the option to request additional time can increase accessibility for users to complete tasks. In those cases where time limits are set, such limits can be determined through evaluation of the expected user group.

EXAMPLE In telephone-based applications, a user is often required to respond to a voice prompt within a set amount of time (e.g. 2,5 s), after which he/she is presented with an error message due to a partial response or no response at all. Such applications can instead be designed to ensure that there is a time limit imposed on responses.

The following is relevant to time-constrained task design accessibility.

— Accommodate the slowest user.

— Prompt users to request additional time if it appears more time is required.

— Provide a wait message if users are faster than the systems. The wait message presented by means of at least two senses increases accessibility. See 8.2.

— Allow users to interrupt (i.e. pause) the presentation of a long voice message or instruction. If pause functionality is provided, it is helpful if the user can continue presentation of the message from the point at which the pause occurred with a single action or command (e.g. “Resume” function). See 8.7.4.2.

8.11 Distinctive form of product, control or packaging

8.11.1 Identification by form

A distinctive form can make it easier for those with visual impairment and reduced touch sensitivity to identify a product, to interpret the parts of a product to be joined during assembly and to distinguish between different controls. A familiar form can also aid those with impaired cognitive ability.

[ISO/IEC Guide 71:2001, 8.11.1]

Considerations on properties of tactile sensitivity (i.e. spatial resolution, form recognition, etc.) in designing distinctive forms increase accessibility of product, control or packaging.

EXAMPLE Coins of almost all countries have differing sizes, shapes and tactile grooves differentiating specific monetary values.

8.11.2 Orientation of product or control

Where possible, the form of the product or control should also indicate the orientation of the product or control, so the top or bottom, front or back, can be easily located by someone with a visual impairment.

[ISO/IEC Guide 71:2001, 8.11.2]

Tactile marking is a useful tool to indicate the orientation of the product or control. See 8.2.2.1. The location of tactile marking critically affects accessibility and similar positioning and spacing of markings facilitate accessibility.

EXAMPLE A prepaid card has a notch near the bottom-right corner so that users can know the correct direction for inserting the card into the machine. See 8.2.2.1 and Reference [63].

8.11.3 Tactile warnings

The use of universally recognized tactile warnings on the container or packaging enables identification of toxic or corrosive materials. Similarly, tactile warnings are normally required in buildings, such as at stair openings, on steps, on platforms and at dangerous storage areas.

[ISO/IEC Guide 71:2001, 8.11.3]

Tactile information of a common meaning is useful for identifying and avoiding a particular product containing toxic or corrosive materials. This can be used for indicating danger to visually impaired persons.

EXAMPLE A tactile triangle or a three-pointed symbol is used to indicate dangerous contents of containers. It is placed on the handling surface such that users will notice it immediately when they hold a container. See ISO 11683.

8.12 Ease of handling

8.12.1 Size, shape and mass

> These characteristics of a product will affect how easy it is to lift, hold and carry. Lifting and carrying is eased if articles are shaped to facilitate easy grasping, with either or both hands. Light, compact articles are generally preferable thus the density of manufacturing materials needs consideration. Provided safety is not compromised wherever possible, products should be capable of operation by only one hand, preferably either hand.
>
> [ISO/IEC Guide 71:2001, 8.12.1]

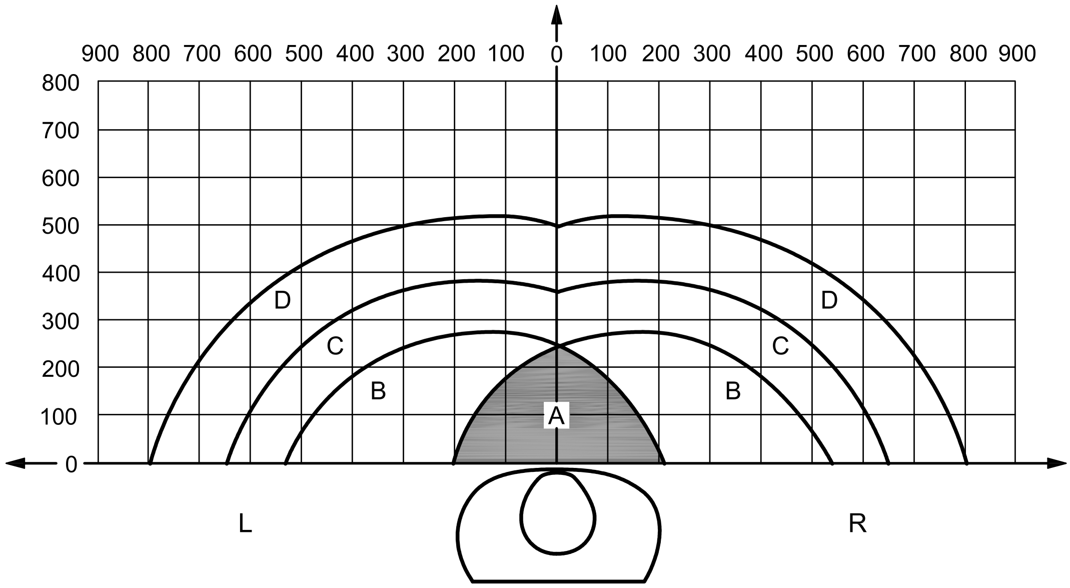
Products of appropriate size, shape and mass that meet the needs of the target user population and the task facilitate accessibility. For example, users drop objects they are required to whose weight exceeds their strength or gripping ability. The aspects of handling which require particular attention to ensure ease of use by a greater number of older persons or persons with disabilities are summarized in Table 8.

Table 8 — Aspects of handling for ease of use

Aspect	**Influence of the aspect in a product or service**	**Example**	**Additional data**
Strength required	For a product to be handled easily with one or both hands, avoid excessive load of the skeletal muscle of upper limbs (i.e. muscles that contribute to forward elevation of upper limbs or holding of products, and so on). The muscular strength of the skeletal muscle is greatest in youth and middle age.	The strength does not exceed 30 % of the physical strength of a 5th percentile woman [46].	See 9.3.4
Posture	Some users have difficulty kneeling or squatting. Some users are limited to a seated position or are unable to bend joints.	Ensure products/services can be used while seated.	—
Reach and grasping area	Users have a limited region to comfortably reach and grasp objects.	An example of the grasping area is shown in Figure 14 [46].	See 9.3.2 & 9.3.2.1
Safety	Users can be injured if required to reach over unsafe areas, such as hot surfaces, or if handling unexpectedly sharp objects.	—	—
Angle of rotation of the joints	Some users have difficulty rotating their wrist or arms through large angles.	—	See 9.3.2.3
Frequency of actions	Strain on a joint can result from repeated actions, particularly where force is excessive.	—	—
Movement speed	Some users have difficulty moving quickly.	—	See 9.3.3
Precision required from movements	Some users have coordination difficulties or tremor, making simple actions like inserting a key more difficult.	—	—
One-hand use	Some users have only one functioning hand. Products can be designed for one-handed use of either the left or right hand.	—	—

EXAMPLE Grasping area for right and left hands [46]. See Figure 14.

Dimensions in millimetres



Key

A optimum grasping area for both hands (envelope curve)

B optimum grasping area (envelope curve)

C functional grasping area (envelope curve)

D extended grasping area (envelope curve)

L left hand

R right hand

NOTE These envelope curves are related to the body size of the 5th percentile of women grasping with three fingers at a work surface height of 750 mm [46].

Figure 14 — Grasping areas

8.12.2 Instruction manuals and location of markings

> The size, number of pages and weight of paper used in an instruction manual can affect the ease with which it is held and pages are turned, which will influence the extent it is used.
>
> [ISO/IEC Guide 71:2001,8.12.2]

The following accessibility considerations are relevant to the use of instruction manuals for products.

— User instructions that contain information about placement, configuration or attachment of the product ensure accessibility. This also applies to products that require installation, if the installation of the product is not restricted exclusively to a qualified fitter.

— User instructions that are restricted to the type and design of one product can increase accessibility.

— The binding of printed instruction manuals such that pages remain open easily (e.g. spiral binding) can increase accessibility.

— Instruction manuals printed across the fold of paper can cause accessibility problems.

— Accessibility of audio user instructions is increased with a structure using suitable means such as acoustic signals or tracks (CD, audio cassette, Daisy Books) enabling a desired chapter to be found more easily. For tapes, acoustic signals can be indicated by means of low-frequency signals that can only be heard during fast-forward or fast-rewind.

8.12.3 Controls

8.12.3.1 Handling

> The force required to twist, turn, push or pull controls or fastenings is significant for people with various impairments. Operating controls should allow comfortable grip, avoid twisting of the wrist, avoid the need for simultaneous actions and offer minimal resistance. Textured surfaces, to increase friction, assist the application of force. Provision of alternative controls offering greater leverage or power-assistance should be considered. Reprogrammable operation and personal preferred settings can be effective, particularly for people with cognitive impairment.
>
> [SO/IEC Guide 71:2001, 8.12.3.1]

The following accessibility considerations are relevant to operating controls.

— Easy to reach controls increase accessibility. See 8.12.1 and 9.3.2.1.

— The force transfer can be supported by an appropriate mechanical design for handling.

  EXAMPLE 1 It is easier to grab and move a knob or a hand grip if it fits into the hand.

  EXAMPLE 2 Non-slippery surfaces can be used when friction force is utilized.

— Combined adjustment movements (such as simultaneously pressing and turning) cause accessibility problems.

  However, for safety reasons some combined movements (such as child-resistant containers) may be used. See 6.2 for accessibility and safety issues.

— The absence of time constraints imposed on the operation of controls can increase accessibility. See 8.10.3.

— The relationship between travel, adjustment duration and feedback (reaction time and reaction speed) that meet the expectations of the user group can increase accessibility.

— Feedback directed towards at least two senses is more effective for a wider range of people. See 8.2.

— Provision of tactile feedback to the users of controls with a key drop (no touch key) and a pressure point can increase accessibility.

— The assembly and disassembly of products (for example a kitchen aid) can be facilitated by appropriate design.

— Foot operation replaced with another form such as voice operation can increase accessibility.

— An alternative to two-handed operation can increase accessibility for persons who have only one functioning hand.

  EXAMPLE 3 Design of controls in accordance with Table 9 for dimensions and with Table 10 for adjustment [64].

Table 9 — Dimensions of manual controls [64]

Millimetres

Method of grip	Part of the hand applying force	Width or diameter of manual control	Length of manual control along the axis of movement or axis of rotation
Contact grip	Finger	⩾ 7	⩾ 7
	Thumb	⩾ 20	⩾ 20
	Hand (flat)	⩾ 40	⩾ 40
Pinch grip	Fingers, thumb	⩾ 7 to ⩽ 80	⩾ 7 to ⩽ 80
	Hand, thumb	⩾ 15 to ⩽ 60	⩾ 60 to ⩽ 100
Clench	Finger, hand	⩾ 15 to ⩽ 35	⩾ 100
NOTE Details of the different types of grip including explanations and figures can be found in ISO 9355-3. See 9.3.4.2.			

Table 10 — Classification of force/torque for manual controls [64]

Force/torque for female	Class
< 7 N	Negligible
< 0,33 N·m	
7 N to < 17 N	Low
0,33 N·m to < 1,0 N·m	
17 N to < 33 N	Low to average
1,0 N·m to < 2,0 N·m	
NOTE The data given in Table 10 are standard ergonomic values and maximum for accessible design. To address the needs of persons with less force, the values for a small female can be a good approach for ensuring accessibility.	

8.12.3.2 Spacing

Controls should be spaced to avoid interference when another one is being operated.

[ISO/IEC Guide 71:2001, 8.12.3.2]

Tactile markings can be used in conjunction with controls to avoid interference for persons with visual disabilities. The placement of the controls, however, can take into account the potential for control interference on the use of tactile markings. See 8.2.2.1. This issue also relates to the dexterity of the user and design for enhancing dexterity. See 9.3.1.

8.12.3.3 Status

Multisensory feedback should be provided on the status of controls.

[ISO/IEC Guide 71:2001, 8.12.3.3]

The status of the controls and of the condition of the operation of the total system is required to be clearly recognisable by the user in due time. Thus, provision of status information via two senses is important. For example, tactile or auditory information can be used as well as visual information.

8.12.4 Containers and packaging

Containers should allow easy opening and closing by adopting appropriate shapes, sizes and surface finish. Packaging, such as some food wrappings which are difficult to open can result in injuries as users resort to sharp knives or other gadgets to attempt opening. Operating forces should be as low as reasonably attainable, compatible with security of contents.

[ISO/IEC Guide 71:2001, 8.12.4]

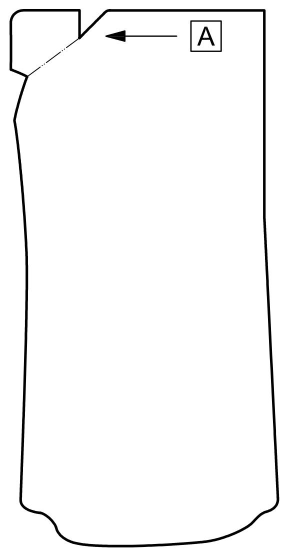
The design of containers can facilitate opening and closing by use of appropriate shapes, sizes and surface finishes. Particular attention can be given to the needs of older persons, whose grasping power is often weakened.

Where the manufacturer intends the packaging (both disposable and re-usable packaging) to be used by the consumer, opening and closing, if necessary, by one hand can increase accessibility. See 8.12.1.

There is a trade-off to be made between the requirement for child safety and the need for ease of opening (e.g. pill bottles). For child safety, see ISO/IEC Guide 50.

The following accessibility considerations are relevant to ease of opening.

— In a soft plastic container, a notch in the shape of a wedge can be provided to help the user to tear off a corner. See Figure 15 [45].



Key

A able to be opened by hand

Figure 15 — Example of soft plastic container openable without tools

— Containers sealed with soft packaging material can provide a tongue with a large area to grip. See Figure 16 [46].

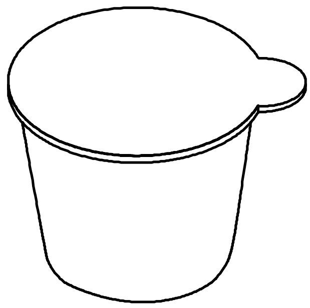


Figure 16 — Example of container with tongue for gripping

— For screw-top containers, texturing or knurling can be formed on the cap to enable it to be unsealed even by wet hands. See Figure 17.

Figure 17 — Example of screw-top container with longitudinal groove

— Unlike bottle caps, a swing-stopper or a flip-top closure on bottles can be opened using one hand. See Figure 18.

Figure 18 — Example of bottle designed for easy opening

The following accessibility considerations are relevant to the design of the shape of containers so that they can be used easily, even by users with weakened grasping power.

— An appropriate shape for the entire weight and size of the container and its contents can prevent it slipping when held.

— The provision of ridges in a rugged or spiral state so that the fingers of the hand can firmly grasp the surface of the container can increase accessibility. See Figure 17.

— Devices and products that are designed to be opened can follow the requirements and recommendations for accessible products — except, of course, for safety caps. In principle the requirements of 8.12.3 are applicable.

8.12.5 Duration of actions

Products should not need a long handling time and unnecessary repetition of operations should be avoided.

[ISO/IEC Guide 71:2001, 8.12.5]

For operation using auditory and visual information, see 8.10.2.

8.12.6 Timed responses

> Whenever possible, users should be able to control any limits on the amount of time available to them to read or respond.
>
> [ISO/IEC Guide 71:2001, 8.12.6]

Typical in the application of timed responses are elevator doors that open for a sufficient amount of time to allow persons using a wheelchair to enter or exit. For example, a 10 s duration has been adopted by the Japanese Elevator Association as its *de facto* standard value [65]. The EC standard requires a duration up to 20 s, configured depending on the type of use [66].

For timed responses in applications operated via speech or touch-tone input over the telephone, see 8.10.3.

8.12.7 Elements in buildings and the built environment

> Elements and parts of buildings such as windows, doors, bathroom-elements, lifts/elevators, lobbies, intercom systems, etc., should be accessible and easy to handle. This concerns the application of force, positioning, logical structure and having enough space to move around when using assistive devices.
>
> The same applies to the built environment (for example, street furniture, pedestrian crossings, and parking meters) and handling in public transport (doors, ticket machines, etc.).
>
> These aspects are particularly valuable for those with impairments in seeing, balance, dexterity, manipulation, movement, strength and cognition. See also 8.3 and 8.16.
>
> [ISO/IEC Guide 71:2001, 8.12.7]

8.12.7.1 General consideration

Elements of the built environment are used by persons with a wide range of impairments, including residents, visitors, spectators, customers, employees, or participants in sports events, performances and conferences. Management and maintenance can affect safe access to, and use of, facilities by persons with disabilities.

A built environment designed to anticipate and overcome restrictions preventing disabled persons from making full use of premises and their surroundings increases accessibility. An accessible environment is one that a disabled person can enter and make use of independently or, if necessary, with the assistance of another person. New facilities can be designed to increase accessibility for persons with disabilities. In existing buildings, additional features such as handrails, tactile signs and hearing enhancement systems enhance accessibility. In principle, the descriptions of 8.12.1 and 8.12.3 apply.

The following basic concepts and considerations increase accessibility to elements in buildings and the built environment.

— The body size and stature of a person can determine the spatial dimension and proportion of constructional facilities and their equipment.

— The planning and location of features of buildings that take account of variations in the height of a person’s eye and consequently his or her field of view increase ease of orientation.

— The area of movement can be determined not only by body size but also by assistive technologies such as walking frames, walking sticks and wheelchairs. Wheelchair users need the most space to move, particularly when turning. That is why the necessary areas of movement for wheelchair users can be the basis for the measurement of areas of movement (e.g. traffic areas, corridor widths) in accessible facilities.

— The reaching area can be determined by body stature (size, width) and the person's mobility, and thereby defines the accessibility of service elements. The reach of persons with walking aids or persons in wheelchairs is very heavily dependent on their individual skill in moving the upper body.

— Visibility and other operational elements can be considered as well as reaching.

The following dimensions for elements in buildings are taken from existing standards and guidelines [67], [68].

— For a wheelchair user with an upper-body impairment, the area between 400 mm and 1 050 mm above the upper edge of the finished floor is reachable by hand. The lateral reaching area is up to 250 mm from the wheelchair's outer edge. See 8.12.1.

— With respect to the lateral reaching area of wheelchair users, controls need 500 mm clearance from adjacent walls and/or constructional facilities to allow for the dimensions of a wheelchair.

— The recommended height for controls is 850 mm. The fingertips of standing adults lie between 730 mm and 750 mm. Adults can thus always reach controls installed at the recommended height. Persons with mobility impairment can reach controls at this height without lifting their walking aids. Also, wheelchair users with an upper-body impairment can directly — with the arm still partly resting on the arm rest — grip a control positioned at a height of 850 mm.

— The height of doors and passages can be determined by the body size of the people who use them.

EXAMPLE 1 The minimum height of doors is 2 000 mm [71].

— The width of doors and passages can be determinated by the needs of wheelchair users. See 8.12.7.2.

EXAMPLE 2 The minimum width of doors is 900 mm. Due to construction problems in special cases like high-speed trains, a door width of 800 mm can be acceptable [69].

8.12.7.2 Clear floor or ground space

The following accessibility considerations are relevant to the maximum dimensions for clearance of a manually driven wheelchair (overall length 1 200 mm; width 700 mm in ISO 7193).

— The width is increased approximately 50 mm to 100 mm on each side for the elbows of the user. That means that the optimum width overall for wheelchair and elbows on both sides is 900 mm.

— Approximately 50 mm to 100 mm is added to the wheelchair length with respect to the user's protruding feet.

EXAMPLE The width overall for wheelchair and elbows on both sides is 900 mm (optimum) [70], [71].

8.12.7.3 Manoeuvring clearance

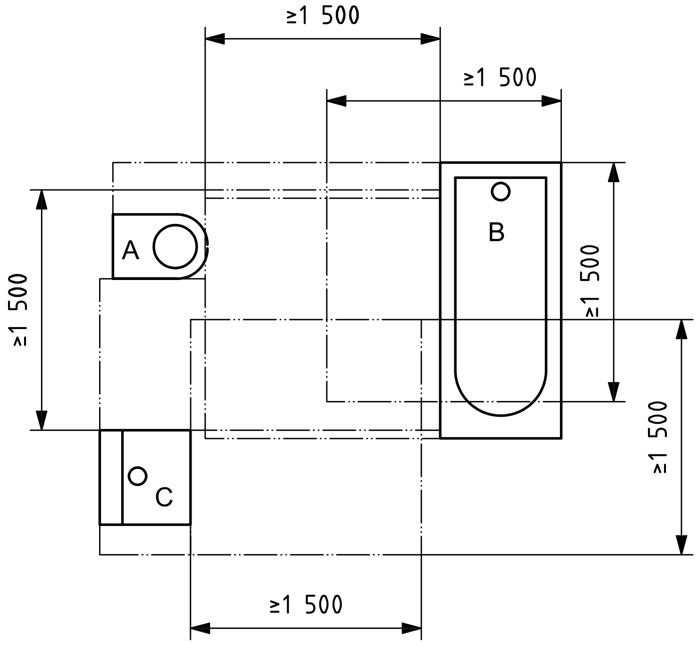
Buildings and other constructional facilities can be arranged to fulfil the fundamental geometric requirements of all persons with regard to areas of movement, areas of approach, movement spaces, height of handles and the ability to drive under objects.

The following accessibility considerations and measurements (given as minimum values) are relevant to manoeuvring clearances.

— Areas of movement and movement spaces restricted by obstacles can cause accessibility problems.

— The areas of movement in the same room, for example for toilets and hand-wash basins, may overlap. See Figure 19.

Dimensions in millimetres



Key

A toilet

B bathtub

C washbasin

Figure 19 — Example of plan of bathroom [71]

— When wheelchairs are pushed by a third party, the total length of both does not exceed 1 500 mm when stationary and 1 750 mm when moving.

— In primary living spaces like living rooms, sleeping rooms, kitchens, bathrooms and corridors, an area of movement of 1 500 mm × 1 500 mm for manoeuvring by wheelchair operators enhances accessibility. See Figure 20.

— Open doors of any kind or in any position that limit the width of a passage can cause accessibility problems.

Dimensions in millimetres

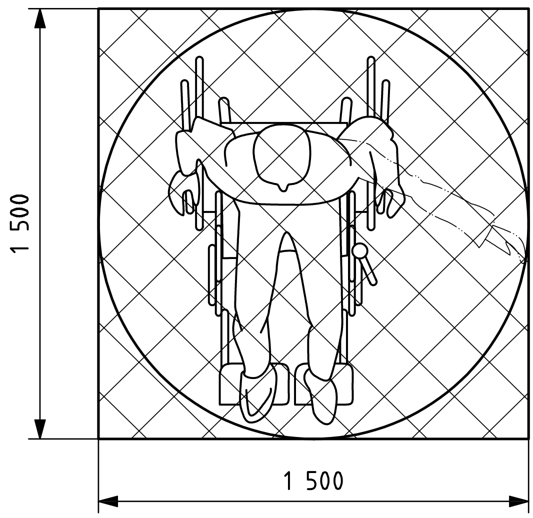
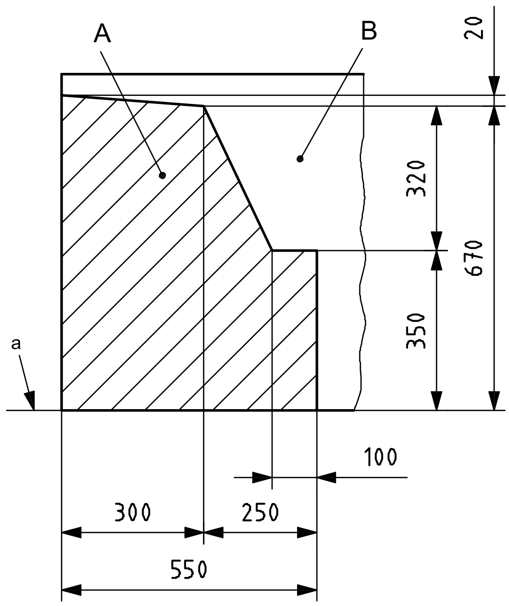


Figure 20 — Manoeuvring clearance

8.12.7.4 Knee and toe clearance

Where space below an object such as a basin is added to clear floor, ground space or turning space, a design providing enough space for knee and toe clearance is required. Additional space below an object cannot be considered as part of the clear floor or ground space or turning space. See Figure 21.

Dimensions in millimetres



Key

A leg space

B construction compartment

[a] OFF.

Figure 21 — Leg clearance

8.12.7.5 Protruding object

Protruding objects that do not reduce the clear width for accessible routes can increase accessibility.

8.12.7.6 Walking surfaces

The following is relevant to the design of walking surfaces:

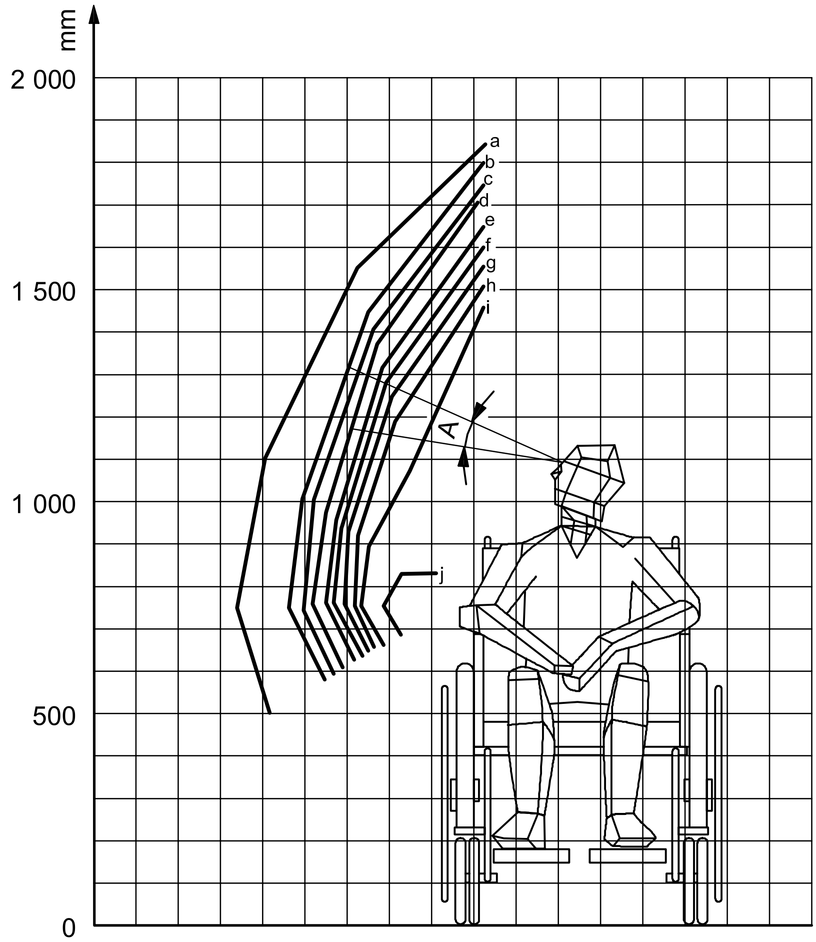
- for walking surfaces that are a part of an accessible route, see 8.16;
- for floor or ground surfaces, see 8.18.4;
- the running slope of walking surfaces that is too steep can cause accessibility problems, see 9.3.3.2;
- for changes in level, see 8.16.4;
- walking surfaces that provide clearances according to 8.18.3 can increase accessibility, see also 8.12.7.9.

8.12.7.7 Elevators

For the manoeuvring clearances of lifts and elevators, see 8.16.2.

8.12.7.8 Reach ranges

Most people, whether standing or sitting and regardless of their ability to move the upper body and arms, can reach a height of 850 mm. The ability of wheelchair users to move their upper body varies widely, resulting in a large range for reach. Figure 22 shows reach ranges of a wheelchair user depending on arm mobility, as an example.



Key

A highest comfortable viewing angle

a 10 %
b 20 %
c 30 %
d 40 %
e 50 %
f 60 %
g 70 %
h 80 %
i 90 %
j 100 %

Figure 22 — Comfortable sideways reach contours for wheelchair users

The following examples can be given as dimensions of reach ranges for a person in a wheelchair whose individual ability to move the upper body and arms is unobstructed.

— Where a forward reach is unobstructed, the upper forward reach can be 1 200 mm maximum (optimum = 850 mm) and the lower forward reach can be 360 mm minimum above the floor or ground. See Figure 23.

Dimensions in millimetres

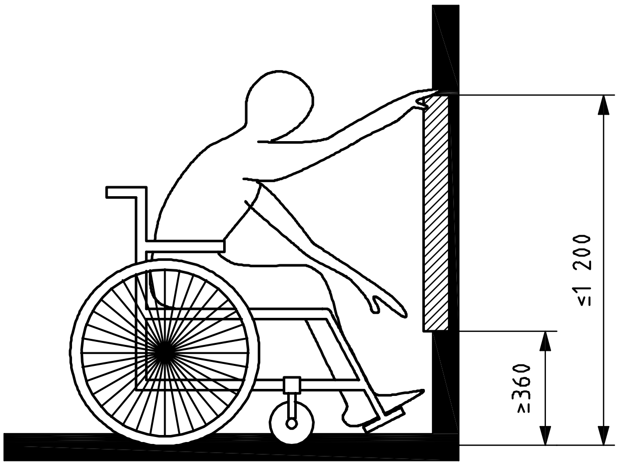


Figure 23 — Unobstructed forward reach (full mobility of the upper body and arms)

— Where a clear floor or ground space allows a lateral approach to an object and the sideways reach is unobstructed, the upper sideways reach can be 1 220 mm maximum (optimum = 850 mm) and the lower sideways reach can be 360 mm minimum above the floor surface or ground. These reach values are still valid as long as obstructions on the floor do not exceed a depth of 255 mm. See Figure 24.

Dimensions in millimetres

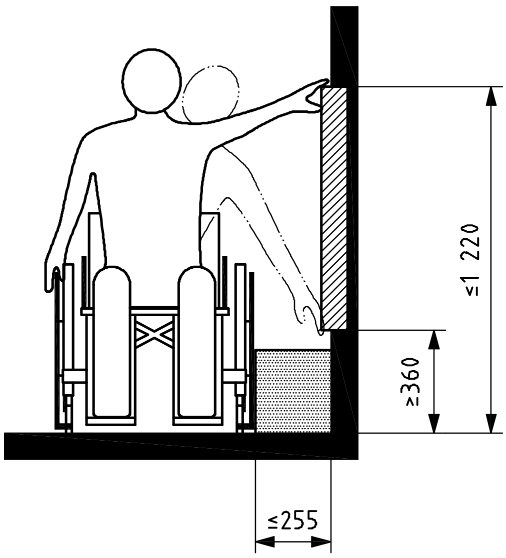


Figure 24 — Unobstructed sideways reaches

8.12.7.9 Dimensions of passage for wheelchairs

The following considerations and examples of the dimensions of passage for wheelchairs are relevant to increased accessibility.

— The minimum width for wheelchair passage is affected by the physical dimension protruding from the wheel (elbows). The minimum free width of the passage is, for example, 900 mm. The intensity of use of' the corridor is used as a criterion for fixing the minimum width and length of the corridor. For example, the minimum width is

  1) at least 1 800 mm if there is intense simultaneous use in both directions by the population at large, including persons in wheelchairs,

  2) at least 1 500 mm if the route is less busy and passing places are provided for wheelchair users,

  3) at least 1 200 mm in exceptional circumstances, e.g. for rarely used access routes, and

  4) at least 900 mm for paths within curtilage of a single dwelling [68].

— For corridors with corners where it is necessary to turn, the minimum width (the available width for passage in a corridor, clear of any obstructions) is 1 500 mm [68].

— Where a door opens into a frequently used corridor, the corridor width allows a clear space of 900 mm within the corridor when the door is open [68].

— The width is at least 1 200 mm for a ramp, and 1 000 mm for a stepped access route [68].

— If corridors are longer than 15 000 mm and narrower than 1 800 mm the provision of an area of 1 800 mm length with a minimum width of 1 800 mm enables the passing of two wheelchairs.

8.12.8 Assembly and maintenance

The following accessibility considerations are relevant to the assembly and maintenance of products.

— With products that can be dismantled as intended, see 8.12.1, 8.12.3.1, and 8.12.4 for the individual components and the way they are handled.

— Cleaning and maintenance do not impair product features (i.e. surfaces, colours, printing and grip, etc.) which remain intact for the life of the product.

8.13 Expiration date marking

> In order to reduce the risk of food poisoning, clear expiration date marking of food is important, as is the ability to interpret this. It is of particular value to those with an impairment in taste or smell.
>
> [ISO/IEC Guide 71:2001, 8.13]

An expiration date expressed in an alternative format as well as in clear language can increase accessibility. See 8.2 and 8.7.

NOTE An expiration date is important not only for foods but also for products, because of safety, emergency and health considerations. For example, the expected performance of a helmet or the expected effect of a medicine decreases with time due to the change of its component substances.

8.14 Contents labelling and warning of allergens

Clear contents labelling is important, as is the ability to interpret this. Warning of potentially hazardous substances, such as chemicals, gases and smoke is of particular value for those with visual impairment or in taste or smell. Clear content labelling of products and packaging is important for individuals who suffer from food or contact allergies. Attention should be drawn to any change in composition of existing products.

[ISO/IEC Guide 71:2001, 8.14.1]

Specific labels for "allergy-tested" products and packaging, as well as clear instructions for safe use or operation, are helpful.

[ISO/IEC Guide 71:2001, 8.14.2]

8.14.1 Allergy labelling/ingredients list

For measures against allergy, labelling is very important and effective. It is most important to avoid using known sensitizing substances. But, in some cases, sensitizing substances are required to manufacture products or provide services. The risk of contact allergy can be minimized by listing ingredients on products, packaging materials, and other printed information. The list can be presented in alternative formats.

EXAMPLE For persons with visual impairments, tactile markings on packages of medicines are used.

8.14.2 Warnings and cautions

By placing warning and caution labels on products, packaging materials, and instruction booklets, the risk of inducing allergic reactions can be minimized in those with allergies or those who have been sensitized. Expressions such as, "Contains xxxxx" or "Those with xxxxx allergy should not use this product" can be used.

NOTE 1 An allergy is a condition that brings about a pathological reaction in a sensitized organism due to a second contact with an antigen.

NOTE 2 *Allergen* is a collective term for substances that cause allergies. Allergens include proteins, carbohydrates, and chemical compounds. See Note 4, below.

NOTE 3 *Antigen* is a collective term for compounds that stimulate the body and induce immunological reactions. Except for proteins, substances become complete antigens only when combined with proteins in the body.

NOTE 4 *Sensitization* refers to an immunological condition in the body caused by exposure to a certain antigen. Clinically, after a person comes into initial contact with an antigen, an allergy occurs with the second exposure.

NOTE 5 The globally harmonized system of classification and labelling of chemicals (GHS) has been prescribed by the United Nations. The UN recommends that each country comply with GHS as soon as possible.

8.15 Surface temperature

Surfaces which may be touched inadvertently during normal operation should not get excessively hot or cold. The choice of materials to be used, for example, under cold conditions, and the use of appropriate insulating materials needs consideration.

[ISO/IEC Guide 71:2001, 8.15.1]

Warnings of where temperatures may be excessively high or low for functional reasons are of particular benefit to those with limited sensitivity in their touch receptors. The format of the warnings should be accessible to people with visual or cognitive impairment.

[ISO/IEC Guide 71:2001, 8.15.2]

8.15.1 Appropriate range of surface temperature of objects

Sensitivity to temperature decreases progressively with age. Normally, when the surface of objects with which persons come in contact is extremely high or low in temperature, its danger or discomfort is perceived. However, when older persons come into contact with objects of moderately high or low surface temperature, it takes them longer to perceive thermal changes. Older persons are less sensitive to hot and cold stimuli, so they are more susceptible to severe injury from contact with hot or cold objects.

A temperature-controllable surface can be kept within an appropriate temperature range to prevent skin burn and discomfort. Special attention is required for persons with impaired peripheral nerve function or thermoregulation, who are less sensitive to heat or cold or who take vasodilator medicine. See 9.2.3.4 for data on thermal sensation as a function of surface temperature for younger and older persons.

8.15.2 Ambient air temperature

Older persons are less sensitive to cold in summer and warmth in winter. Both the acceptable and the comfortable temperature ranges are wider for older persons than for younger persons [73].

Thermal sense, i.e. a feeling of warmth or coldness varies among young persons throughout the year due to seasonal acclimation. Thermal sense also changes with age in accordance with thermoregulatory ability, which decreases with age.

Special consideration for the appropriate thermal environment is necessary for persons whose thermoregulation and peripheral nerves are impaired, or who take vasodilator medicine (ISO/TS 14415).

See 9.2.3.4 for the effects of surface temperature and air temperature.

8.16 Accessible routes

8.16.1 Changes of level

Accessibility in and around buildings can be improved by avoiding unnecessary changes in level. Even very small changes of level, edges and protrusions can cause tripping. Where level changes cannot be avoided, they should be as low as possible, and clearly marked.

[ISO/IEC Guide 71:2001, 8.16.1]

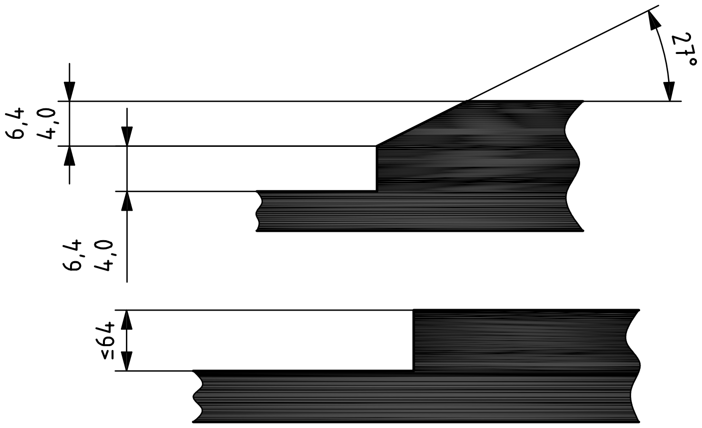
All substantial entrances to buildings and plants and all areas in dwellings that are attainable without steps increase accessibility.

The following accessibility considerations are relevant to the design of changes of level.

— Vertical changes of level that are as low as possible can increase accessibility.

  EXAMPLE The maximum vertical change in level is 6,4 mm for simple vertical changes. When the changes are bevelled with a slope not steeper than 1:2, a larger maximum height is possible. See Figure 25.

Dimensions in millimetres



27° slope = 1:2

Figure 25 — Maximal vertical change in level for simple vertical change and bevelled edge

— The design of the walking surface is according to 8.16.4.

— Changes of level that are clearly marked and well visible can increase accessibility. See 8.4 for lighting.

8.16.2 Lifts/elevators and ramps

Where there is a change of level, lifts/elevators and ramps should be provided. The slope of ramps should be appropriate in order to be safe and usable by persons using powered scooters, walking aids and wheelchairs. Lifts/elevators need to be of adequate size. [ISO/IEC Guide 71:2001, 8.16.2]

8.16.2.1 Lifts/elevators

The following accessibility considerations are relevant to the design of lifts/elevators.

— Sufficient inside dimensions of elevator cars and a sufficient width of elevator doors for persons using walking aids and/or wheelchairs can increase accessibility [65], [66], [67]. For width of doors, see 8.12.7.

  EXAMPLE Lifts and elevators have a minimum cabin dimension of 1 100 mm × 1 400 mm [66].

— Lifts have handrails in accordance with 8.16.3.

— Controls and operable parts are according to 8.12.3, 8.3 and 8.6.

— A mirror can be installed inside facing the door of the lift so that the wheelchair users can see behind them.

8.16.2.2 Ramps

The following accessibility considerations are relevant to the design of ramps.

— The slope of ramps designed with considerations of the width, length and the landing length for wheelchairs, as well as the ease of handling of wheelchairs, can increase accessibility. See 9.3.3.2.

— The design of the walking surface is according to 8.18.3.

— For changes of level, see 8.16.1.

— For handrails, see 8.16.3.

8.16.3 Stairs

Any stairs and steps should be designed to accommodate older persons and persons with disabilities by providing handrails of an appropriate diameter and height on both sides. Steps should be of a consistent rise and tread to accommodate the length of a human adult foot. Ends of flights of stairs should be marked by appropriate colour contrast.

[ISO/IEC Guide 71:2001, 8.16.3]

8.16.3.1 General

The following accessibility considerations are relevant to the design of stairs.

— Stairs (in particular the main staircase) that have straight runs can increase accessibility.

— Steps on a flight of the stairs that all have uniform riser heights and uniform tread depths can increase accessibility.

— The following increases accessibility: two times riser + tread = 630 mm. A riser of 170 mm and a tread of 290 mm can be optimum for the widest range of people [72].

— Spiral staircases are not accessible, because the optimal step dimension only applies in the middle of the steps. When using handrails, the outer parts of the step of a spiral staircase have to be used.

— In public buildings, the provision of landings every 12 upward steps at maximum can increase accessibility.

— The use of stairs that have handrails in accordance with 8.16.3.2 can increase in accessibility.

— Open risers can cause accessibility problems.

— When designing stair treads and landings subject to wet conditions, slip resistance can increase accessibility.

— Clearly visible steps through the use of contrast in brightness and colour, at least at the edge of each step, can increase accessibility. The areas at the approach to stairs, both at bottom and top levels, can be marked to draw attention.

EXAMPLE Marking stripes of 40 mm to 50 mm width at the forward edge of the step. See Figure 26.

Dimensions in millimetres

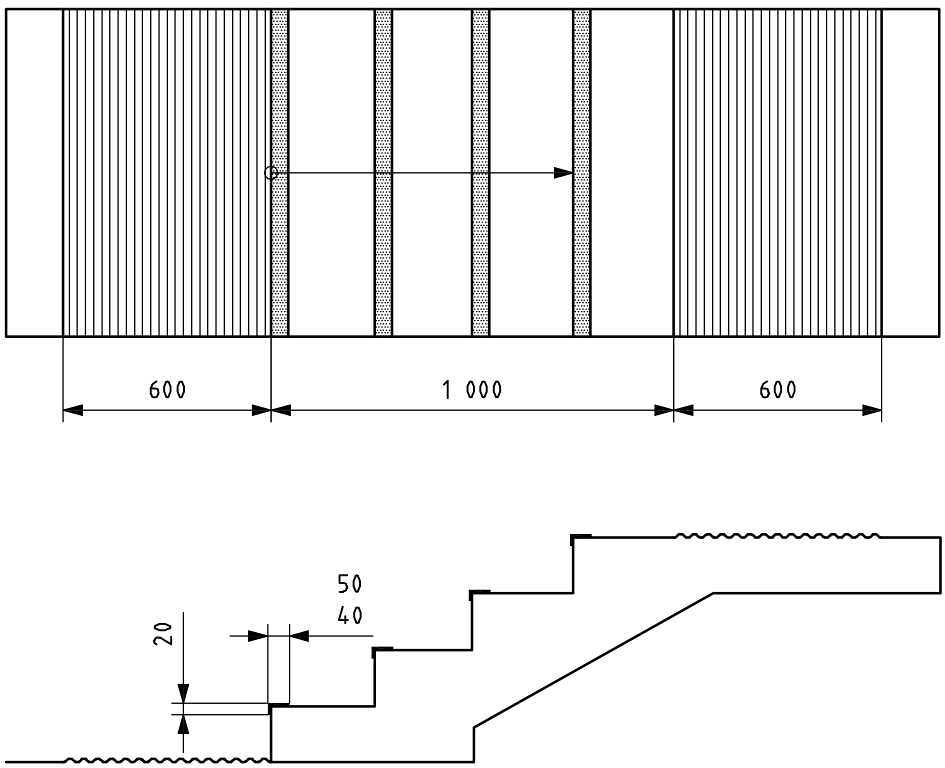


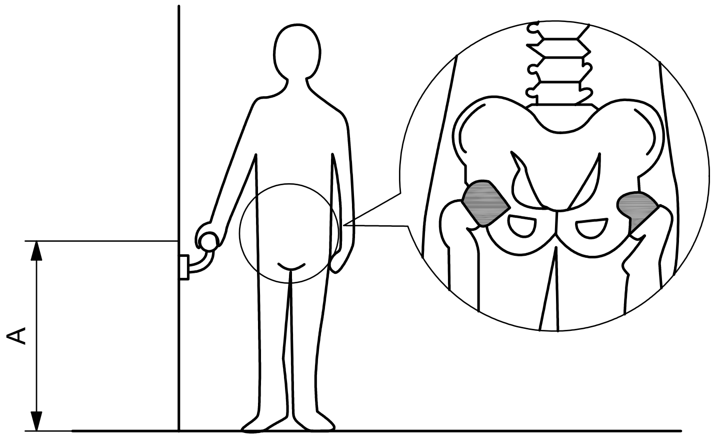
Figure 26 — Optimal marking of stairs

8.16.3.2 Handrails

Handrails are required on ramp runs with a rise greater than, for example, 150 mm, and on stairways. Handrails are not generally required on walking surfaces with running slopes less than a certain ratio, for example, 1:20 [67], but some people need them even for a flatter slope.

The handrail is most effective when its height is approximately equal to the height of the hip joint. The muscular skeletal load is minimal when the height of the handrail is approximately equal to the height of trochanter major. The height of handrails can therefore be set at the averaged height of the hip joint of their users. See Figure 27. The appropriate height for door handles is approximately the same as the height of handrails. Handrail height cannot be used to set the height of any safety barrier.

EXAMPLE A stair handrail height of 900 mm is used in European countries, and one of 700 mm to 900 mm in Japan.



Key

A height of hip joint

Figure 27 — Preferred height of handrails [74]

8.16.4 Flooring

Flooring should be reasonably slip-resistant, firm and stable: (see 8.18.3.) Floor guidance for visually impaired people should be provided. [ISO/IEC Guide 71:2001, 8.16.4]

Floor guidance can be provided by both tactile and visual information. See 8.2.2.1 for tactile information. For visual information, colour and contrast for persons with low vision can be appropriately chosen taking account of their visual properties. See 8.18.3 and 9.2.1.7.

8.16.5 Swing, sliding or powered door-closing systems

These can knock people off balance and should incorporate appropriate safety mechanisms. Consider alternative controls such as (hands-free) automatic operation. The timing of any procedure or operation should allow more time for people who move slowly. [ISO/IEC Guide 71:2001, 8.16.5]

Doors can be clearly recognizable, secure to pass through, and easy to open and to close. When designing doors and their installation, consideration on clearance can facilitate accessibility. The manoeuvring clearance for both sides of each door can follow 8.12.7. A number of national standards and guidelines for buildings exist that cover accessibility of door systems [67], [68], [75].

8.16.6 Seating

This should be provided at appropriate locations in a facility or environment to enable users to rest. [ISO/IEC Guide 71:2001, 8.16.6]

The following accessibility considerations are relevant to the design of seating for wheelchair users.

— Provision of wheelchair spaces, companion seats, and designated aisle seats in assembly areas can increase accessibility. See Table 11 [67].

Table 11 — Example of minimum number of required wheelchair spaces

Number of seats	Minimum number of required wheelchair spaces
4 to 25	1
26 to 50	2
51 to 150	4
151 to 300	5
301 to 500	6
501 to 5 000	6, plus one for each 150, or fraction thereof, between 501 through 5 000
5 001 and over	36, plus one for each 200, or fraction thereof, over 5 000

— Assignment of visitors' seats for companions to the seats/spaces for wheelchair users can increase accessibility.

— Seats/spaces for wheelchair users and the corresponding access to these spaces, clearly identified and highly visible, can increase accessibility.

— Wheelchair spaces are an integral part of the seating plan.

— Provision of at least one companion seat for each wheelchair space can increase accessibility. Companion seats can be equivalent in size, quality, comfort, and amenities to the seating in the immediate area and can be movable. At least 5 % of the total number of aisle seats provided can be located closest to accessible routes.

— Provision of seats for persons with walking aids also increases accessibility in assembly areas.

— Provision of specific seats with better acoustical properties for persons with hearing difficulties also increases accessibility in assembly areas. See 9.2.2.

8.16.7 Coverage

Accessibility should be planned for all areas where people normally work or use the environment; it should be ensured that the accessible routes connect those areas by the shortest possible path. Care should be given to the inclusion of sanitary facilities within the accessible routes.

[ISO/IEC Guide 71:2001, 8.16.7]

No additional guidance is offered.

8.16.8 Route information

Guidance on accessible routes through a building is of particular value to those with a visual, movement or cognitive impairment.

[ISO/IEC Guide 71:2001, 8.16.8]

The following considerations are relevant to the design of accessible routes.

— Provision of an information and guidance system in corridors and other traffic areas of publicly accessible buildings can increase accessibility. For larger complexes, the information and guidance system can extend to the building approaches and interconnections.

- Access and entrance areas are also locatable for persons with sensory limitations (in alternative formats, see 8.2). Adequate illumination is necessary in an emergency.
- In publicly accessible buildings, provision of an information board and/or a three-dimensional information model can help persons with sensory limitations in familiarizing themselves with the spatial arrangement of the building's functions.
- Provision of an intercom and a door opener at the front doors of buildings can increase accessibility.
- When the arrangement of the doorbells at the front of the building reflects the arrangement of the units inside the building, accessibility can be increased.

8.16.9 Emergency routes

> It is essential that emergency evacuation routes are obvious, intuitive and accessible to wheelchair users and others with a movement or visual impairment.
>
> [ISO/IEC Guide 71:2001, 8.16.9]

When designing building fire protection systems, considerations on the needs of persons with motor and sensory restrictions can increase accessibility.

EXAMPLE Supplying safe areas for persons who are not capable of self-rescue.

Supplementary ways to facilitate the evacuation of areas in case of danger can increase accessibility.

The following accessibility considerations are particularly relevant to the design of emergency routes.

- Provide visual information by means of light signals inside for the deaf and persons who are hard of hearing.
- Provide acoustic information for the blind and those with visual impairments.
- Provide tactile maps outlining evacuation routes.

8.17 Logical process

8.17.1 Operations

> These, such as the opening of packaging and assembling, installing or operating a product, should follow simple, straightforward and logical sequences. This assists persons with visual or cognitive impairment.
>
> [ISO/IEC Guide 71:2001, 8.17.1]

Minimizing the need to perform two or more tasks at the same time can help the user who may have cognitive impairments. Simplification of tasks such that complexity is reduced also helps users who are older or have cognitive impairments in using the product or system.

8.17.2 Feedback

Consideration should be given to the provision of appropriate feedback when each action in a sequence of actions is successfully completed. [ISO/IEC Guide 71:2001, 8.17.2]

Older users and users with cognitive impairments will perform better if the system or product minimizes the burden placed on memory. This allows them to avoid risks and hazards (e.g. forgetting to perform a critical action) and facilitates task performance, generally. Depending on the design situation, this goal can be accomplished in several ways. See 9.4.3.1 and Annex A.

The following accessibility considerations are relevant to the use of feedback.

— Information that is to be remembered and subsequently recalled during task performance can be provided in a form that persists (e.g. a persistent visual display of the information), unless that information is expected to be well-learned and available in the user's long-term memory.

— Where possible, provide visual cues or voice/visual reminders of task-specific information, critical to task performance, but which users are likely to forget.

— Whenever possible, provide users with some form of feedback after each step performed in a multi-step process or procedure, so that they do not forget steps or lose their place in the sequence.

— Make use of memory aids (i.e. mnemonics) where appropriate to increase the likelihood of user recall of important information or steps in a process or procedure.

— Design tasks with many simple steps instead of fewer, complex, steps.

— Reduce working memory load by reducing the amount of information that needs to be held available in memory in order to perform the task.

8.17.3 Repeated actions

Within a task, repetition can be helpful because it makes learning easier. (This may conflict with the needs of someone with a strength impairment, see 8.12.5.) Individuals with cognitive impairments can use most well designed controls and displays, but they take longer to learn to use them and need error protection. [ISO/IEC Guide 71:2001, 8.17.3]

No additional guidance is offered.

8.17.4 Other design considerations concerning cognitive abilities

Where there is a decrease in cognitive abilities, the following accessibility considerations are relevant [46].

NOTE This factor has been newly introduced with this Technical Report.

— Products and services can be designed to be suitable for the task and to support users in dealing with planned interactions. The cognitive limitations of older persons in processing information can be considered.

— Procedures that it is reasonable to automate can be carried out by the product itself.

EXAMPLE 1 Automatic program sequence and program indication for washing machines and dishwashers.

— Default values can be offered to the user so that he or she does not have to set them. However, it is possible to change default values.

EXAMPLE 2 The suggested spin speed of washing machines can be adjusted within a given range.

— Unnecessary steps in a procedure can be omitted.

— In general, steps in a procedure which follow one another can be combined as a single function.

— The affordability of a product can be taken into consideration. The design of the product, together with an indication how it is to be used, facilitates its use (ISO 1503).

EXAMPLE 3 Mechanical door handles, cups and cutlery.

— Products can be used in as far as possible without an instruction manual. Complex tasks, e.g. maintenance, require additional documentation.

— Where procedures are complex, product control systems can make all essential steps and conditions known immediately to the user by feedback or by inquiry.

— Clear feedback precisely related to the situation for which it is needed minimizes the need to refer to instruction manuals or additional sources of information.

— Consistently designed feedback helps users to understand the process easily.

EXAMPLE 4 A red flashing light stands for danger, interruption and stop.

— Feedback that is adjustable to the expected knowledge of users also helps occasional users.

EXAMPLE 5 Pressing the command button for lifts is confirmed both by an acoustic signal and by illumination.

— Products can indicate their operating mode automatically and support two senses.

EXAMPLE 6 Traffic lights with light and sound signals. Lifts with light indicators and speech output. PCs with video display units and speech output. Mobile telephones with sound and vibration.

— An interruption in program sequences caused by the product (e.g. misoperation) not only results in the machine stopping but also indicates the cause of the interruption.

— Controls with the same design and layout can indicate the same function, even across devices.

EXAMPLE 7 Emergency OFF switch.

— Operating sequences can be controllable and error-tolerant. Appropriate indications can be made to the user.

— Products fulfil the expectations of the user.

— The possibility of changing the operating condition of different products used in the same environment (such as the kitchen) in a uniform manner prevents users from dealing with different user interfaces.

— With products that are of similar type, the controls and displays have a similar arrangement. Feedback and control logic are also designed along the same lines.

— The possibility to adapt products and their programs to individual situations, abilities and preferences supports the specific user needs.

— Support and guidance in the dialogue between the user and the product can be given, such as explanations of options or next steps.

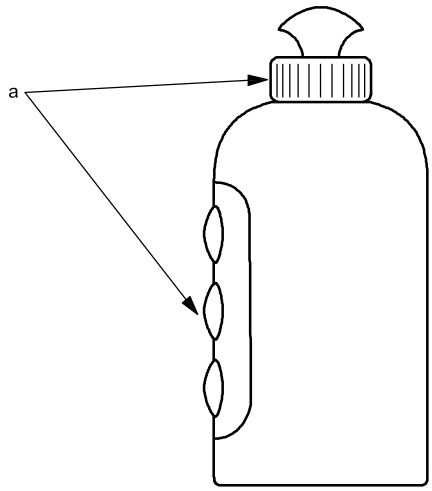
8.18 Surface finish

8.18.1 Slip-resistance and texture

The surface finish of a product/material is important for people with limited dexterity. A non-slippery surface aids gripping and manipulating. The use of distinct textures can also help someone with a visual impairment to distinguish different parts of a product or to locate controls. [ISO/IEC Guide 71:2001, 8.18.1]

The stability of a surface is one of the characteristics that keep the surface slip-resistant. A stable surface is one that remains unchanged by contaminants or applied force, so that when the contaminant or force is removed, the surface returns to its original condition. A firm surface resists deformation by either indentations or particles moving on its surface.

EXAMPLE A shampoo bottle that is designed with consideration given to slip-resistance. See Figure 28 [45]. A rough surface increases the slip-resistance and makes it easier to open the bottle.



a Tactile texture.

Figure 28 — Example of receptacle made resistant to slipping

8.18.2 Sharp points

Surfaces should be free from sharp points and edges which are a potential hazard to anyone but are particularly so for someone with a visual or touch impairment. [ISO/IEC Guide 71:2001, 8.17.2]

Designing surfaces, edges and corners of products (e.g. desk tops, keyboards) and of walls so as to avoid injuries can increase accessibility.

The following accessibility considerations are relevant.

— Furnishings, edges, and corners on furniture in public areas designed and secured to avoid injury can increase accessibility.

— Sharp edges of surfaces or controls are avoided.

  EXAMPLE The rounding of edges and corners e.g. radius ⩾ 2 mm (ISO 9241-5).

— Furnishings can be set up and mobile parts of furnishings can be arranged in such a way that, with intended use, no hazards develop. Hazards with furnishings can be avoided if necessary traffic routes are not restricted within areas containing furnishings. The danger of crushing by mobile parts of furnishings can be avoided. See ISO 12100-1, ISO 12100-2, and References [76] or [77].

— The smoothing of surfaces of walls and rounding corners and edges of supports can prevent injury by unintentional contact up to a height of, for example, 2 m.

— If unintentional contact cannot be avoided, the remaining danger can be kept as small as possible.

8.18.3 Flooring

> Floors should be slip-resistant to facilitate movement by those with a visual impairment, impaired balance and general difficulty in movement. Cushioned carpeting is not recommended as a springy surface does not offer a firm and stable foothold and deep-pile carpet causes resistance for those with a shuffling gait, risking a stumble. This type of carpet can also be a hazard for people using walking aids. A change of surface material can cause a danger and should be indicated.
>
> [ISO/IEC Guide 71:2001, 8.17.3]

The following accessibility considerations are relevant to the design of flooring.

— Floors can be designed to be slip-resistant under all conditions (e.g. wet and dry) and to facilitate movement by those having impaired balance, general difficulty in movement or visual impairments.

— Cushioned carpeting is avoided because a springy surface does not offer a firm, stable foothold, and deep-pile carpet causes resistance for those with a shuffling gait, increasing the risk of stumbling. This type of carpet can also be a hazard for persons using walking aids. Equally, a change of surface material in the same location can pose a danger.

— Floor coverings that stand out in contrast to other building construction and elements of equipment, and the support orientation of users by visual and tactile means can increase accessibility.

— Consideration of the flooring used for stairs is especially important.

8.18.4 Non-glare surface finish

Some surfaces that have a polished finish or that are of a highly reflected material can cause glare by reflecting light or images. This reduces the visibility of these surfaces. Surface finish that minimizes glare can increase accessibility, particularly, for floors, visual displays and instruction papers.

NOTE This factor has been newly introduced with this Technical Report.

8.19 Non-allergenic/toxic materials

> Avoidance of toxic and allergenic materials is particularly important for people with impaired tasting or smelling ability and those with contact, food or respiratory allergies. Examples of everyday objects that contain nickel or chromium, which can create an allergic response, include doorknobs and window frames.
>
> People with visual impairment who rely on touch or tactile feel may be at risk if they come into contact with allergenic materials.
>
> [ISO/IEC Guide 71:2001, 8.19]

Because a variety of substances can induce contact allergies, allergy-related issues should be considered when designing products and services. It is necessary to thoroughly examine standards, even for those areas that seem to be unrelated to allergies, e.g. garments contaminated by formaldehyde in air, packaging or storage, and air conditioning can also be considered. In particular, it is necessary to give careful consideration to products and services with which people come in direct contact, and substances that can come into contact with, or be ingested, through bleeding or volatilization. With garments, jewellery, watches and glasses, which are worn or directly come in contact with the body, it is necessary to closely analyze sensitizing substances. Airborne contact dermatitis is caused when an airborne substance adheres to the skin, and can be caused by incense, aromatic substances or formaldehyde released from buildings, building materials or furniture.

The most basic measure against allergy is to avoid being sensitized by allergens. It is important to avoid exposure of the human body to allergens originating from products and services through contact, ingestion or inhalation. Products incorporating measures against contact allergy have low sensitizing potential and are highly safe for healthy people, and at the same time can reduce the burden on persons who develop contact allergies or those who already have contact allergies.

It is necessary to minimize the use of materials, elements and ingredients with a high sensitizing potential when designing products and services. Standards developers as well as product designers need to keep in mind that some products come into contact with the skin through unexpected product usage or due to their design. During product manufacture, new antigens and allergens can be synthesized due to mixing, heating or chemical processing.

The following are additional considerations relevant to the avoidance of contact allergy [78].

— Gain an understanding of the properties of elements and materials, and take into account durability and corrosion.

— Design so as to prevent substances with high sensitizing potential from easily eluting or evaporating.

— Gather cases and information on contact allergies, and use them for design purposes.

In addition, it is necessary to take into account the properties of materials and elements, e.g. with resins, a minute amount of monomers can remain and act as allergens. Therefore, if it is not clear whether a resin contains allergens, a test is necessary.

It is not possible to conduct a contact allergy test for materials, elements, raw materials or ingredients in advance in healthy people, because of immunological reactions. As a Type-IV allergy test (see 9.5.1.2), the guinea-pig maximization test (GPMT) is available. Because it is very difficult to conduct an animal study, quantitative structure-activity relationships (QSAR) have been used in recent years.

EXAMPLE In a standard for a housing plan, building materials, furniture and matting, it is required that measures against house dust, which can cause respiratory allergy, be considered. In a standard for cleaners, it is required that allergens be removed.

8.20 Acoustics

8.20.1 Acoustical design

> Attention to acoustical design will ensure that the environment is suitable for good verbal communication with low background noise, low reverberation and high quality amplification as appropriate. People with visual or cognitive impairment rely to a greater extent on sound clues.
>
> [ISO/IEC Guide 71:2001, 8.20.1]

Design of the environment from an acoustical point of view is important for the application of warnings of hazards and dangers and information messages for workplaces, public areas, meeting rooms and auditoriums, as described in ISO 9921.

Speech information is provided with various levels of background noise. The speech transmission index (STI) is one standardized evaluation method for speech communication (ISO 9921); its measurement is described in Reference [79]. See 9.2.2.5 and 9.2.2.6.

To achieve better conditions for speech communication, the following considerations are relevant to the design of acoustical environments.

— **Speech level**

  Provide spoken announcements that have sufficient sound pressure levels (see 8.7.4.1) and sound quality at the speaker's mouth or loudspeaker. Vocal effort can be considered for direct speech communication without amplification (ISO 9921).

— **Noise level**

  Make the environment as quiet as possible to achieve a sufficient signal-to-noise ratio. See 8.7.4.4.

— **Reverberation time**

  This is the time, expressed in seconds, that would be required for the sound pressure level to decrease by 60 dB. This can be measured by a standardized method (ISO 3382). Since reverberation is a detrimental factor, especially for elderly listeners and listeners with hearing impairments, shorter reverberation times are preferable for speech communication. Sound absorption structures can be applied to decrease reverberation energy and shorten reverberation time. Typical sound absorption structures are composed of, porous materials, membrane absorbers and cavity absorbers.

— **Early reflections**

  Early reflection, i.e. sound reflection bouncing from walls arriving within 50 ms of direct sound, is effective both for persons with normal hearing and those with hearing impairments, to increase the speech level at the listening point and achieve a higher signal-to-noise ratio for direct communication. Too much sound absorption around speech sources reduces the benefit of early reflections.

8.20.2 Amplification and adjustment

Building these into audio equipment widens the range of users who may be accommodated. [ISO/IEC Guide 71:2001, 8.20.2]

No additional guidance is offered.

8.20.3 Communication systems

Even with a good acoustic environment, hearing-impaired people have difficulty in hearing at a distance from the source of the sound. The availability of communication systems such as induction loops, infrared and radio systems means that they should be included. [ISO/IEC Guide 71:2001, 8.20.3]

For induction loops for hearing aid purposes, see Reference [80].

8.21 Fail-safe

Product or system design should ensure that even when incorrectly assembled or installed or there is mistaken use of controls, the product or system will fail in a safe manner without hazard to the user. [ISO/IEC Guide 71:2001, 8.21]

No additional guidance is offered.

8.22 Ventilation

Ventilation systems should not cause or enhance respiratory allergies or irritation. [ISO/IEC Guide 71:2001, 8.22]

No additional guidance is offered.

8.23 Fire safety of materials

Consideration should be given to the fire-resistance qualities in products and buildings which are used by people with disabilities. Materials susceptible to ignition by a small source such as a cigarette, match or other small flame present a potential hazard if they continue to burn, producing toxic smoke or result in rapid growth of fire. [ISO/IEC Guide 71:2001, 8.23]

No additional guidance is offered.

9 Ergonomic data on human abilities and the consequences of impairment

9.1 General

The needs and abilities of people change as they advance from childhood to old age and the abilities of individuals in any particular age group vary substantially. It is important to recognize that functional and cognitive limitations vary from comparatively minor impairment to more extreme forms. [ISO/IEC Guide 71:2001, 9.1.1] This clause, to be used in conjunction with Clause 8, provides the tools for identifying and addressing the needs of older persons and persons with disabilities in standardization work. [ISO/IEC Guide 71:2001, 9.1.2] A brief definition and description of each ability used in the Tables have been given along with information on the effects of ageing and the practical implications of impairment. Examples have been given, where appropriate, of hazards from which older persons and persons with disabilities are more at risk because of their functional limitations. [ISO/IEC Guide 71:2001, 9.1.3]

This clause provides ergonomic data on human abilities with an emphasis on describing how human abilities change between youth and old age. Where possible, design considerations and methods of using the data are presented. For some human abilities, large-scale data sets are presented by descriptive statistics to illustrate the individual differences. The accumulated data are not always utilized directly in designing products and services. However, knowledge of human abilities is indispensable for standards developers and product designers whose work takes into account the needs of older persons and persons with disabilities.

9.2 Sensory abilities

9.2.1 Seeing

Description

Seeing relates to sensing the presence of light and sensing the form, size, shape and colour of visual stimuli.

[ISO/IEC Guide 71:2001, 9.2.1.1]

Effects of ageing

The incidence and severity of visual impairment increase with age. Changes in the physical structure of the eye affect several aspects of visual functions, including:

— loss of visual acuity (the image appears indistinct),

— loss of near and/or distance vision (inability to accommodate changes of focus),

— reduced field of vision (inability to see things to the side, top or bottom of where looking),

— perception of colour, including age-related yellow vision (inability to distinguish colours),

— depth perception (inability to judge distances),

— speed of adaptation to changing light levels (temporary inability to see whilst eye adjusts to different lighting levels, for example on entering a building), and

— sensitivity to light; generally, older persons need more light to read than they did at 20 years of age.

[ISO/IEC Guide 71:2001, 9.2.1.2]

Design considerations

People with no useful vision depend mainly on tactile and acoustic input. The majority of people with difficulties seeing have some vision, and therefore use visual stimuli such as size, luminance and colour contrast. Typically the simpler an image and the clearer its definition, the easier it is to see and read.

[ISO/IEC Guide 71:2001, 9.2.1.3]

Risks and hazards

People with a visual impairment are at an increased risk from, for example:

— sharp points and edges on products being handled, particularly if the user relies on touch to identify features,

— physically unstable items that might fall out of reach,

— changes in surface level, obstacles or protrusions which may result in slip, trip, collision and fall hazards, or cause injuries,

— open fire and flames,

— hot surfaces that might be touched inadvertently,

— corrosive substances unless they are labelled with a universally recognized tactile warning,

— evacuation procedures which rely solely on visual indicators,

— visual warnings which rely solely on colour or on colours with poor contrast between text and background.

[ISO/IEC Guide 71:2001, 9.2.1.4]

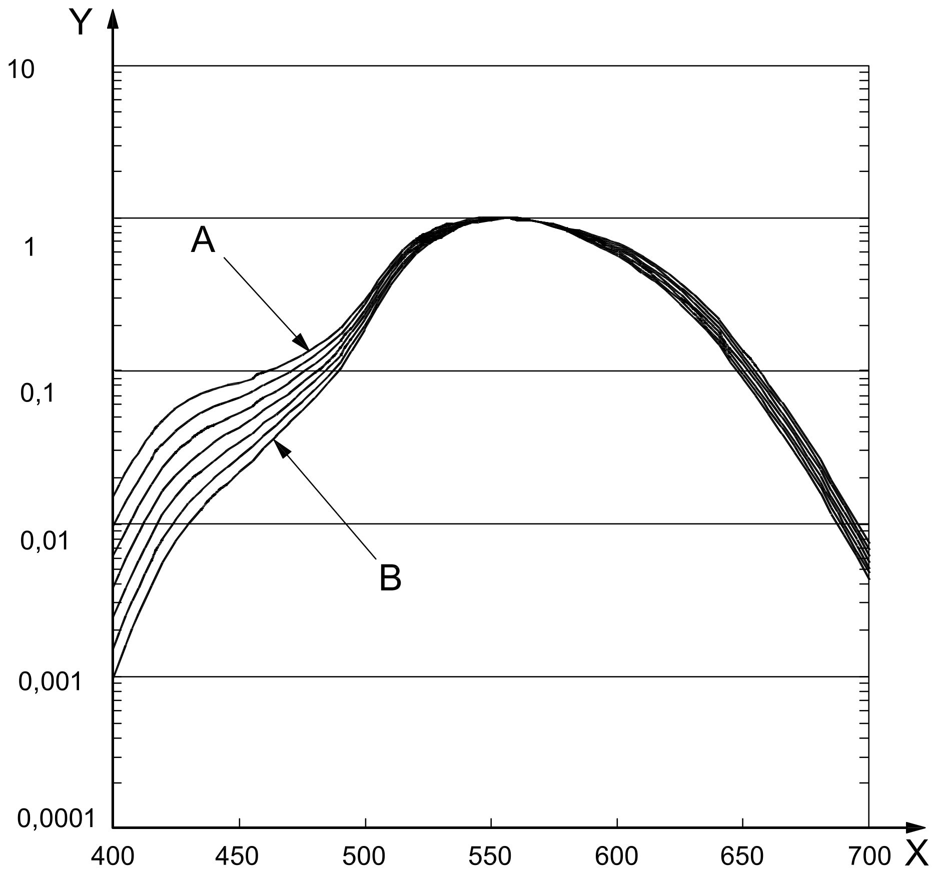
9.2.1.1 Spectral sensitivity of the eye

The human eye responds to monochromatic light in the wavelength range from about 400 nm to 700 nm, the so-called “visible range.” The eye has peak sensitivity at around 550 nm in photopic lighting levels (i.e. moderate daylight intensity level where light adaptation has occurred) with less sensitivity towards both ends of the visible spectrum.

Figure 29 shows the spectral sensitivity function measured by flicker photometry with a foveally-fixed 2° target field at photopic lighting levels. Data were collected for 91 people ranging in age from 11 to 78 years [81]. The data are organized into seven age groups containing the geometric average of all participants in a respective decade. The numerical values of sensitivity are given in Annex B.

NOTE This flicker photometry study alternated a test and a reference light with a fixed 12 Hz frequency to find a non-flicker or minimum flicker point at which the test and the reference light are regarded as equal luminance.

The sensitivity to bluish lights in the short-wavelength region between 400 nm to 500 nm decreases with age. Bluish light will look darker to older people. However, this effect usually disappears if an older person has had an artificial eye lens surgically implanted to remove a cataract. Care can be taken when using blue lights in visual information displays, especially traffic or emergency signs, so that they are not perceived as being too dark by older people. See 8.5.1 and 8.5.4.



Key

X wavelength nm

Y relative sensitivity

A average of people in their second decade

B average of people in their 70s

Figure 29 — Spectral sensitivity curves of eye for seven age groups from 11 to 78 years

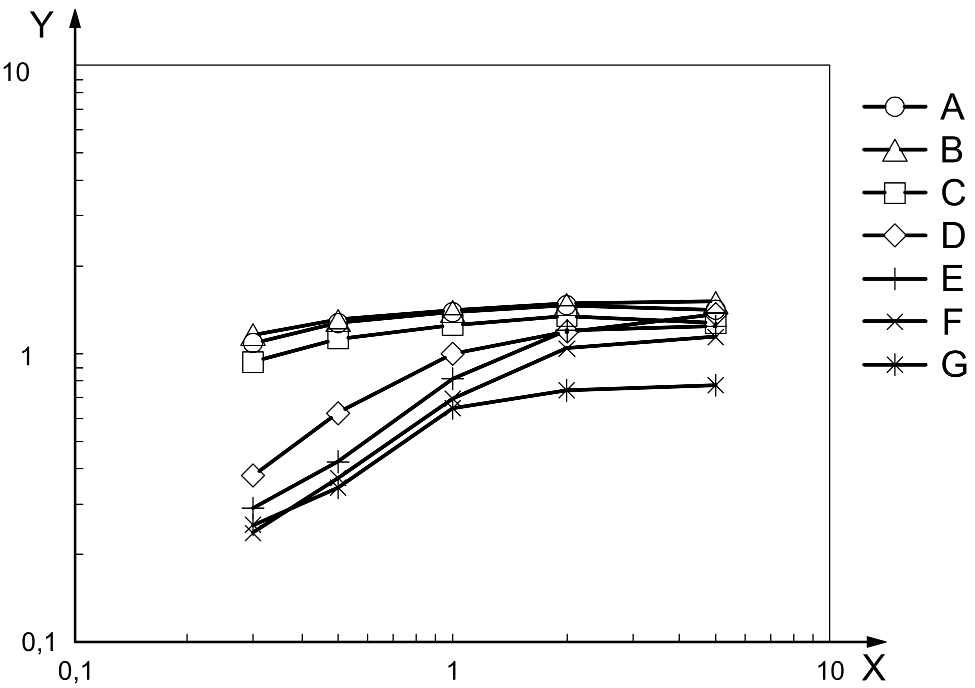
The spectral sensitivity curve is used for photometry that evaluates light in terms of visual sensation, i.e. bright or dark objects or light sources. The sensitivity function for young people with no visual disabilities has been standardized by the International Commission on Illumination (CIE) and is traditionally used in photometry. The age-related change the function shown in Figure 29 has not yet been established in the photometry field, but could be used in evaluating light with people of any age. See Annex B.

9.2.1.2 Visual acuity

Visual acuity is a function of the eye for detecting spatial resolution and details, and is one of the most fundamental visual characteristics. As a person grows older, visual acuity is diminished as the eye loses accommodative power or the ability to maintain focus. Visual acuity is also diminished as the eye lens becomes more opaque with age, thereby distorting details in images. Among a number of other affecting factors, viewing distance and luminance level are the most significant in estimating visual acuity.

9.2.1.2.1 Effect of viewing distance

Figure 30 shows visual acuity as a function of viewing distance for seven age groups from 10–19 years to 70–79 years of age [82]. The data were obtained with a high contrast test chart (Landolt ring "C" printed black on a white background) at the luminance level of 100 cd/m^2. The participants wore optical lenses so as to obtain the best corrected acuity at the far point (5 m). The data were collected from a total of 111 participants stratified into different age groups.



Key

X viewing distance (m)
Y visual acuity
A 10–19 years of age
B 20–29 years of age
C 30–39 years of age
D 40–49 years of age
E 50–59 years of age
F 60–69 years of age
G 70–79 years of age

NOTE 1 Data were taken at a luminance level of 100 cd/m^2, for corrected eyes at 5 m.

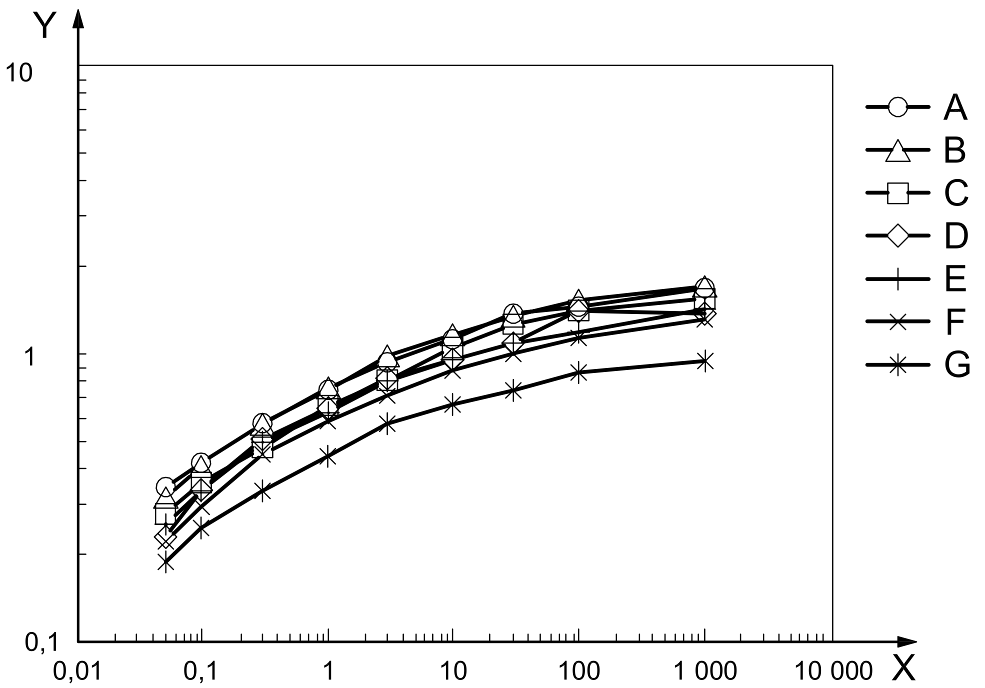
NOTE 2 A visual acuity score of 1,0 is the nominal reference.

Figure 30 — Visual acuity as function of viewing distance for seven age groups

For participants 10–19 years of age, visual acuity remains almost constant though a slight reduction is observed at shorter viewing distances. For participants 70–79 years of age, acuity clearly decreases with shorter distances. Annex C provides numerical data of visual acuity as a function of viewing distance.

9.2.1.2.2 Effect of luminance level

The luminance level also significantly affects visual acuity. Figure 31 shows how visual acuity changes with luminance levels for different age groups. The data were obtained from 111 participants at a viewing distance of 5 m. Clearly, visual acuity decreases as the luminance level decreases. The manner of the change, however, is almost the same for all age groups suggesting that one function can summarize the effect of luminance. Standards developers and product designers need to be careful not to require tasks demanding high visual acuity in darkened conditions. The relative values of the change are tabulated in Annex C, taking 100 cd/m^2 level as a normalizing point of 1,0.



Key

X luminance (cd/m^2)

Y visual acuity

A 10–19 years of age

B 20–29 years of age

C 30–39 years of age

D 40–49 years of age

E 50–59 years of age

F 60–69 years of age

G 70–79 years of age

NOTE 1 Data were taken at a viewing distance of 5 m, for corrected eyes at 5 m.

NOTE 2 A visual acuity score of 1,0 is the nominal reference.

Figure 31 — Visual acuity as function of luminance level from 0,05 cd/m^2 to 1 000 cd/m^2 level for seven age groups

The changes in visual acuity demonstrated in Figures 30 and 31 can be considered when visual signs are designed for older people in particular. The visual sign or letters contained therein need to be enlarged whenever visual acuity is assumed to be decreased such as in near viewing distances or in poorly illuminated conditions.

A method of estimating the minimum legible font size for a person at any age, any viewing distance and any luminance level is given in Annex C. The data on visual acuity and the estimation method for minimum legible font size presented in Annex C can be applied to almost all cases where font size and its visibility are concerned. See also 8.6, 8.7.1 and 8.7.3.

9.2.1.3 Span of fundamental colour and colour combination (category of colour)

Colour is perceived and processed in the central brain by grouping similar colours. This is called *categorical colour perception*. For example, orange-red and purple-red are both perceived in the red category. There are a limited number of colour categories, each corresponding to a fundamental or basic colour name, such as red, green, blue and yellow. See Annex D for more information.

The theory of categorical colour explains that colours will appear distinctive from one another if they are selected from different categories. Conversely, colours selected from the same category are easily confused. Categories are defined by a span or grouping of similar colours within a certain colour space such as the Munsell Colour space. Knowing how many categories of colour humans can identify and which hues are included in each category is useful when selecting colour combinations. Because colour perception changes with age and lighting levels, it is desirable to define the span of each colour category for those conditions.

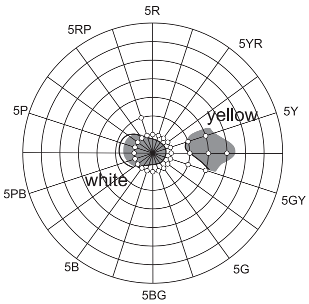
For older people at moderately bright luminance levels, Figure 32 identifies 13 spans of fundamental colours (red, orange, yellow, green-yellow, green, blue-green, blue, purple-blue, purple, purple-red, white, grey, black) shown in the Munsell colour space [83]. The Munsell colour space is a three-dimensional system used to specify colour by hue, chroma (saturation, or how close the colour is to grey), and value (the lightness or darkness of the colour). Figure 32 shows four different cross-sections of this three-dimensional space, with each slice representing a particular value. The higher values indicate lighter colours; the lower values darker ones. The grey areas in Figure 32 correspond to a span of colours that participants found similar and placed in one of the 13 fundamental colour groups. In some cases, two identical cross-sections are placed side-by-side to avoid overlapping fundamental colours. In those situations, line contours are drawn to indicate where the overlap would have occurred. The small open circles in the charts represent the colours used in the experiment.

NOTE The data were obtained by a method based on colour similarity judgment, i.e. participants were asked to judge whether or not a presented colour was similar to another fixed as one of the fundamental colours. When 50 % of the total participants judged a given colour to be similar to the fundamental, then that test colour was placed in the respective category. No data were collected at the high chroma region due to the limited availability of sample colours.

When creating visual signs or objects with two or more colours, selecting colours from different categories will make the differences between elements visible and conspicuous. Based on this idea and the data shown in Figure 32, Table 12 is provided to help standards developers and product or service designers in selecting colour combinations. The degree of distinctiveness of the colour combination is classified into three levels, high, moderate and low, depending on the similarity data.

The span of fundamental colours depends on the extent of visual impairments such as colour blindness or low vision as well as age and lighting level. This report only supplies data for older people and does not include data for persons with low vision or colour deficiency. Data for other important conditions, such as for younger people or at dark illuminance levels, are shown in Annex D.

The data shown in Figure 32 were taken for reflected samples such as printed colours on paper or on a sign. In principle, the data are only applicable to those reflected samples. However, in the case of *self-luminous colour* such as colour in VDT displays, the data are applicable if the colour is specified in Munsell colour notation by appropriate transformation using colorimetry or visual matching. This ensures the widest application of the data. However, the data are obviously not applicable to those who wear coloured glasses or in other situations where the colour can shift before reaching the eye.



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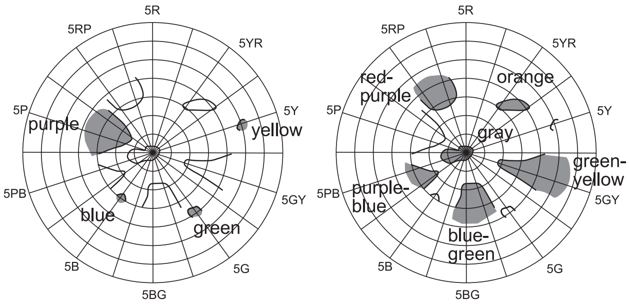
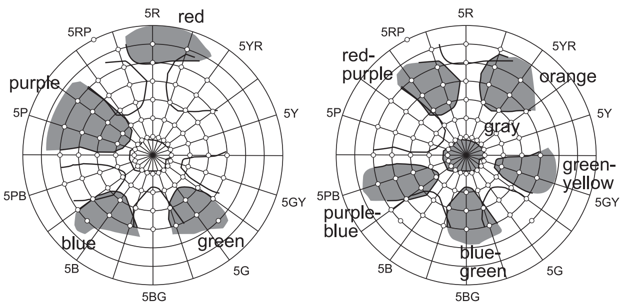
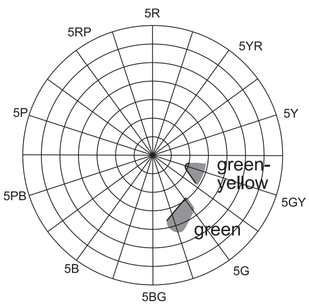


value 7



value 5



value 3

NOTE There are a total of 13 fundamental colours (12 shown here, with one colour, black, missing). The span of each fundamental colour extends to three dimensional axes (hue, chroma and value) and four cross-sections (equal lightness level) of the value axis are illustrated.

Figure 32 — Spans of fundamental colours for older persons at photopic (moderately bright) level

Table 12 — Colour combination of fundamental colours and their distinctiveness (for older people at photopic level)

	R	RY	Y	GY	G	BG	B	PB	P	RP	GRE	WHT	BLK
R		–	o	o	o	o	o	o	+	+	o	o	o
RY			+	o	o	o	o	o	+	+	+	o	o
Y				+	o	o	o	o	o	o	o	+	o
GY					+	+	o	o	o	o	+	+	+
G						–	+	o	o	o	+	o	+
BG							–	+	o	o	+	+	+
B								–	+	o	+	o	+
PB									+	+	+	o	+
P										+	+	o	+
RP											+	+	o
GRE												+	o
WHT													o
BLK													

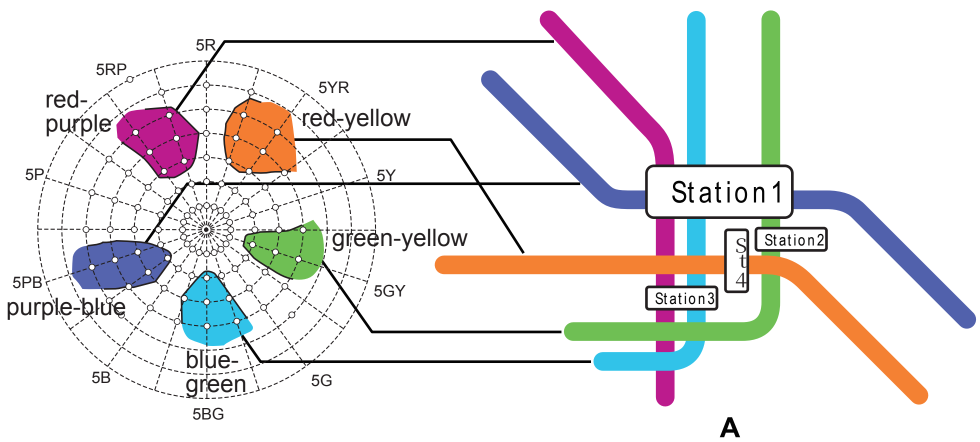
o extremely high distinctiveness

+ moderate distinctiveness

– low distinctiveness

NOTE Abbreviation of colour names in the Table 12 are: (R) red, (RY) orange or red-yellow, (Y) yellow, (GY) green-yellow, (G) green, (BG) blue-green, (B) blue, (PB) purple-blue, (P) purple, (RP) red-purple, (GRE) grey, (WHT) white, (BLK) black.

EXAMPLE Colour combination based upon a span of fundamental colours: colouring of a subway network [83]. When colouring five subway lines on a network map, a set of five fundamental colours is selected by referring to Figure 33. Colours will be from different categories if none of the fundamental colours selected overlap. In Figure 33, five fundamental colours (red-yellow, green-yellow, blue-green, purple-blue, and red-purple) are selected as an example. Different sets of colours are also possible. Using the five fundamental colour groups selected, any five colours within the respective category span can be picked to ensure the subway lines remain distinguishable. For example, any red-yellow hue from within the red-yellow span can be selected.



Key

A subway network

NOTE All the colours used here are at value 5 (moderate lightness level). Other darker or brighter colours can be chosen by selecting colours from the value 3, 7 or 9 levels.

Figure 33 — Example of colour combination for older people viewing under photopic condition

The use of categorical colours has additional advantages for standards developers and product or service designers. Because the span of fundamental colours identifies many acceptable hues within a particular group and not an exact specification, flexibility is provided to artists to make appropriate aesthetic choices and to manufacturers to deal with colour reproduction issues in their application fields. The concept and utilization of colour categories can also be applied in any medium where visual information is shown such as public signs, markings and visual display designs. See also 8.2.3.1, 8.5, 8.7.3 and 8.8.

Reduced or different performance in colour discrimination or colour identification compared to that of the majority of people is called *colour vision defects*.

9.2.1.4 Colour vision defects

Congenital colour vision defects are brought about by a lack of, or reduced, response of one or two types of photoreceptors among the three types of photoreceptors in the retina of the human eye. According to the classification of the defects in terms of the photoreceptors, two major classes of colour vision defects exist, protan and deutan. *Protan* is a lack of, or reduced numbers of red-sensitive photoreceptors. While, *deutan* is a lack of, or reduced numbers of green-sensitive photoreceptors. Depending on the type of defect and the genetic group, approximately 5 to 8 % of the population are affected by these two colour vision defects. There is a third type of colour vision defect called *tritan*, which is a lack or reduced responsivity of blue-sensitive photoreceptors, but the incidence of this type is so rare that it is estimated that only 0,002 to 0,007 % of the population have it.

Protan and deutan are called the *red-green* defects because the disorder of colour vision appears in the red-green axis of the chromaticity diagram, implying that some combinations of green and red lights cannot be discriminated. Tritan is assigned as a yellow-blue defect with a disorder of yellow-blue axis. Accessibility of signs and displays can be increased by taking these disorders into account in colour discrimination. Colour defects have no deterioration on visual acuity.

Acquired colour vision defects are the defects caused by disease or injury, not only at the retinal level but also at central level. These are similarly classified as congenital defects but various types of defect can be observed in acquired colour vision defects and classification is therefore not clearly made.

9.2.1.5 Useful field of view

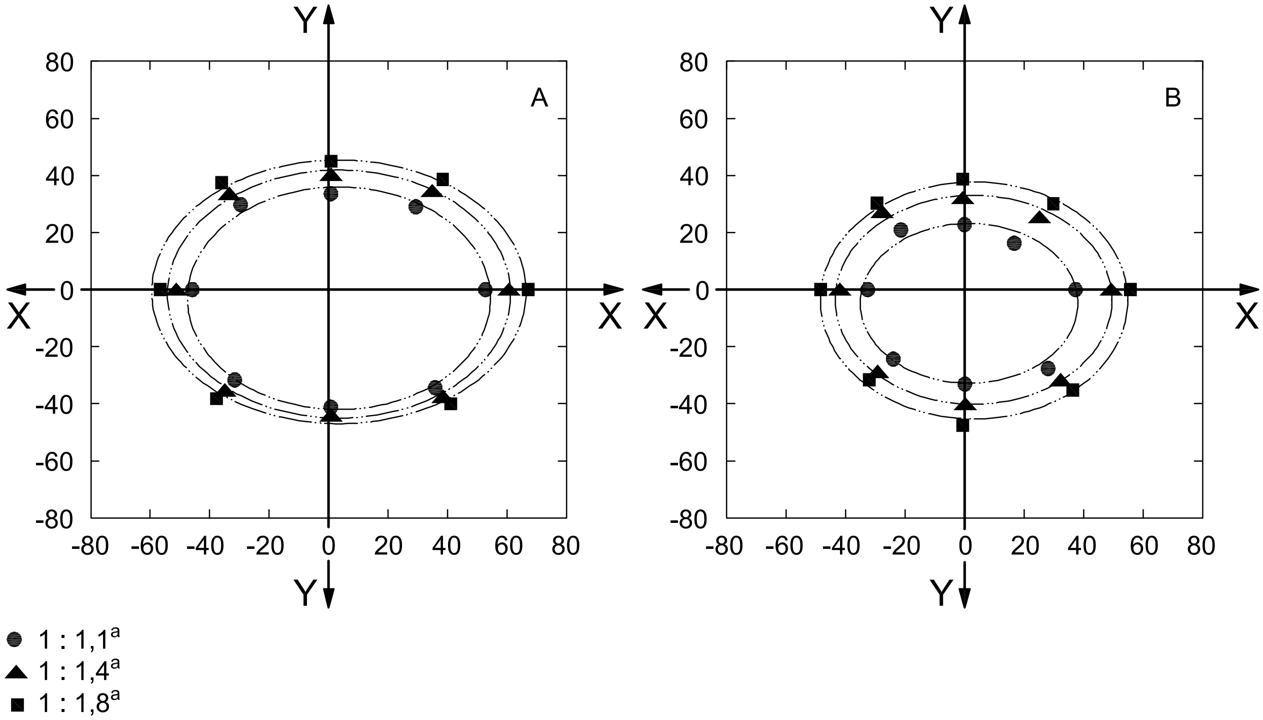
The visual field extends more than 180° horizontally in front of a human being’s eyes. Due to the non-homogeneous characteristics of the retina over such a wide range, the extent of visibility over the visual field is largely dependent on the position at which a visual stimulus is presented. The central visual field, which subtends about 1° of visual angle, has excellent ability for visual information processing (good spatiotemporal resolution, vivid colour perception, etc.), but as stimuli move toward the periphery, the quality of visual perception decreases. Useful field of view (UFOV) is characterized by the range that assures good performance of a specified visual task such as colour detection or object recognition.

The UFOV can be measured for a large variety of visual functions or tasks, e.g. detection, spatial and temporal discrimination, object recognition, moving or flashing identification. The most simple and useful UFOV data are measured by a simple detection task that requires the participant to detect a target presented in the periphery.

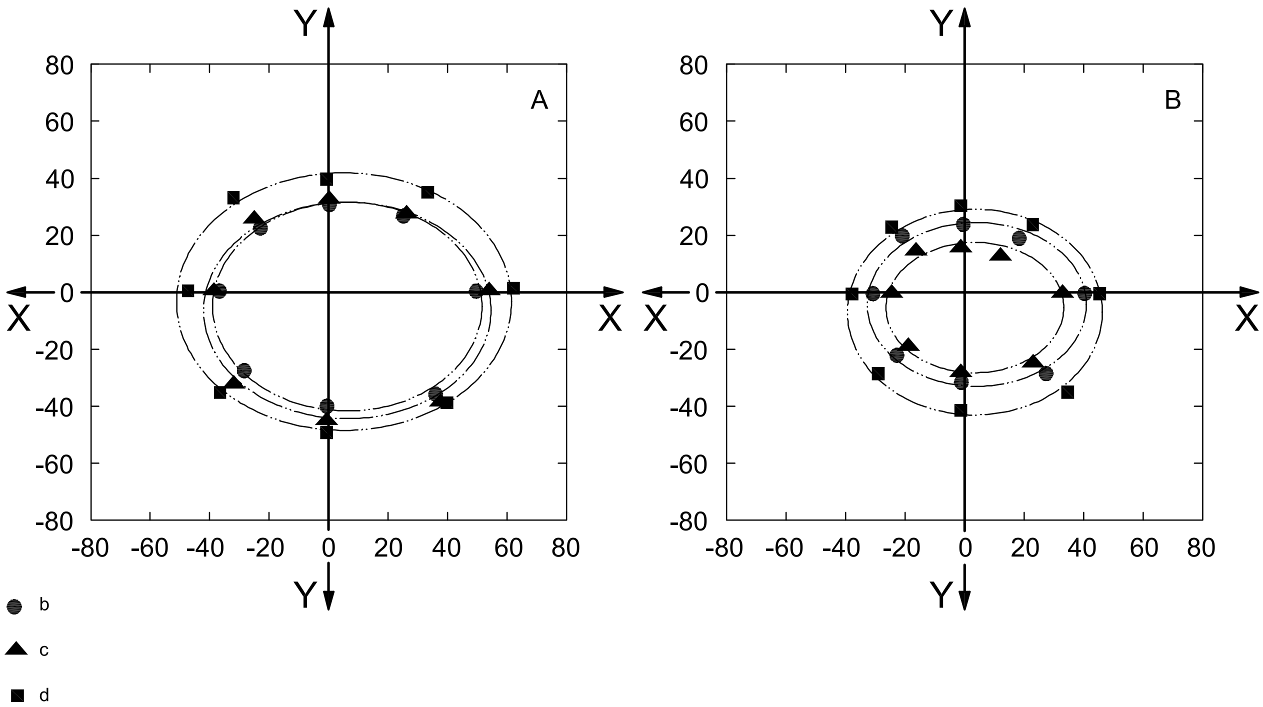
Figure 34 shows examples of the UFOV area defined by the 50 % detectability of a disk target with variable contrast, [34 a)] or with variable colour, [34 b)] presented on a uniform grey background for 50 younger people (18–26 years old), and for 50 older people (50–78 years old) [84]. Contrast is defined here as ratio between background and test target. It is clear that the UFOV is smaller for older people than for younger persons under all conditions.

Data for the UFOV can be used to determine the visibility of a target appearing in peripheral vision. Applications can be found when designing traffic signs, public emergency signs for evacuation, signs in a bus station, labelling of ATM functions in banks, and the location of switches or controls. As shown in Figure 34, the range of the UFOV declines with age, and is affected also by characteristics of the target such as size, contrast, illumination and so on. The larger the target size and the higher the contrast, the larger the UFOV span becomes. Colour difference between the target and the background is also an important factor affecting the UFOV span. The larger the colour difference, the larger the UFOV span. See also 8.3.1.1.

In peripheral vision visual sensitivity for temporal changes of light stimuli is higher than that in central vision. A light that is flickering or blinking is better detected and useful in visual signalling in the peripheral field (off visual axis).



a) Useful field of view for target only with luminance contrast (50 % detectability contour)



b) Useful field of view for coloured target on white background (50 % detectability contour)

Key

X eccentricity (horizontal), in degrees

Y eccentricity (vertical), in degrees

A younger people

B older people

[a] Luminance contrast (background to target).

[b] Red.

[c] Green.

[d] Blue.

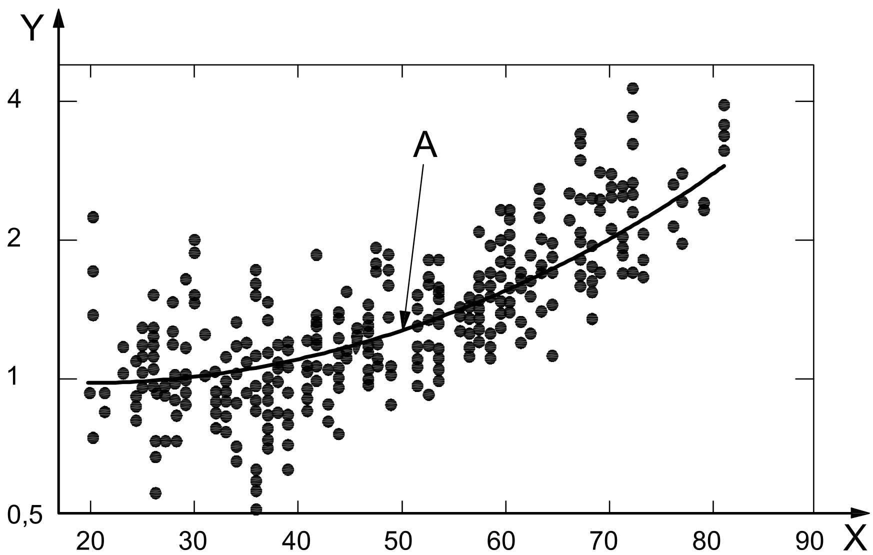
Figure 34 — Comparison of UFOV between older and younger people

9.2.1.6 Glare

Glare is the condition of vision in which light sources produce undesirable perceptual effects due to the scatter of light in the eye. These effects manifest themselves in different ways, as described by the two types of glare. *Disability glare* impairs vision and can even make certain objects invisible in the visual field. *Discomfort glare* causes annoyance or pain without impairing vision. The ageing effect on glare is critical for both types because the scattering of light in the eye increases with age. See also 8.4.4.

NOTE Disability glare involves a decrease in detectability of light signals or readability of visual signs due to the existence of very bright light near the line of sight (e.g. visibility during night driving in the presence of headlights or street lights, or visibility of traffic signals near the sun in the daytime). Discomfort glare involves the lighting of workplaces or living rooms where comfort is one of the main concerns in the visual environment.

Disability glare is caused when the scattering of light in the eye creates a veiling light superimposed over a retinal image. This veiling light, which is undesired, extra light in the eye, effectively washes out the retinal image and diminishes contrast. The relative age factor for disability glare is given by the CIE [58] as shown in Figure 35. This age factor indicates the relative increase of veiling light in the eye caused by a glare light source compared to a younger person for whom the veiling light is assumed to be nearly absent. At 70 years old, this factor is 2,0 meaning that twice as much veiling light falls on the retina in the eye of an older person, as compared to a younger person in the same viewing condition. Therefore, disability glare will be much more troublesome for an older person.



Key

X age

Y age factor

A $1 + (A/70)^4$ where A is age

Figure 35 — Relative age factor for disability glare or scattering effect in the eye [58]

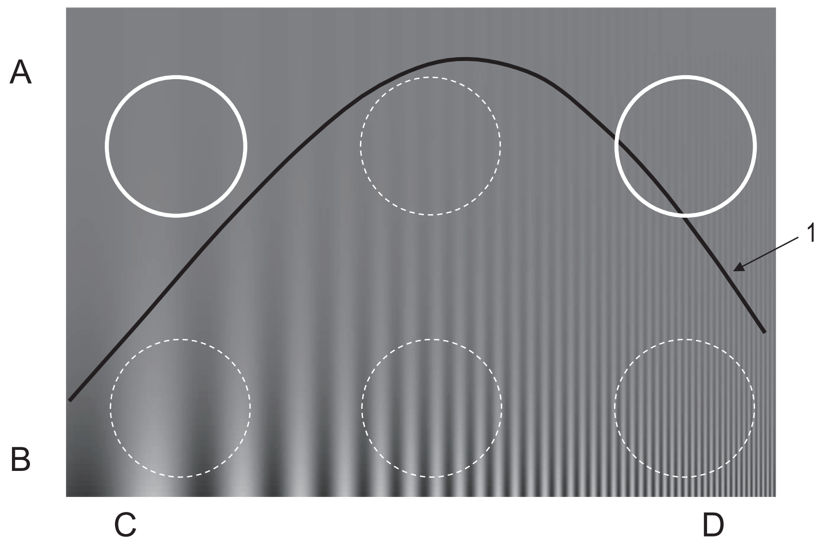
The CIE provides a method to measure discomfort glare known as the unified glare rating (UGR) and also recommends values for various workplaces which are presented in its standards [56], [85]. Unfortunately, ageing effects are not addressed.

9.2.1.7 Contrast sensitivity, including low vision sensitivity

Contrast is one of the most important issues when designing visual signs and other objects. Visual sensitivity to contrast is often measured by having participants identify whether they can see a grating pattern usually comprised of a repeating series of light and dark lines spaced at constant distances from one another. A grating pattern that cannot be seen distinctly simply appears as a solid shade of grey. The observations are made for many different gratings, which vary in contrast and spatial frequency.

NOTE 1 Spatial frequency is defined as the number of pairs of dark and light lines in 1° of visual angle. Spatial frequency units are cycles per degree (cpd). A grating with 3 cpd would have three pairs of dark and light lines in 1° of visual angle.

The contrast sensitivity function (CSF) summarizes the series of observations for persons with different contrasts and spatial frequencies. This is illustrated in Figure 36, where spatial frequency and contrast are shown together with a line that indicates the CSF. The CSF forms a grating detection borderline. In this example, human beings would have difficulty seeing patterns exhibited inside the solid circles. The human visual system has a peak of contrast sensitivity at 3 or 4 cpd. The sensitivity decreases gradually towards both ends of the spatial frequency spectrum, both for higher (i.e. finer gratings) and lower (i.e. coarser gratings) frequency regions.



Key

A low contrast

B high contrast

C low spatial frequency (coarse pattern)

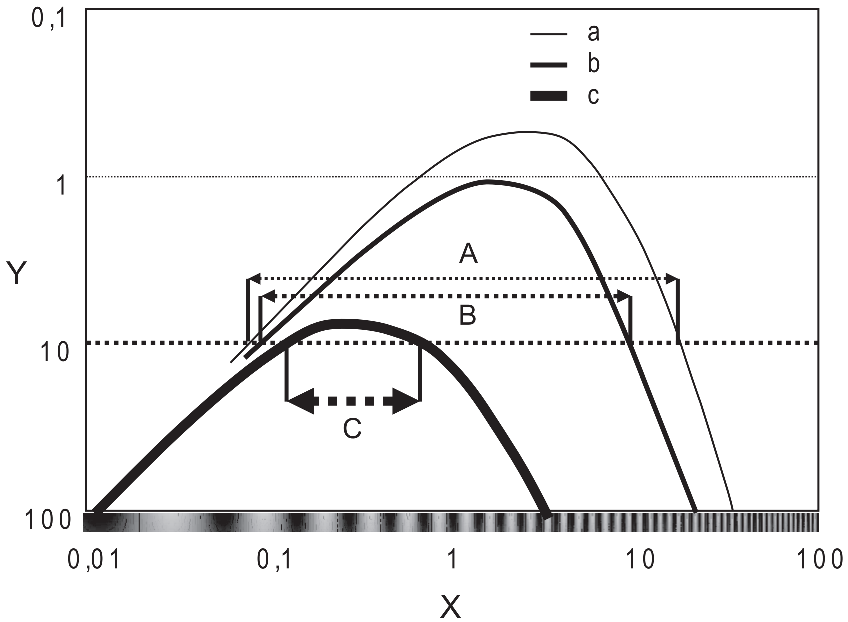
D high spatial frequency (fine pattern)

1 grating detection borderline (CSF)

Figure 36 — Contrast sensitivity function plotted by spatial frequency and contrast

Figure 37 shows three contrast sensitivity functions of the human visual system as a function of contrast (Michelson contrast) and spatial frequency. The three curves in the figure represent CSF data for younger and older people as well as those with low vision. The older people are less sensitive than the younger to frequencies higher than several cycles per degree. This means it is difficult for older people to discriminate or recognize the fine gratings that contain components in this higher frequency region. For persons with low vision, the data show much less sensitivity in middle-to-high frequency regions compared to younger or even to older people. Care needs to be taken when accommodating people with low vision because they are often unable to discriminate even coarse patterns in visual signs that can be easily discriminated by younger or older people [86], [87].

NOTE 2 Modulation contrast (Michelson contrast) is defined as $(L_{max} - L_{min})/(L_{max} + L_{min})$, where L_{max} and L_{min} are the maximum luminance and minimum luminance of one cycle of the dark and light pattern of the grating.



Key

X spatial frequency, cpd

Y contrast, %

A visible range at 10 % contrast for younger persons

B visible range at 10 % contrast for older persons

C visible range at 10 % contrast for persons with low vision

[a] Younger (20–29 years of age).

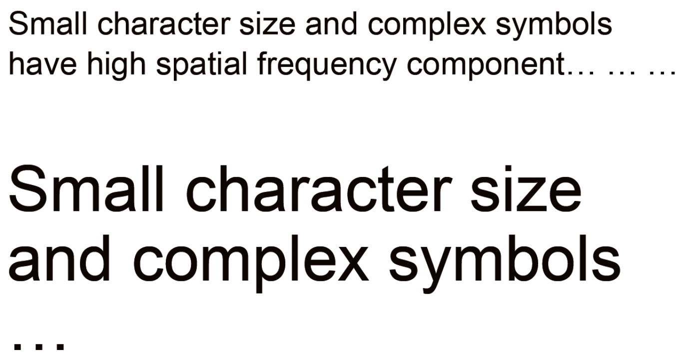
[b] Older (70–79 years of age).

[c] Low vision.

Figure 37 — Contrast sensitivity function of human visual system for younger and older people and people with low vision

The CSF data can be used by standards developers or product or service designers to estimate whether a particular visual stimulus can be detected if its contrast and spatial frequency are known. It can also provide guidance for a range of acceptable alternatives if only one variable is known. For example, for a visual stimulus at 100 % contrast (the ideal contrast of black and white characters such as those used in a Landolt ring or Snellen chart), the range of visible spatial frequencies are 0,01 cpd to 30 cpd, 0,01 cpd to 20 cpd, and 0,01 cpd to 3 cpd for younger people, older people and people with low vision, respectively. A visual pattern that contains frequency components beyond the range, i.e. higher or lower than the limit, is difficult to see clearly. At a lower contrast, 10 %, for example, the range of visible spatial frequency is very restricted. For a person having low vision, the range is limited to about 0,15 cpd to 0,8 cpd, while it is more extended from approx. 0,09 cpd to 9 cpd and 0,08 cpd to 20 cpd for older and younger people, respectively.

When designing visual signs that contain fine details at higher spatial frequencies, special care should be taken to accommodate the sensitivity losses of older persons and persons with low vision. Figure 38 illustrates how an image is seen by a person with low vision.



a) Normal vision

b) Low vision

Figure 38 — Schematic drawings of perceived images

For character design in electronic displays, the minimum required contrast is defined differently by ISO 9241-3 and ISO 13406-2. The former requires the contrast ratio between the character and the background luminance to be the constant value of 3:1, while the latter states that contrast is equal to at least $1 + 10L_L^{-0,55}$ (L_L is the background luminance). To accommodate these differences, ISO 9241-303 proposes a new formula together with the introduction of an age-related multiplier factor that increases the needed contrast for older people. This is shown below as an example.

EXAMPLE Calculation of minimum contrast required for characters designed for electronic displays:

$$CR_{min} = 2,2 + 4,84\ L_L^{-0,65} \quad (7)$$

where

CR_{min} is the minimum contrast;

L_L is the background luminance.

Then, the minimum contrast is adjusted for age using the following equation with the multiplier from Table 13:

$$CR_{min,\ age} = k_{age} \times CR_{min} \quad (8)$$

where

$CR_{min,\ age}$ is the minimum contrast required for a given age;

k_{age} is the contrast multiplier;

CR_{min} is the minimum contrast not adjusted for age.

Table 13 — Contrast multiplier for different ages

Age of Users years	**Contrast multiplier** k_{age}
20	1,00
25	1,00
30	1,02
35	1,07
40	1,17
45	1,34
50	1,58
55	1,90
60	2,28
65	2,66

9.2.1.8 Lighting level

The appropriate lighting level is a function of the visual characteristics of a person as well as the visual task in which the person is involved. A person's age and the extent of his or her visual impairment will affect the luminance level needed. The literature does not provide extensive data or methods on the appropriate lighting level for older persons or those persons with visual impairments in a wide variety of task situations.

9.2.2 Hearing

Description

Hearing functions relate to sensing the presence of sounds and discriminating the location, pitch, loudness, quality and comprehension of sounds. Hearing loss can range from a mild reduction in hearing to profound deafness.

[ISO/IEC Guide 71:2001, 9.2.2.1]

Effects of ageing

The majority of people with hearing loss are older people. As people age, they tend to lose the ability to detect higher frequency sounds. Many older people use a hearing aid.

[ISO/IEC Guide 71:2001, 9.2.2.2]

Design considerations

With or without a hearing aid, the level, frequency and clarity of any sound are important. Prelingually deaf people may have difficulty understanding written and spoken language.

[ISO/IEC Guide 71:2001, 9.2.2.3]

Risks and hazards

People with a hearing loss are at an increased risk if spoken announcements and warnings are not loud or intelligible enough for them, or if frequencies are too high to detect.

[ISO/IEC Guide 71:2001, 9.2.2.4]

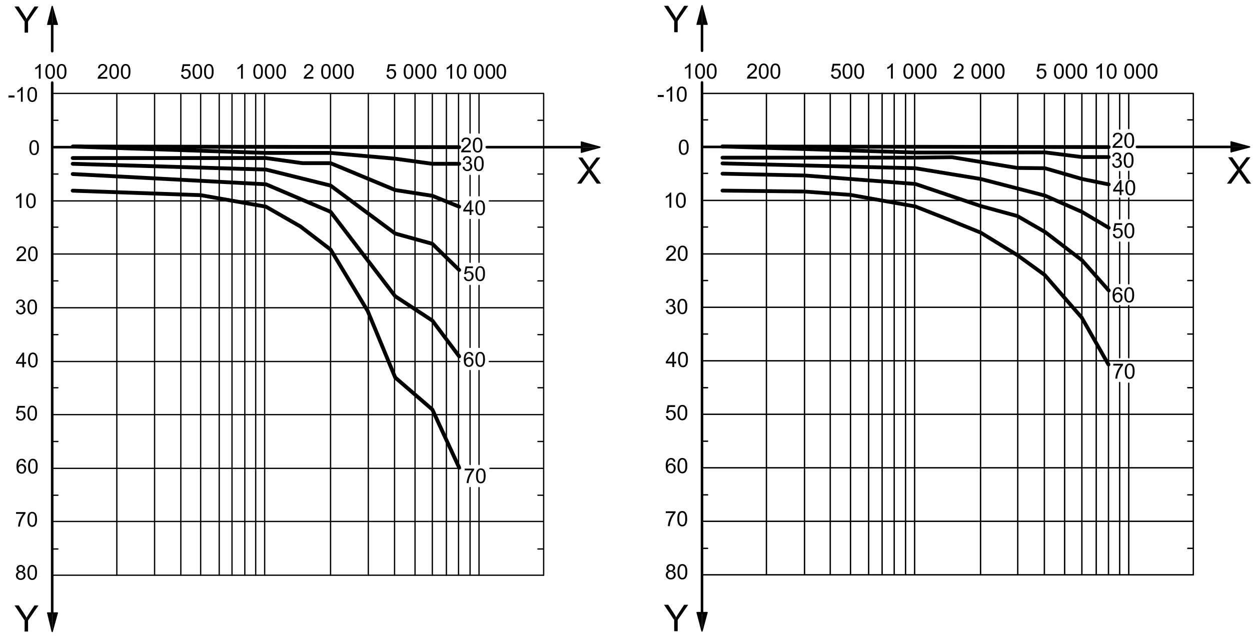
9.2.2.1 Hearing-sensitivity decrease as a function of age

The sensitivity of human hearing usually falls progressively with age and the impairment of hearing develops more rapidly for sound at high frequencies than at low frequencies.

ISO 7029 provides descriptive statistics of the hearing threshold for populations of various ages and for males and females separately. It provides data within the range of audiometric frequencies from 125 Hz to 8 000 Hz and for populations with average hearing capacity with respect to their age within the age limits of 18 years to 70 years inclusive.

Figures 39 and 40 show selected distributions from ISO 7029 which plot the hearing threshold deviation as a function of frequency, with the listener’s age as a parameter. The hearing threshold deviation is the expected median value of hearing thresholds for a particular age relative to the median hearing threshold of an 18 year old listener. For example, to ensure that 90 % of 70 year old adults can hear a 2 000 Hz signal as well as does an 18 year old, the signal would have to be made at least 30 dB louder.

Auditory signals and spoken announcements can be made audible if their sound levels are determined considering the age-related hearing sensitivity decrease. See 9.2.2.2 and 9.2.2.3 for additional data. These data can be used in designing auditory signals for products, and warning signals and spoken announcements for the workplace or other public spaces. See also 8.9 and 8.7.4.1.



a) Males, 50th percentiles (medians)

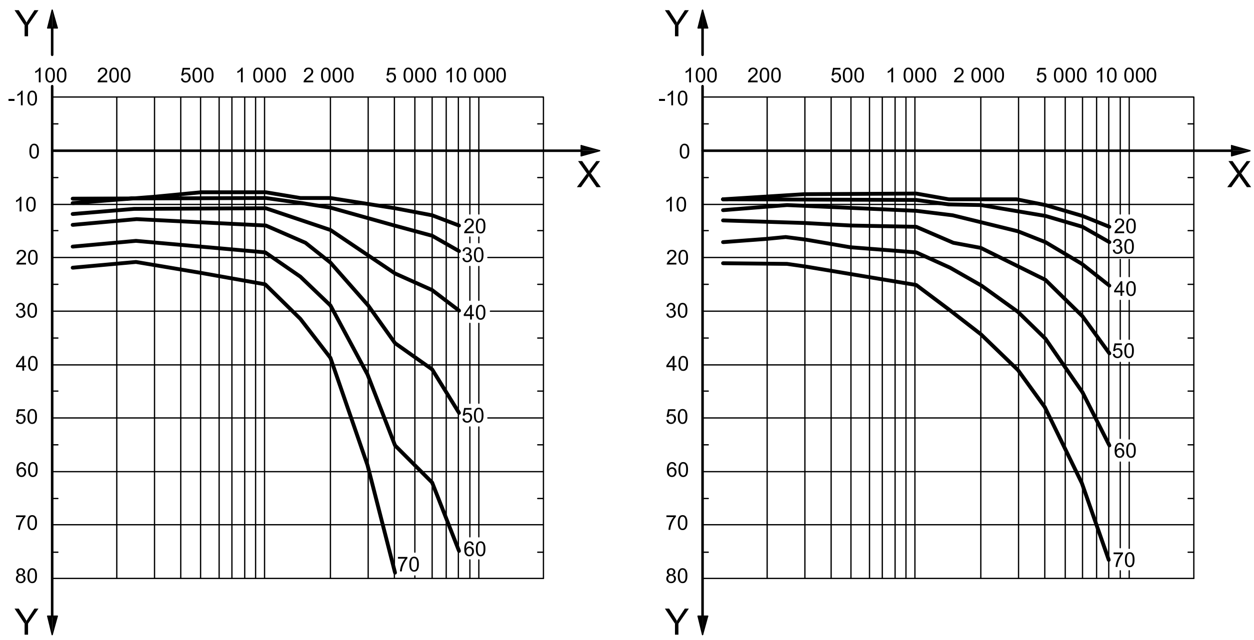
b) Females, 50th percentiles (medians)

Key

X frequency, Hz

Y hearing threshold deviation relative to 18 year old threshold, dB

Figure 39 — Hearing threshold as function of age — 50th percentiles (ISO 7029)



a) Males, 10th percentiles values

b) Females, 10th percentiles values

Key

X frequency, Hz

Y hearing threshold deviation relative to 18 year old threshold, dB

NOTE Values at ends of curves are ages in years.

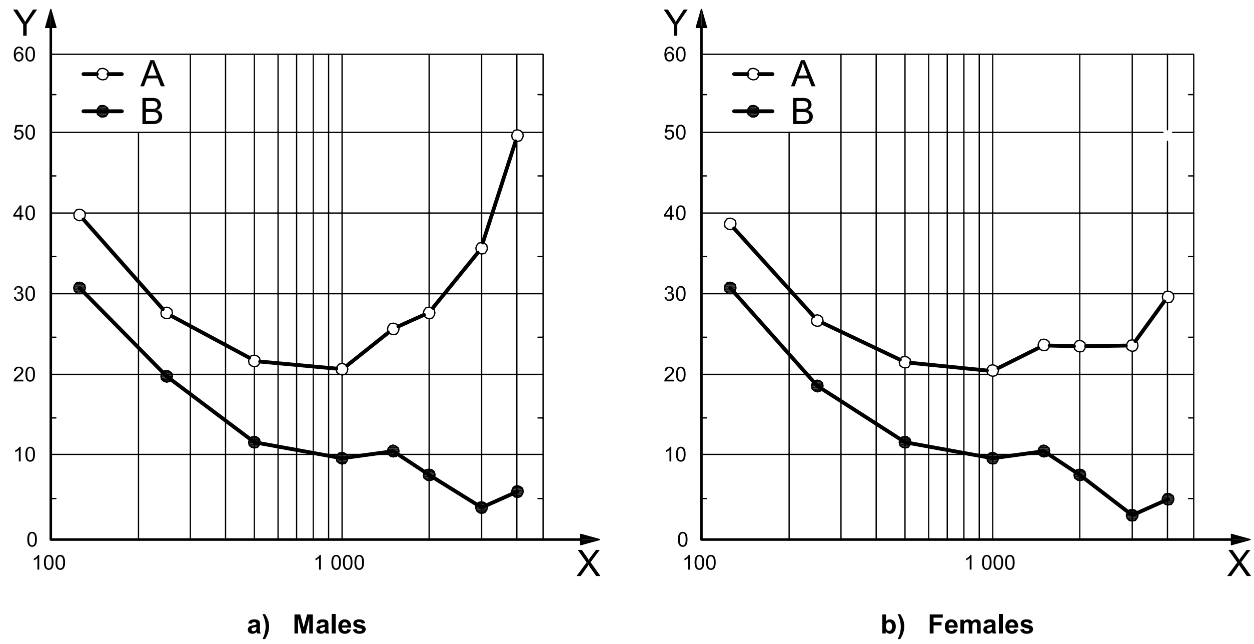
Figure 40 — Hearing threshold as function of age — 10th percentiles (ISO 7029)

9.2.2.2 Sound pressure level of auditory signals

9.2.2.2.1 Auditory signals in quiet environments

An auditory signal is expected to be audible for listeners in a quiet environment when its sound pressure level is higher than their absolute threshold. When the signal is composed of multiple frequency components, at least one component is required to exceed the threshold to make the signal audible.

Figure 41 shows the 10th percentiles of absolute threshold for persons in two age populations when they listen to a pure tone of frontal incidence in a free field. 90 % of the population are able to hear a signal in a quiet environment if the frequency and sound pressure level fall under the respective curve. These curves were obtained by combining the normative threshold (ISO 226) and the age-related threshold shift (ISO 7029).



Key

X frequency, Hz

Y sound pressure level, dB

A 60 years of age

B 20 years of age

Figure 41 — The 10th percentile hearing threshold curve of persons aged 20 and 60 (ISO 226:2003)

Although the signal level is required to be higher than the absolute threshold in order for them to be audible, an excessively intense sound can be annoying for the listener.

In quiet surroundings, acoustic signals of 55 dB – 65 dB (A) are usually preferable [46] for listeners including older people without serious hearing loss [88].

9.2.2.2.2 Auditory signals in noisy environments

In noisy conditions, the audibility of a signal is determined by the frequency component that has the largest power in relation to the interfering noise. When the level of that component exceeds the noise in the same frequency band by a certain amount, the signal is audible against the noise.

The minimum level difference between an audible signal and a background noise has been determined experimentally, as shown in Table 14 [89]. The listeners were young adults aged 18 to 24 and older adults aged 55 to 79, all having otologically normal hearing for their ages. The signal was a short pure tone and the background noises were domestic noises typical in Japan [90]. When the signal level was higher than the noise level by the amount given in Table 14, ninety percent of each listener group responded that the signal was barely audible. In the same experiment, both listener groups responded that the signal was audible enough when the signal level reached 75 dB.

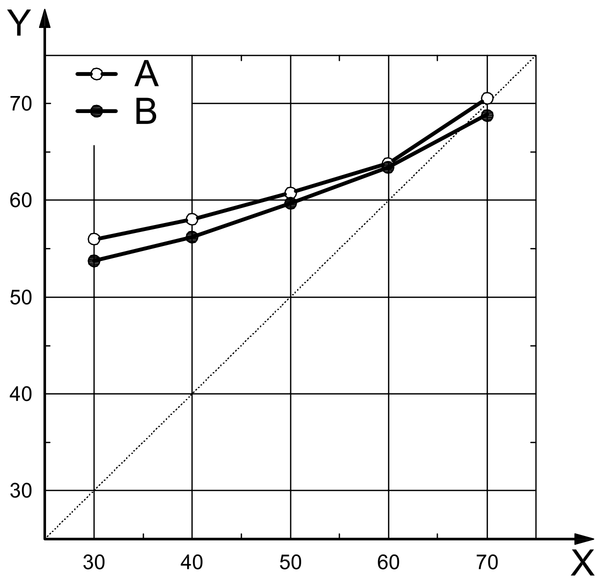
Table 14 — Minimum level difference between signal and background noise in order for the signal to be audible against the noise

Centre frequency of one-third octave band, Hz		250	500	1 000	2 000	4 000
Minimum level difference between the signal and the noise, dB	For young adults	11	11	6	4	3
	For older adults	11	11	4	11	11

9.2.2.3 Sound pressure level of spoken announcements in public space

When spoken announcements are comfortably loud, listeners require little effort to comprehend them. But, when the sound level of announcements is too high or too low, word recognition generally decreases.

The comfortable range of spoken announcements in quiet and noisy conditions can be determined experimentally with younger and older listeners. Figure 42 shows the results of one such experiment examining the preferred speech announcement level against different background noise levels [88]. Announcements were Japanese four-mora words. Eight words were successively presented to listeners via loudspeakers in a soundproof room against noise that simulated the sound frequency of multiple talkers. The listeners were 26 young adults aged 19–23 and 60 older adults aged 64–82 all with Japanese as their first language. They were instructed to listen to the presented words carefully for a word recognition test after each presentation. This method and data can be applied to spoken announcements in a public space, not those over a telephone.



Key

X noise level, A-weighted decibels

Y speech level, A-weighted decibels

A older adults

B young adults

Figure 42 — Preferred speech announcement level as function of background noise level

9.2.2.4 Design of voice instructions

Voice instructions are widely used not only as an alternative format for visually impaired persons, but also for general information for all persons in private as well as in public spaces. These may be heard in the presence of background noise, which may decrease comprehension of the instructions and a consideration for better understandable design will be required.

The following accessibility considerations are relevant to the design of voice instruction.

— The frequency range of the speech instructions between 300 Hz and 3 400 Hz [46] is a minimum requirement.

  NOTE 1 Frequency ranges above 3 400 Hz are expected to give better perception of consonants in general.

— Use a “relaxed” or “normal” vocal effort (ISO 9921) to avoid reducing speech quality.

  NOTE 2 Relaxed and normal vocal effort is, respectively, 54 dB and 60 dB in the case of a male speaker. Vocal effort is defined as an A-weighted speech level, $L_{\text{s A,1 m}}$ (dB re 20 μPa) at 1 m in front of the speaker's mouth (ISO 9921).

— Use clear speech, which typically has higher temporal amplitude modulation and contrast in frequency. Maintain the quality of speech transfer, such as in the channel of a sound system, to minimize unwanted distortion of the speech signal.

9.2.2.5 Audible conditions for speech communication in a noisy environment

The auditory conditions necessary to keep speech communication understandable and to prevent listening difficulty are provided in Reference [91]. The conditions are presented in decibels, taking into account the age-related decrease of hearing ability (see 9.2.2.1). Since spoken announcements are sometimes heard against a background noise, a specific signal-to-noise ratio is to be maintained. See 8.7.4.4 and 9.2.2.3.

NOTE 1 *Signal-to-noise ratio* is the numerical difference between the sound-pressure level of the speech signal compared to the sound-pressure level of the background noise.

Figure 43 presents a study of word recognition rate and listening difficulty as a function of signal-to-noise ratio. Data were measured using young (19–24 years old) and older (64–82 years old) listener groups in an ambient noise environment of around 50 dB (A-weighted) [92]. Only 10 % of the participants experienced listening difficulty when the signal-to-noise ratio was 10 dB (A-weighted) for young listeners and 15 dB (A-weighted) for older listeners. A signal-to-noise ratio of 10 dB (A-weighted) also corresponds to the point where young listeners begin to have perfect word recognition rates.

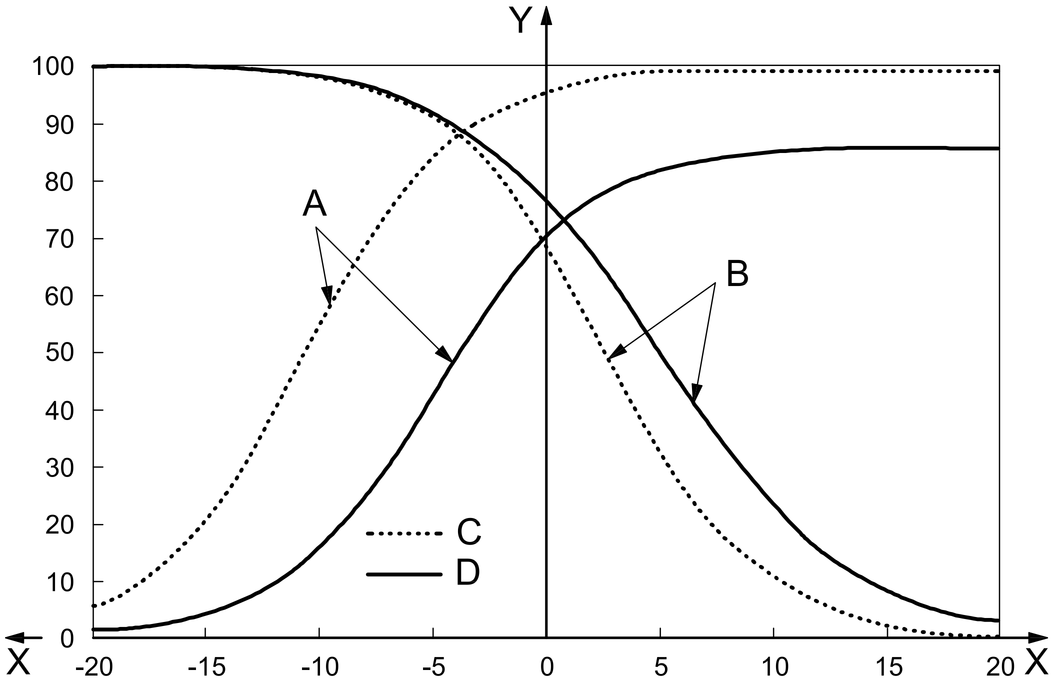
NOTE 2 The mean PTA [(pure tone average) of the hearing threshold at 0,5 kHz, 1 kHz and 2 kHz)] of the young and elderly listener groups’ hearing levels were 4 dBHL and 23 dBHL, respectively.

The Japanese word recognition test score of average young listeners used here was calibrated with a phonetically balanced (PB) word score in ISO 9921. The score of the Japanese word recognition test for older listeners is presented in relation to average young listeners. Finally, STI values (see 8.20.1) corresponding to each score for the older listeners were estimated with the relation between PB word scores and STI values in ISO 9921. See also 8.20.1. The PB word score is the percentage of correct of word recognition obtained by speech intelligibility testing with PB word list.

Results of this psychoacoustic experiment and others suggest the following criteria to ensure audible speech communication for elderly listeners without severe hearing loss:

— in order to maximize understanding of simple speech information, a signal-to-noise ratio larger than 10 dB (A-weighted) [46], see Figure 43;

— in order for listeners to listen to speech without difficulty, a signal-to-noise ratio larger than 15 dB (A-weighted), see Figure 43.



Key

X signal-to-noise ratio, A-weighted decibels

Y world recognition rate and listening difficulty, %

A word recognition

B listening difficulty

C young listeners

D older listeners

Figure 43 — Example of word recognition rate and listening difficulty as function of signal-to-noise ratio for young and older listener groups

9.2.2.6 Acoustical design for speech intelligibility

When creating environments where maximizing speech intelligibility is important, acoustical design methods can be applied to reduce background noise and reduce reverberation time. These properties are all affected by the size and shape of an environment, its contents, as well as its construction materials.

NOTE 1 *Reverberation time* is the length of time for a sound signal to drop 60 dB from its original level. See 8.20.1.

To predict speech intelligibility in an environment, the speech transmission index (STI) measure can be used. This measurement method is presented in Reference [79]. ISO 9921 presents the necessary intelligibility ratings for several applications as shown in Table 15. ISO 9921 also presents the relationship between intelligibility ratings and STI. Table 16 presents the relationship between intelligibility ratings and STI value for normal listeners as given by ISO 9921, and that for elderly listeners calculated with the data plotted in Figure 43.

NOTE 2 The STI is a single value which measures the physical quality of speech transmission channels. STI values vary between 0,0 (unintelligible) and 1,0 (perfectly intelligible). See 8.20.1.

The following procedure can help standards developers or product designers determine and evaluate the speech intelligibility for their environment:

a) **Determine the desired STI**

First, determine the situation in which communication will take place, as described as the application in Table 15 and reference the “Minimum intelligibility rating” for that context. After determining the type of users impacted, use Table 16 to determine the acceptable STI range to achieve the intelligibility rating. For example, when creating a public address system that older users will need to hear, select the minimum intelligibility rating of “Fair” (Table 15) and a desired STI range between 0,60 to 0,75 (Table 16).

b) **Determine the predicted STI**

Determine the signal-to-noise ratio and the reverberation time of the environment to predict the STI value as described in ISO 9921. Figure 44 is an example dataset presenting the relationship between reverberation time, (ISO 3382) signal-to-noise ratio, and STI [79]. For example, if the environment’s signal-to-noise ratio is 12 dB and its reverberation time is 0,2 s, then the predicted STI value is about 0,8.

c) **Compare the desired STI to the predicted STI**

If the predicted intelligibility rating does not meet desired criteria, reduce the environment’s noise level and/or reverberation time to meet the criteria and repeat the analysis.

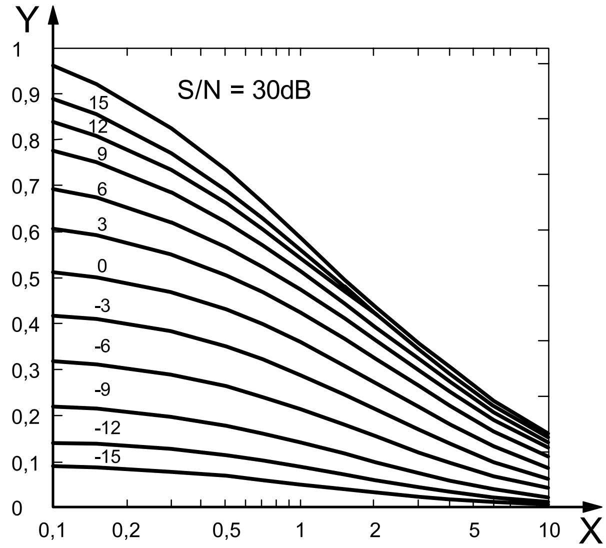
Table 15 — Recommended minimal performance ratings for acceptable speech intelligibility and vocal effort in six applications, as described in ISO 9921

Application	Minimum intelligibility rating	Maximum vocal effort
Alert and warning situations (correct understanding of simple sentences)	Poor	Loud
Alert and warning situations (correct understanding of critical words)	Fair	Loud
Person-to-person communication	Fair	Loud
Person-to-person communication (prolonged normal communication)	Good	Normal
Public address in public areas	Fair	Normal
Personal communication systems	Fair	Normal
NOTE Loud and normal vocal effort is, respectively, 72 dB and 60 dB in the case of a male speaker. Vocal effort is defined as an A-weighted speech level, $L_{\text{s, A, 1 m}}$ (dB re 20 µPa) at 1 m in front of the speaker's mouth in ISO 9921.		

Table 16 — Intelligibility rating and relation between STI for persons with normal hearing and older listeners

Intelligibility rating (ISO 9921)	**STI for normal hearing person** (ISO 9921)	**STI for older listeners** (23 dBHL of PTA of 0,5 to 2 kHz based on Figure 44)	**Meaningful PB-word score for people with normal hearing** (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 3 STI-values for older listeners were estimated based on Figure 44 with conversion from signal-to-noise ratio to STI. Since the maximum score of the older listener group cannot reach 100 %, all the scores are standardized by the maximum score to estimate STI-values for older listeners.



Key

X reverberation time, s

Y speech transmission index (STI)

S/N signal-to-noise ratio

Figure 44 — Example of relationship between STI, reverberation time in an ideal diffused sound field and signal-to-noise ratio

NOTE 4 Normal vocal effort for a male voice (ISO 9921), and typical room noise spectra [91] were used to obtain the STI. The STI value for similar conditions could be obtained with the reverberation time and S/N.

9.2.3 Touch

Description

Touch functions relate to sensing surfaces and their texture or quality. There will be reliance on other stimuli, particularly visual and auditory.

[ISO/IEC Guide 71:2001, 9.2.3.1]

Effects of ageing

As people age, they lose sensitivity and can no longer rely on touch and pain to give early feedback on temperature or injury.

[ISO/IEC Guide 71:2001, 9.2.3.2]

Design considerations

People with artificial hands or who lack touch sensation may not be able to use tactile screens or similar types of control devices.

[ISO/IEC Guide 71:2001, 9.2.3.3]

Risks and hazards

People with a hypersensitive touch will be hurt by stimuli which might cause only discomfort to other people – for example, by sharp points and edges, and very hot/cold surfaces. These stimuli are also more likely to harm people with limited sensitivity, who might remain in contact with them for too long.

[ISO/IEC Guide 71:2001, 9.2.3.4]

9.2.3.1 General

The sense of touch is classified into four categories: tactile, haptic, thermal, and pain senses. *Tactile* sense is mediated by the mechano-receptor in skin in a static contact mode, so-called “passive touch”. The detection of grooves and vibration falls into this category. *Haptic* sense is generated by active touch where exploratory touch, usually by hands or fingers, works to get information about texture and the geometric distances of objects. Most of the information obtained by touch in everyday life is classified into this category. *Thermal* and *pain* senses are each of them cutaneous sensations, used to obtain information on temperature and nociceptive stimuli.

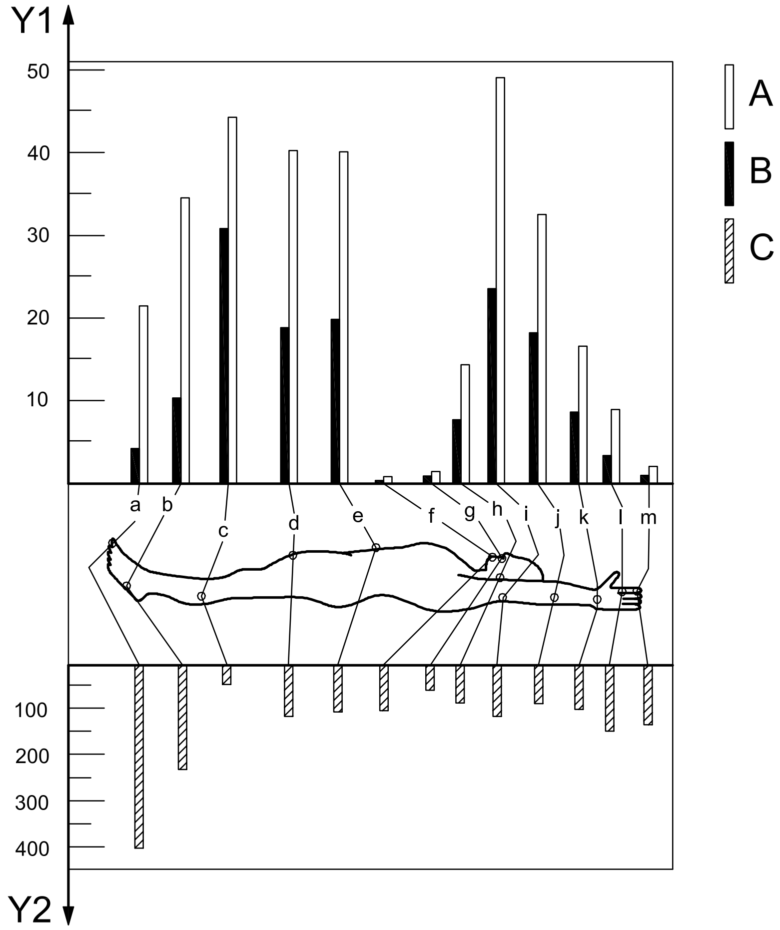
In 9.2.3.2, 9.2.3.3.and 9.2.4, data are given on the spatial and temporal resolution of the tactile sense as well as on the thermal sense. Useful data for other senses of touch, such as pain sense, are not currently available for accessible design.

9.2.3.2 Tactile spatial resolution

Spatial resolution is the most important tactile characteristic to be considered when creating alternatives to visual information on spatial content. Spatial resolution is the ability to determine the distance between two objects presented simultaneously on the skin. The threshold is generally measured by the closest distance two objects can be apart and still sensed separately.

Tactile spatial resolution largely depends on the part of the body concerned. The most sensitive parts include the fingers, nose and lips, and the least sensitive parts, the back, legs and the soles of the feet. For fingers, the resolution is approximately 1 mm–3 mm, with the forefinger having the highest sensitivity.

The ageing effect on tactile spatial resolution has been reported [93]. Figure 45 shows the averaged two-point gap acuity for 30 younger persons (18-28 years of age) and 31 older persons (over 65 years of age) for 13 body regions. The data show that for all body regions, the thresholds are much higher for older participants than younger. Older persons thus have much less tactile spatial resolution capability. The vertical bars in the lower half of Figure 45 show the percentage difference in threshold from average younger to average older. The most prominent ageing effects can be seen in the soles of the feet and toes. In general, sensitivity decreases for older persons by about 50 % for a whole body region.



Key

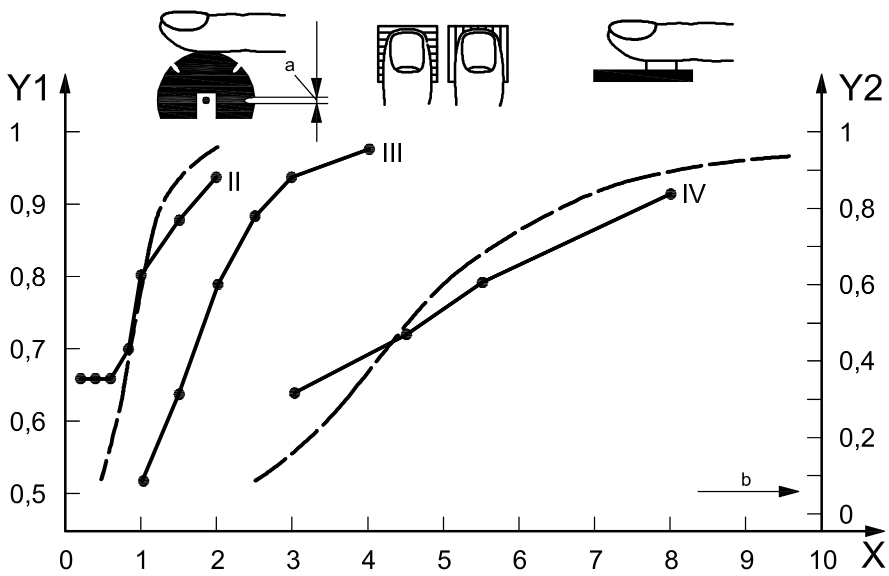
Y1 mean threshold (mm)
Y2 % decline with age

A over 65 years of age
B 18 years–28 years of age
C % decline

[a] Toe.
[b] Sole.
[c] Calf.
[d] Thigh.
[e] Belly.
[f] Tongue.
[g] Lip.
[h] Cheek.
[i] Upper arm.
[j] Forearm.
[k] Palm.
[l] Finger (base).
[m] Fingertip.

Figure 45 — Ageing effect on tactile spatial resolution

Spatial resolution also changes with the type of user task. Figure 46 [94] shows three typical examples of tactile spatial resolution measured for different tasks: 1) to detect a gap with variable width embedded in a rotating rounded surface (left, curve II), 2) to recognize the orientation of a tactile grating pattern with variable width (middle, curve III); 3) to recognize a raised letter of variable size (right, curve IV). The abscissa denotes gap width, grating period and letter size (in height) in millimetres for each task. The probability of correct response for detection or recognition is shown as the ordinate. The threshold, when defined by a 75 % correct response rate, for the gap detection and the grating orientation recognition is about 1 mm and 2 mm, respectively. For letter recognition, the threshold, defined as 50 % correct, is 5 mm. The dashed curves, overlapped with curve II and curve IV in Figure 46, represent curve III scaled horizontally by factors of 1/2 and 5/2, respectively, to make a relative comparison.



Key

X stimulus dimension (gap width, grating period, letter height)

Y1 probability of correct response (gaps and gratings)

Y2 probability of correct response (letters)

a Gap.

b Chance level.

II, III and IV see text for explanation.

Figure 46 — Tactile spatial resolution

The threshold values presented here can be used when tactile markings or signals are designed. However, it should be noted that tactile spatial resolution depends on the stimulus condition such as temperature of the surface, moving or static stimuli, on whether it is wet or dry. It is also critical to specify the type of touch, either free-moving (an active touch in which the person can move fingers or hands voluntarily to obtain tactile information) or fixed touching (a passive touch where fingers are not allowed to move but the stimulus moves). It is generally agreed that an active touch is more sensitive than a passive touch.

Persons with diabetes may have neurosensory pathology where tactile sense becomes less sensitive or causes pain instead. For example, it would be painful for some persons with diabetes to read Braille for a long period of time.

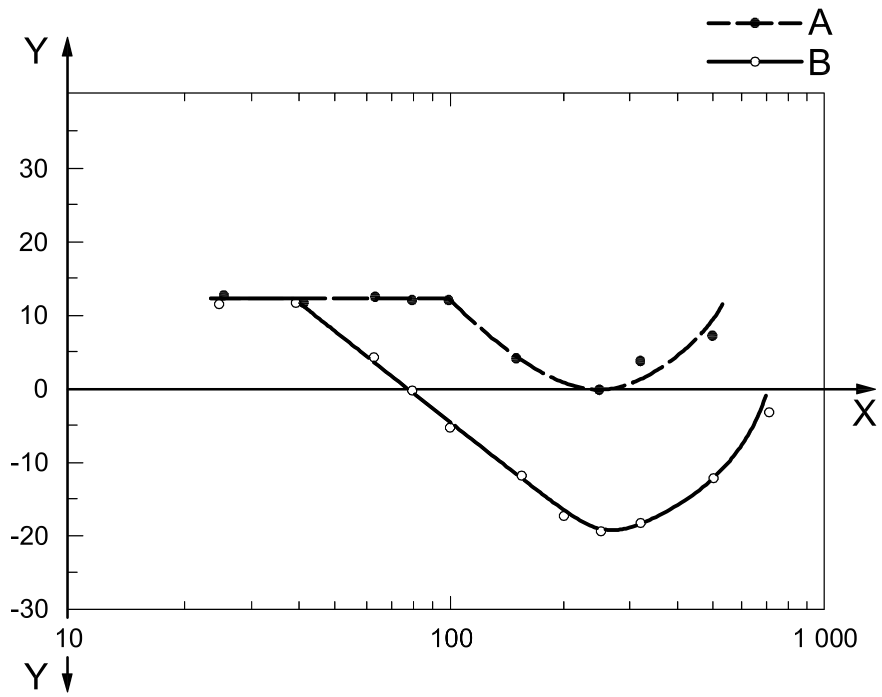
9.2.3.3 Tactile temporal resolution

Vibration, or the temporal change of a tactile stimulus, is useful for conveying information. For example, this vibration is used in alarm clocks and mobile phones in silent mode. People are relatively sensitive to vibrations, but sensitivity declines with age.

NOTE The temporal change of the stimulus, or its frequency, is usually measured in hertz and indicates the number of cycle movements in a second.

Figure 47 indicates the manner in which two typical persons at 20 years and 65 years of age are able to detect vibrations of different frequencies and amplitude. The abscissa denotes the frequency of a vibro-tactile stimulus. The threshold is plotted by the ordinate which denotes the amplitude of the vibration stimulus (expressed in dB relative to 1,0 micrometre of vibration). For both a younger and an older person, the frequency at which they were most sensitive (i.e. minimum threshold) is observed at about 250 Hz around which the threshold increases (sensitivity decreases) gradually. Below about 40 Hz for a younger participant, and about 100 Hz for an older participant, sensitivity remains constant. [95]

This data indicates that temporal discrimination sensitivity for tactile vibration decreases with age for a range of higher frequencies above about 40 Hz. Below 40 Hz, there is no age-related difference in tactile temporal resolution.



Key

X frequency, Hz

Y threshold, dB re 1,0 µm (Peak)

A 65 years of age

B 20 years of age

Figure 47 — Temporal resolution of tactile sense for a younger and an older person

9.2.3.4 Thermal sense

9.2.3.4.1 Surface temperature

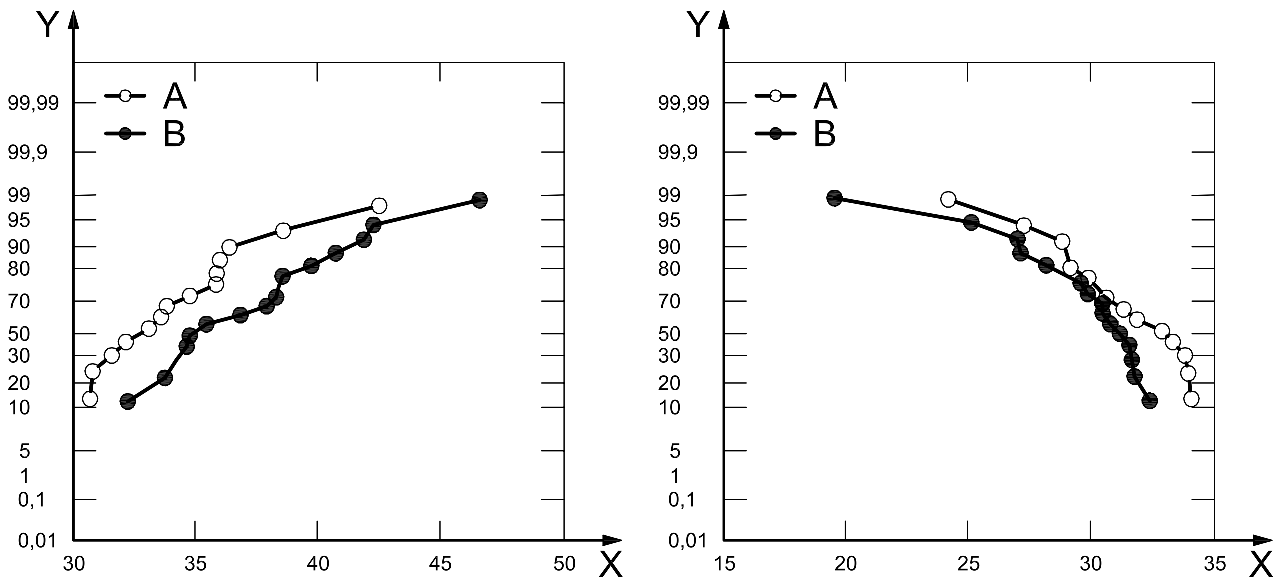
People will indicate that the surface of an object is either warm or cold at different temperature levels. This subjective reporting of temperature varies by age. Figure 48 provides data from a study in which an object at a thermoneutral (an equilibrium condition where no heat is coming in or out) condition between 30 °C and 35 °C (the temperature that people did not report as warm or cold) was gradually made warmer or colder by a thermostimulator while the air temperature remained constant at 28 °C. A total of 16 younger and 16 older individuals were asked to report when they felt the surface temperature become warm or cold. The graphs show the percentage reporting that the surface felt warm or cold at a given temperature level. As the surface temperature increased or decreased, the corresponding percentage of people who reported feeling it as warm or cold increased respectively.

However, there is a clear difference between the stages at which younger and older individuals felt that the surface temperature was warm.

The surface temperature that young persons typically felt as warm was 34 °C or above, whereas the surface temperature that older individuals felt as warm was 38,5 °C or above.

The surface temperature that both young and older individuals typically felt as cold was around 30,5 °C and below.

Therefore, the appropriate and most acceptable surface temperature range for both younger and older persons was between 30,5 °C and 34 °C [96].



a) Warm

b) Cold

Key

X surface temperature, °C

Y percentage, %

A younger persons

B older persons

Figure 48 — Percentage of older or younger persons who reported feeling a surface temperature as either warm or cold

NOTE Measurement and evaluation methods as well as a discussion of the general issues for surface temperature are found in relevant International Standards on the thermal environment (ISO/TS 14415, ISO 13732-1, ISO/TS 13732-2, ISO 13732-3), but useful data and evaluation methods on ageing effects have not been provided.

9.2.3.4.2 Air temperature

The thermal sense (i.e. a feeling of warmth or coldness) of air temperature depends not only on the measured temperature but also on age, season, humidity, air velocity and clothing. The ambient air temperature can be set appropriately by referring to basic physiological data between the thermal sense and air temperature.

Figure 49 [90] contains data showing thermal sense and unacceptable rate (%) as a function of air temperature [73]. The unacceptable rate is defined here as the percentage of people who do find the air temperature condition unacceptable. The data were taken for both Summer and Winter seasons under the conditions in which the relative humidity was 60 %. The mean radiant temperature was equal to the air temperature, and the air velocity was less than 0,3 m/s. The individuals wore long-sleeved shirts and long pants of 0,6 Clo.

NOTE *Clo* is a special unit of thermal insulation used in International Standards: 1 clo = 0,155 $m^2 \cdot K \cdot W^{-1}$. An overall Clo value can be calculated by simply taking the Clo value for each individual garment worn by the person and adding them together (ISO 9920:2007). Zero (0) Clo corresponds to a naked person; one (1) Clo corresponds to a person wearing a typical business suit.

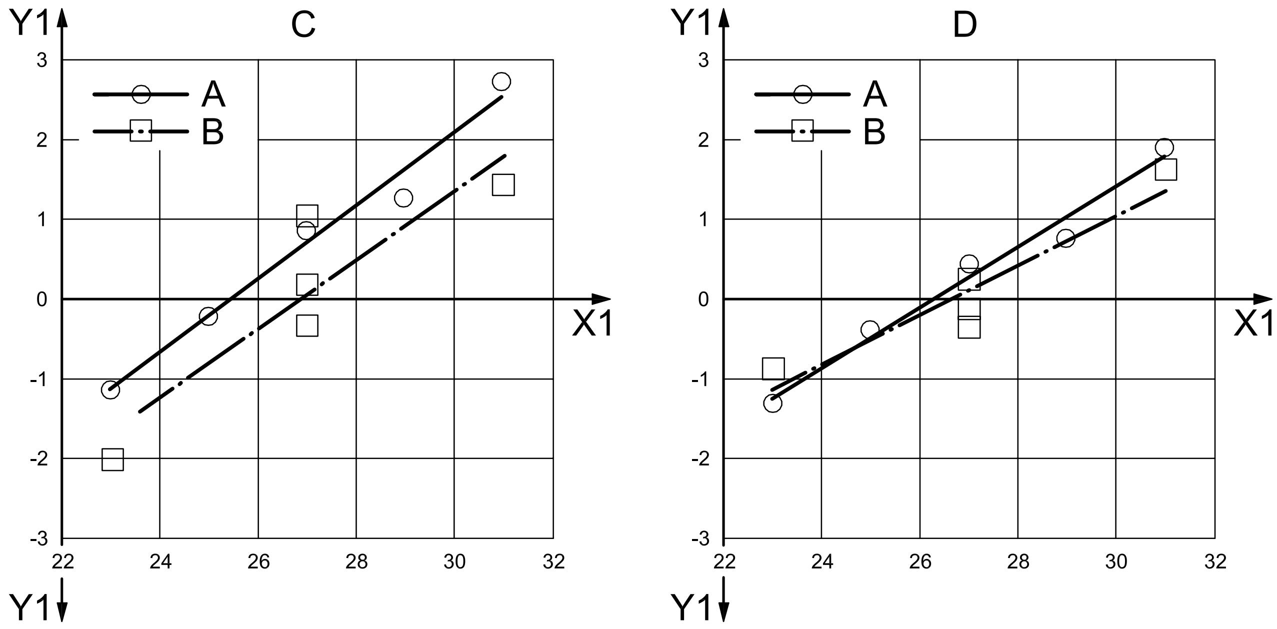
Figure 49 a) shows the relationship between thermal sense and air temperature in Winter and Summer. The effect of seasonal acclimatization indicates that the thermal sense in Winter is hotter than that in Summer. Thus, the point that individuals do not feel hot or cold is obtained at 25,5 °C in Winter and 27,5 °C in Summer, respectively, for younger individuals. The neutral temperature for older individuals wearing the same light long-sleeved clothing is 26,5 °C in both the Summer and Winter seasons.

Figure 49 b) depicts data showing the relationship between unacceptable rate (%) and air temperature. The effect of seasonal acclimatization is also shown, as an unacceptable rate that is lower in Summer than in Winter, at a temperature higher than the neutral temperature.

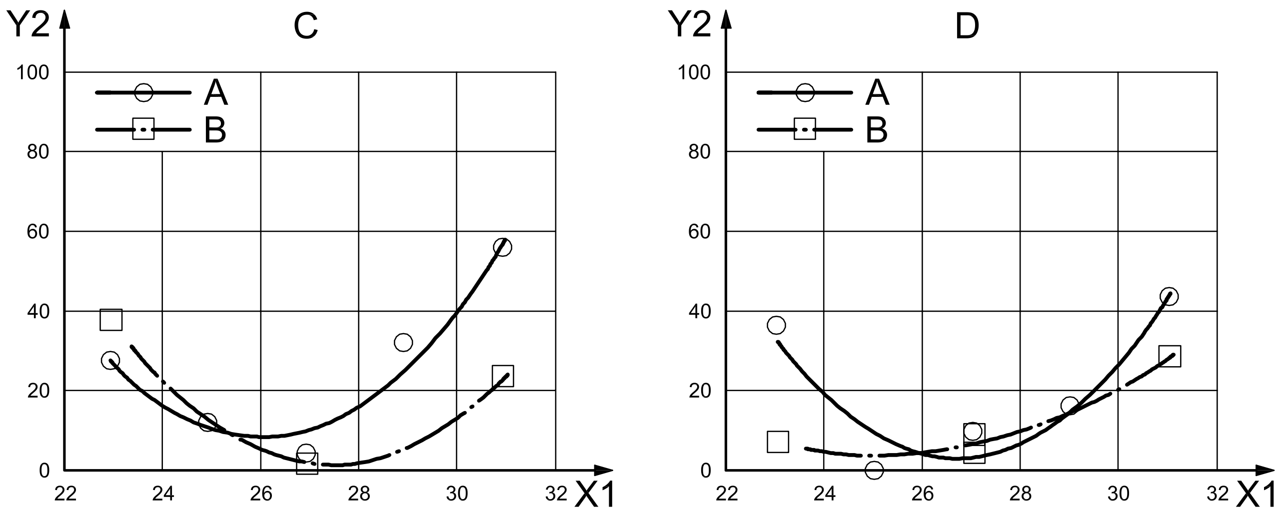
The range over which 75 % of younger individuals feel that the temperature is acceptable is between 23 °C and 28,5 °C in Winter and between 23,5 °C and 31,5 °C in Summer. But as clothing insulation increases up to 1,2 Clo in winter, the acceptable temperature range drops to between 20 °C and 24,5 °C. When the clothing insulation reduces to 0,4 Clo in Summer, the lower threshold of the acceptable temperature range is 26 °C.

These two data sets are combined in Figure 49 c), where the relationship between unacceptable rate and thermal sense is shown. Again, the effects of seasonal acclimatization result in an unacceptable rate that is lower in Summer than in Winter at the cooler than thermoneutral sensation.

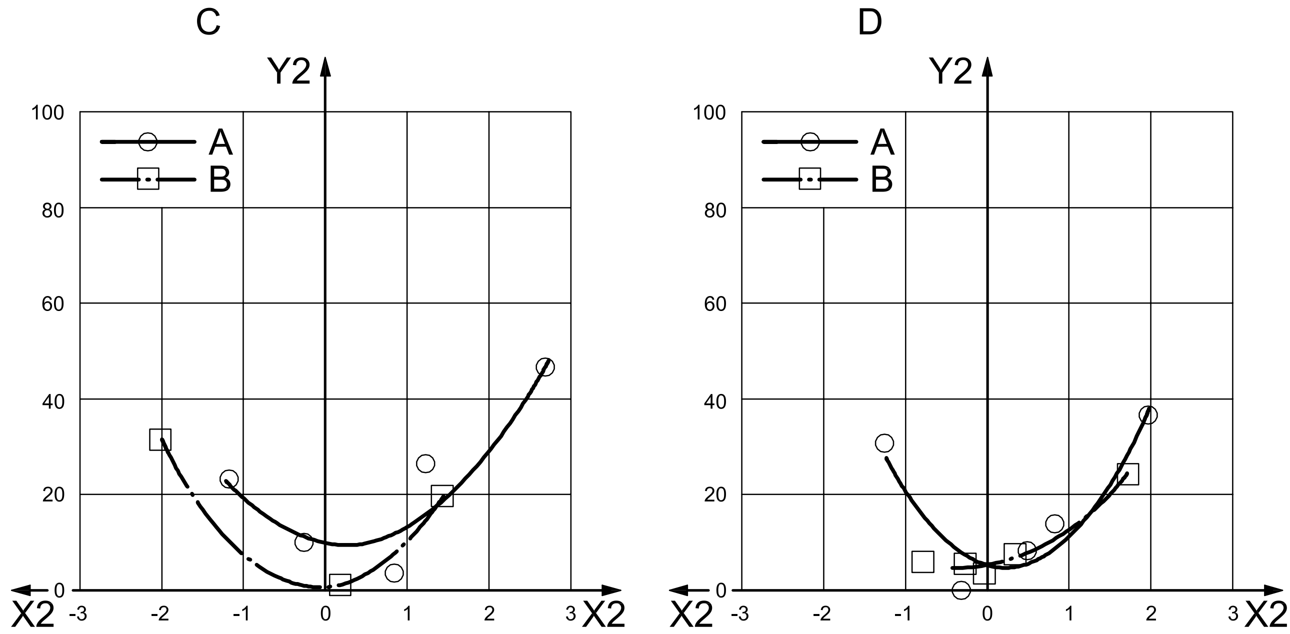
Air temperature has a slightly larger effect on younger people than older people in judgment of thermal sense [Figure 49 a)]. Older people are less likely to feel hot and cold in the higher and lower temperatures, respectively. This decreasing response in thermal sense might be caused by their lower thermoregulatory response ability. Therefore, care should be taken not to expose older persons to extreme ranges of temperature.



a) Thermal sensation vs. air temperature



b) Unacceptable rate vs. air temperature



c) Unacceptable rate vs. thermal sensation

Key

X1	air temperature, °C	A	Winter
X2	thermal sensation	B	Summer
Y1	thermal sensation	C	younger individuals
Y2	unacceptable rate, %	D	older individuals

Figure 49 — Data on thermal sensation in summer and winter for younger and older people [90]

Thermal sense and the unacceptable rate might also reflect gender differences, ethnic differences or national-geographic location differences and so on. The relevant data for those differences, however, are not yet sufficiently available.

9.2.4 Taste/smell

Description

Taste and smell are separate senses but have been grouped together in the Tables because of their similar practical implications. Taste relates to sensing four basic qualities, through receptors on the tongue: bitter, sweet, sour and salty. Smell relates to the use of receptors in the nose to sense odours and smells. The two senses of taste and smell are used together to identify the range of flavours which can normally be distinguished.

[ISO/IEC Guide 71:2001, 9.2.4.1]

Effects of ageing

The ability to detect odours decreases as people get older.

[ISO/IEC Guide 71:2001, 9.2.4.2]

Risks and hazards

Impairment of the sense of taste or smell reduces the body’s defence against toxic materials. For example, people may not be able to detect when food has deteriorated or be alerted to hazards such as smoke.

[ISO/IEC Guide 71:2001, 9.2.4.3]

No additional guidance is offered.

9.2.5 Balance

Description

The ability to maintain balance and avoid falling is dependent on a complex system, which involves the brain coordinating visual stimuli, feedback from the balance mechanism in the ear and movement of the limbs. Continuous control of balance is required during virtually all types of activities.

[ISO/IEC Guide 71:2001, 9.2.5.1]

Effects of ageing

The incidence of balance impairments, and thus falls, increases with age. Age-related attention deficits and visual impairment can reduce the ability to avoid hazards and to react to loss of balance.

[ISO/IEC Guide 71:2001, 9.2.5.2]

Risks and hazards

Slips, trips or other unexpected disturbances to balance require rapid responses in joint rotations and limb movements and can place extraordinary demands on the balance control system. Even very small edges and protrusions can cause tripping. Older persons are more vulnerable to injury from falls as bones break more easily and consequent complications may be life-threatening. Balance impairment can lead to an increased fear of falling. People in wheelchairs, powered scooters and walkers may have balance limitations, and injuries can severely affect their independence.

[ISO/IEC Guide 71:2001, 9.2.5.3]

No additional guidance is offered.

9.3 Physical abilities

In principle, all physical abilities decrease with age. Studies throughout the world have shown a decline in stature with age after peaking at approximately 25 years–35 years.

There is hardly any change with age for static body dimensions. However, the evaluation of available documents from many countries indicates that decreasing mobility and strength related to growing older can cause problems in daily life. In Table 17 and the following clauses, detailed age-dependent data measured by different countries and institutions are presented for these parameters, with emphasis given to those which are of particular relevance to the goal of this Technical Report.

The references in Table 17 give some basic principles and data for physical abilities. Comparative data on physical strength obtained in the UK can be found in Reference [97]. Other references are given in the Bibliography.

Table 17 — List of physical variables

Physical variables	Particular effect of age	Reference
Body dimension (examples)		
Stature	Minimal	e.g. ISO 7250, DIN [98]
Fist height	Minimal	*Handbook of Measurements and Capabilities of the Older Adult* [99]
Sitting height	Minimal	
Eye height, seated	Minimal	
Shoulder height, seated	Minimal	
Frontal grip reach, seated	Minimal	
Upper arm length	Minimal	*Design-relevant characteristics of ageing users* [100]
Elbow - grip length	Minimal	
Elbow - finger tip length	Minimal	
Shoulder breadth	Minimal	
Breadth across elbow	Minimal	*Handbook of Measurements and Capabilities of the Older Adult* [99]
Buttock - popliteal length	Minimal	
Buttock - knee length	Minimal	
Popliteal height	Minimal	
Abdominal depth	Minimal	
Thigh clearance, seated	Minimal	
Hand length	Minimal	
Hand breadth without thumb	Minimal	
Thumb breadth	Minimal	
Forefinger tip breadth	Minimal	
Grip diameter	Minimal	
Foot length	Minimal	
Foot breadth	Minimal	
Exertion of force		
Gripping force	Yes	*Design-relevant characteristics of ageing users* [100], Japanese Ministry of Education, Culture, Sports, Science and Technology [101], DIN [102]
Pulling force	Yes	
Torque	Yes	
Shoulder strength	Yes	[103]
Elbow strength	Yes	[103], [104], [105], [106]
Wrist strength	Yes	[104]

Table 17 (*continued*)

Physical variables	Particular effect of age	Reference
Ranges of movement of joints		
Wrist - pronation	Yes	*Design-relevant characteristics of ageing users* [100]
Wrist - supination	Yes	
Wrist - flexion	Yes	
Wrist - extension	Yes	
Wrist - deviation (radial and ulnar)	Minimal	
Forefinger flexion	Minimal	
Head - flexion	Minimal	
Head - extension	Minimal	
Head - rotation	Minimal	
Head - lateral bending	Minimal	
Reaching envelopes		
Comfortable reaching vertical - standing	Yes	*Design-relevant characteristics of ageing users* [100]
Maximum reaching vertical - standing	Yes	
Comfortable reaching horizontal - sitting	Yes	
Maximum reaching horizontal - sitting	Yes	
Step length/height and walking velocity		
Step length	Yes	*Design-relevant characteristics of ageing users* [100]
Walking normal	Yes	
Walking fast	Yes	
Step height - comfortable ascent	Yes	
Step height - comfortable descent	Yes	
Step height - maximum ascent	Yes	
Step height - maximum descent	Yes	

9.3.1 Dexterity

Description

Dexterity relates to activities of hand and arm use, particularly coordinated actions of handling objects, picking them up, manipulating and releasing them, using one hand, fingers and more specifically, thumbs.

[ISO/IEC Guide 71:2001, 9.3.1.1]

Design considerations

Dexterity impairment includes an inability to bring thumbs and fingers close together or an inability to separate them very far. Complex operations, such as push and turn, which require sustained pressure and twisting of the wrist, may be painful or impossible. These have implications for the size, shape and location of controls. People with involuntary movement have problems with tasks that require precision, such as opening packaging and dealing with fastenings.

[ISO/IEC Guide 71:2001, 9.3.1.2]

Risks and hazards

People with limited dexterity may endanger themselves, for example by inadvertently activating controls, or failing to withdraw a hand quickly from a hazard, such as a flame.

[ISO/IEC Guide 71:2001, 9.3.1]

9.3.1.1 General

Handling objects and fine motor coordination involve the use of the upper extremities, the arms, hands and fingers, in coordination with the trunk and the shoulders. Diminished or lost abilities require the learning of new movements or manipulation processes, with consequent compensatory movements such as sideways feeling movements, turning movements on the body axis to change position and pulling movements for the straightening of the body. Having something to hold on to allows difficult processes of movement to be carried out more simply and more securely to compensate for lost mobility. The following are some considerations for the facilitation of movement:

— systems of vertical poles and/or support handles facilitate movement about the body axis (twisting or leaning) and straightening up of the body (changing position);

— horizontal handrails and round longitudinal handles facilitate lateral gripping forwards movement as well as sliding, securing forward progress instead of forcing the person to find other means of assistance.

The human hand is a highly complex and, above all, universal tool. It allows the greatest variety of processes of manipulation from the pure transfer of strength (e.g. pressing a switch) to highly complicated delicate work (e.g. threading a needle). The more complex the task, the higher the requirements for coordination and interplay of the single functions and components of the hand.

The design of products has a significant impact on their manual operation; gripping surfaces permit safer gripping and the hand shape of matching cross-sections improves coordination and strength transfer. Profile cross-sections of 30 mm–45 mm for support handrails and holding handles have shown themselves to be suitable. Turning movements for the operation of functions already assume relatively complex motor skills. Therefore, the following can be considered to increase accessibility:

— door handles, for instance, are more serviceable than door knobs;

— large format handle grips are better than shell grips or knobs;

— single lever taps are better than turning taps;

— push-button keys or toggle switches are better than turning switches;

— simultaneous double movements, e.g. pushing and turning, often causes problems, and vertical movement orientations are preferable when precise movement processes are necessary.

Steenbekkers and van Beijsterveldt [107] carried out tests of the assessment of psychomotor variables and found that the abilities of hand steadiness, hand-eye-coordination and reaction times all decreased with increasing age.

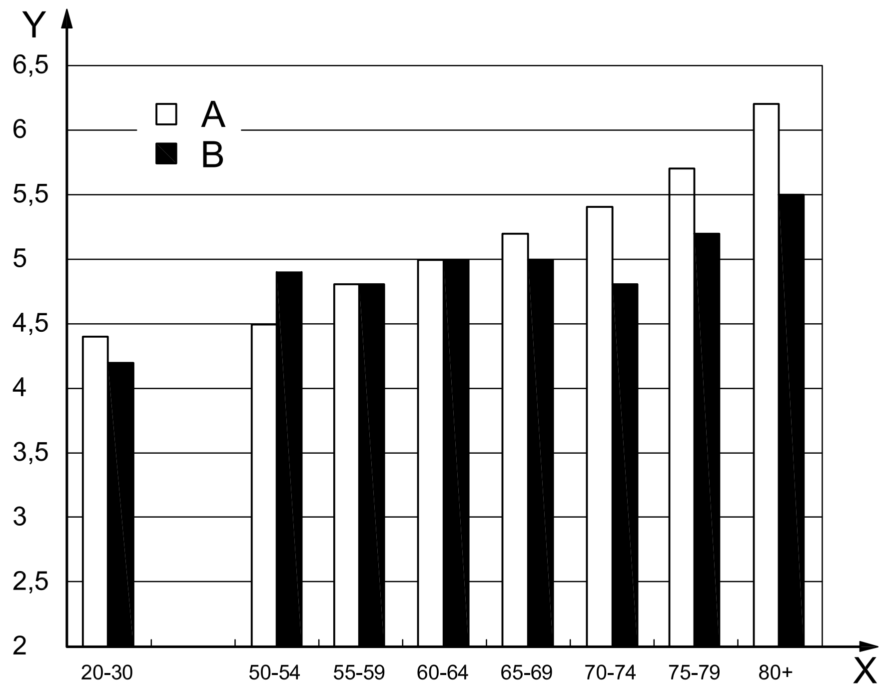
When accurate positioning is required, the aim is to design controllable solutions whereby the hand(s) can be supported and the object to be gripped can be held comfortably, with a clearly perceived spatial orientation. Dimensions and forms of objects and products can be relatively large. The colours and forms support recognition of object and products. See 8.5 and 8.11.

With age, the differences in fine psychomotor skills between individuals increase significantly. Product testing, if relevant, can include situations in which the product is used at dusk or in the dark and by persons with a tremor.

9.3.1.2 Data on hand steadiness, eye-hand coordination and grip diameter

Manipulation of tools depends on hand steadiness and eye-hand coordination among other motor-controlling functions, and those functions decline with age. The hand steadiness can be measured, for example, as the minimum hole diameter of a plate through which a person can pass a pencil or needle without touching the edge.

Figure 50 shows the hand steadiness measured for different age groups from 20 years to over 80 years of age [107]. The hand and arm were not allowed to be supported. The hand steadiness score is equivalent to the minimum hole diameter. The diameter increases with age, meaning that fine motor control deteriorates with increasing age.



Key

X age group, years

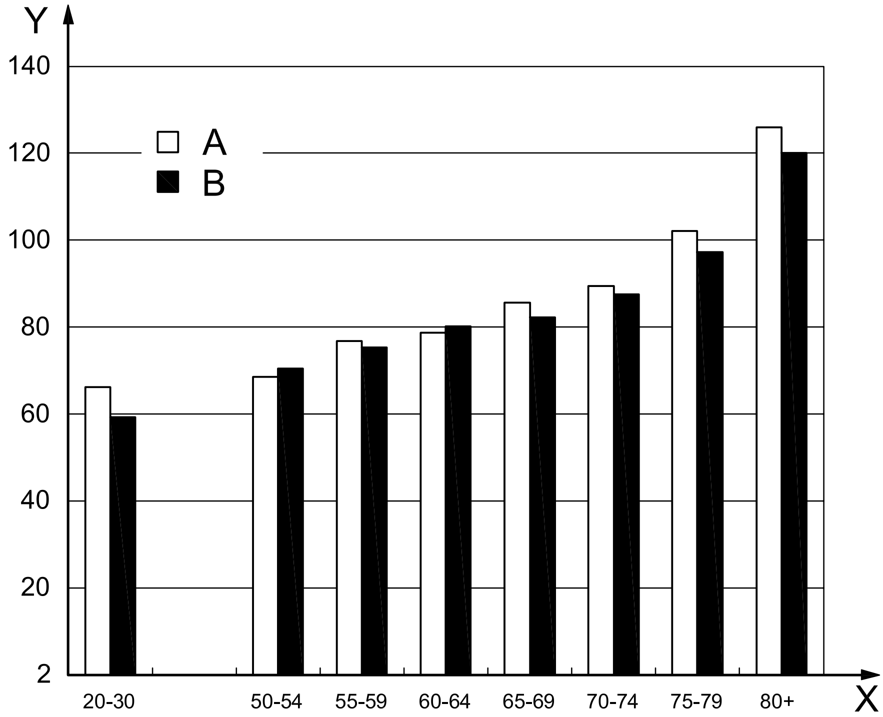
Y hand steadiness score

A men

B women

Figure 50 — Hand steadiness data expressed as minimum hole diameter through which a man or woman can pass a thin stick (2,0 mm diameter) by hand without touching the edge of the hole

Figure 51 is an example of the data showing eye-hand coordination that relates to dexterity [107]. The data show the time required for placing key-shaped pins as fast as possible in the holes on a peg board. The board has 25 key-shaped holes with different directions. It is clear that the time needed to perform this task increases with age.



Key

X age group, years

Y mean time, seconds

A men

B women

Figure 51 — Mean time required for man/woman to place all 25 key-shaped pegs in key-shaped holes

Dimensions of hands, fingers and thumbs are among the critical data that affect operation of products and controls that have knobs, grips, push-buttons, etc.

Table 18 and Figure 52 [107] indicate the maximum diameter of the circle made by the thumb and forefinger when enclosing a cone (in accordance with Reference [108]). The data can be applied to the estimation of the appropriate diameter of an object that has to be gripped.

Table 18 — Grip diameter as a function of age

Age (years)	Men		Women	
	n	**Mean** cm	*n*	**Mean** cm
20–30	55	4,3	68	3,9
31–49	—	4,2	—	3,9
50–54	35	4,2	35	3,9
55–59	46	4,1	50	4,0
60–64	44	4,2	53	3,9
65–69	50	4,1	51	3,8
70–74	59	4,1	62	3,9
75–79	36	4,1	38	3,7
80+	33	3,9	35	3,6
n number of people who participated				

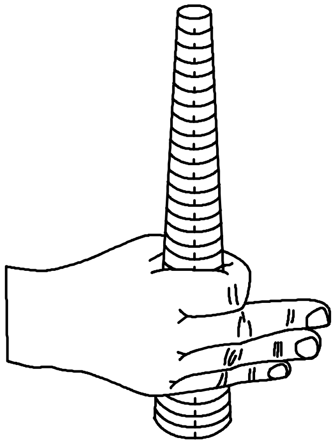


Figure 52 — Measurement of grip diameter

9.3.2 Manipulation

Description

Manipulation relates to activities of carrying, moving and manipulating objects. It includes actions using legs, feet, arms and hands — reaching, lifting, putting down, pulling, pushing, kicking, grasping, releasing, turning, throwing and catching.

[ISO/IEC Guide 71:2001, 9.3.2.1]

Effects of ageing

Manipulation can be impaired by an inability to use both hands (or feet) when carrying out an activity. It is also affected when joint movement, particularly of the hands or arms, is restricted. Speed of manipulation also declines in old age as a result of slower reaction time and slower movement.

[ISO/IEC Guide 71:2001, 9.3.2.2]

Risks and hazards

Individuals with impaired manipulation may risk injury through inadvertently dislodging a device during use. Product design needs to minimize the hazards and consequences of unintended actions.

[ISO/IEC Guide 71:2001, 9.3.2.3]

9.3.2.1 General

The movement of joints, described by the size of the envelopes in the vertical and horizontal planes, and which indicate how far a person can reach in a sitting or standing position, is very important. In addition, the fine-motor functions, hand dexterity, precision, coordination, joint mobility, hand-eye coordination and speed of motor function are also relevant. Basic principles and data can be found in ISO 7250, and in References [107] and [108].

9.3.2.2 Reach envelopes

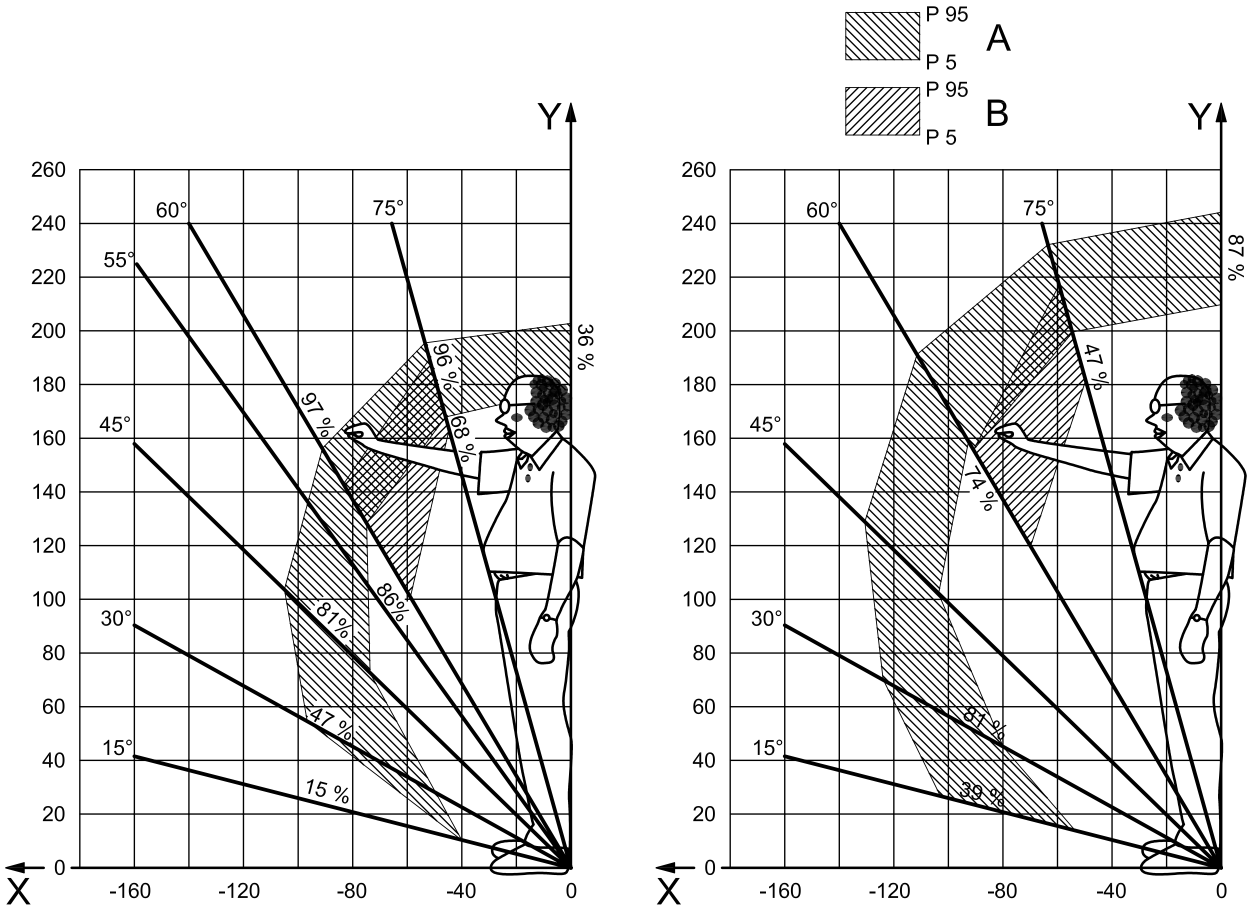
The reach envelopes in upper limbs have a great effect on manipulation. The reach envelope depends on the range of motion (RoM) in upper limbs and, generally, the RoM decreases with age. The following provides age-related differences for reach envelopes when standing and sitting. The data were measured in the Netherlands in 1998 with healthy people [107].

Table 19 provides the envelope of comfortable and maximum vertical reach when standing for six groups of different age and stature. Figure 53 shows graphical representations of the data for a group of people over 75 years of age and less than 165 cm in height, and for a group of people aged between 20 and 30 and more than 175 cm in height.

The data were taken by asking individuals to mark with the right arm on the right side and the vertical plane, the distances and angles within comfortable and maximum reach. Comfortable reach means the reach without bending the body forwards and maximum reach means the reach while keeping both legs stretched and bending the trunk. In Table 19, *n* is the number of people who participated.

Table 19 — Envelope for vertical reach when standing, as a function of age

Age	Stature	Radius	Comfortable		Maximum	
				Mean radius		Mean radius
years	cm	degrees	*n*	cm	*n*	cm
20–30	< 175	90			49	204
		75	34	191	60	204
		60	49	147	60	184
		45			60	149
		60			53	110
		15			27	73
20–30	> 175	90			54	225
		75	29	209	62	225
		60	46	161	62	204
		45			62	165
		60			50	120
		15			24	77
50–74	< 170	90			182	199
		75	179	189	259	198
		60	231	149	258	176
		55	30	115		
		45			250	138
		30			172	99
		15			85	63
50–74	⩾ 170	90			140	216
		75	135	205	207	214
		60	188	160	209	192
		55	20	125		
		45			202	152
		30			143	109
		15			43	72
75+	< 165	90			27	191
		75	50	183	71	189
		60	64	145	72	165
		45			60	123
		30			35	86
		15			11	59
75+	⩾ 165	90			32	210
		75	41	197	63	205
		60	50	157	63	178
		45			55	138
		30			29	98
		15			13	66



a) Envelope for vertical reach when standing for age over 75 years and stature less than 165 cm

b) Envelope for vertical reach when standing for age 20 to 30 years and stature of more than 175 cm

Key

X horizontal distance, cm

Y vertical distance, cm

A maximum

B comfortable

NOTE 1 The person in the graphic illustrates the form of reaching but not the respective stature.

NOTE 2 P5 and P95 refer to the 5th and 95th percentiles.

Figure 53 — Envelopes for vertical reach when standing (see Table 19)

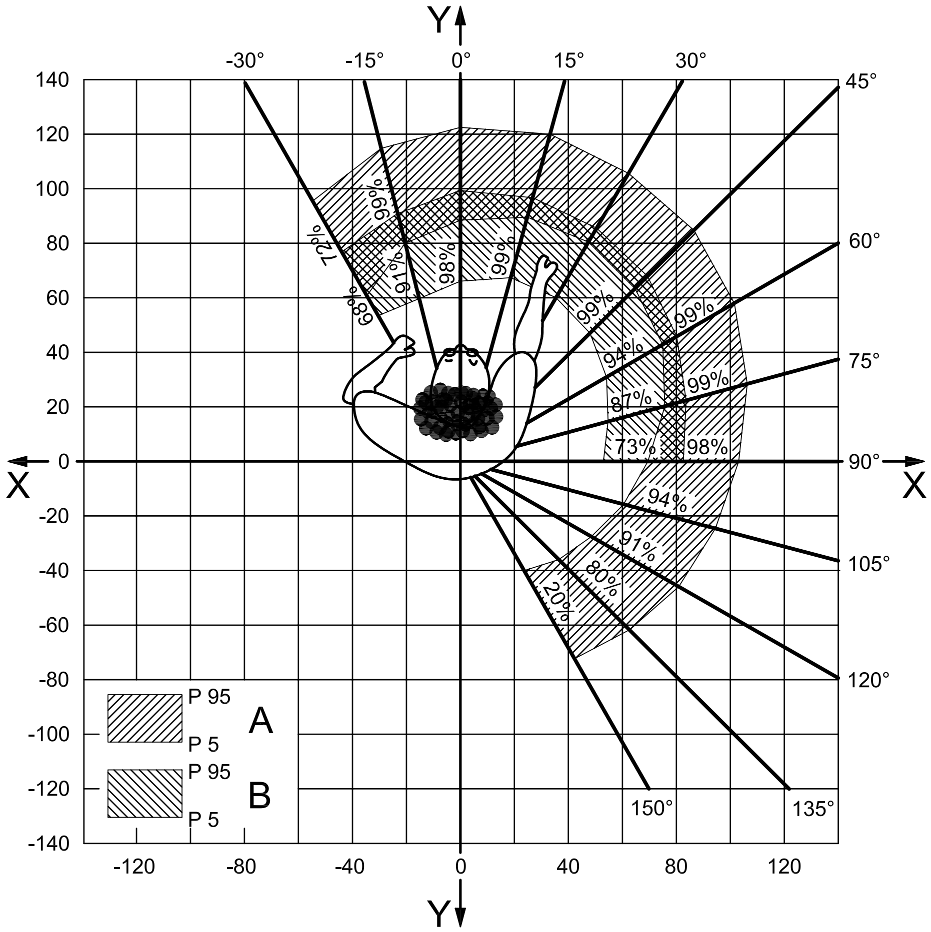
Similarly, Table 20 provides the envelope of comfortable and maximum horizontal reach at sitting for three groups of different age and stature. Figure 54 shows the data for a group of over 50 years of age and less than 170 cm in stature.

The data were taken by asking people to mark with the right arm the area within reach on the horizontal plane at elbow height. *Comfortable reach* is a reach without bending the body forwards; *maximum reach* is a reach with bending the trunk. In Table 20, n is the number of people who participated.

Table 20 — Envelope for horizontal reach when sitting, as a function of age

Age	Stature	Radius	Comfortable		Maximum	
				Mean radius		Mean radius
years	cm	degrees	*n*	cm	*n*	cm
20–30	[a]	–30	63	69	91	108
		–15	99	75	117	116
		0	116	79	117	120
		15	117	81	117	121
		30	117	81	117	120
		45	114	79	117	117
		60	102	76	117	112
		75	87	72	117	105
		90	67	68	117	98
		105			114	92
		120			114	88
		135			111	83
		150			48	82
50+	< 170	–30	246	70	259	95
		–15	330	72	358	103
		0	355	82	360	109
		15	359	84	361	110
		30	360	83	361	110
		45	359	81	361	107
		60	341	76	359	101
		75	314	70	358	93
		90	264	66	354	85
		105			340	79
		120			327	73
		135			289	69
		150			72	68
50+	⩾ 170	–30	169	73	190	103
		–15	233	79	251	112
		0	247	84	251	117
		15	250	86	251	119
		30	249	86	251	118
		45	245	84	251	115
		60	236	80	250	109
		75	207	76	250	102
		90	180	72	247	95
		105			239	89
		120			229	83
		135			212	79
		150			77	76

[a] No specification on stature.



Key

X X axis, cm

Y Y axis, cm

A maximum

B comfortable

Figure 54 — Envelope for horizontal reach when sitting for persons over 50 years of age and stature less than 170 cm (see Table 20)

The data in the comfortable range in both Tables 19 and 20 can be used for situations in which individuals have to reach frequently for products. The data of the maximum range can be used for situations in which individuals have to reach for light-weight products or in which products have to be reached for only occasionally [107]. See 8.12.1.

9.3.2.3 Rotation

9.3.2.3.1 Pronation

The data given in Table 21 and shown in Figure 55 provide the maximum inward rotation of the wrist (pronation). The data can be applied to the position of hand-held objects or controlling parts (especially for rotational manipulation) [107].

Table 21 — Maximum inward rotation of the wrist as a function of age (pronation) [107]

Age (years)	Men		Women	
	n	P_5 degree	n	P_5 degree
20–30	55	75	68	77
31–49	—	—	—	—
50–54	35	76	35	66
55–59	46	79	50	89
60–64	44	84	53	82
65–69	50	79	51	84
70–74	59	80	62	82
75–79	36	77	38	89
80+	33	78	35	98

NOTE Only P_5 (5th percentile) data are available.

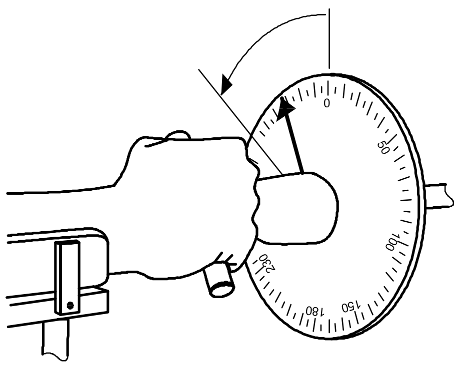


Figure 55 — Measurement of pronation

9.3.2.3.2 Supination

The data given in Table 22 and shown in Figure 56 are for the maximum outward rotation of the wrist (supination). The data can be applied to the position of hand-held objects/controlling parts, especially those which require rotational manipulation [107].

Table 22 — Maximum outward rotation of the wrist as a function of age (supination)

Age	Men		Women	
(years)	n	P_5 degree	n	P_5 degree
20–30	55	64	68	69
31–49	—	—	—	—
50–54	35	46	35	59
55–59	46	56	50	62
60–64	44	62	53	57
65–69	50	50	51	60
70–74	59	51	62	55
75–79	36	55	38	49
80+	33	37	35	49

NOTE Only P_5 (5th percentile) data are available.

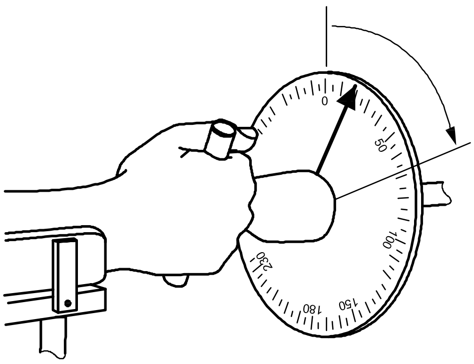


Figure 56 — Measurement of supination

9.3.3 Movement

Description

Movement relates to activities of maintaining and changing the body position and transferring oneself from one area to another using legs, feet, arms and hands.

[ISO/IEC Guide 71:2001, 9.3.3.1]

Effects of ageing

Many impairments in movement are experienced in older age which can result in difficulties in daily living, such as dressing, sitting down and getting up again. Examples include:

— limited ability to bear mass on the legs,

— reduced walking speed and step length and/or height,

— restricted range of movement in the joints of arms, legs and spine,

— difficulty carrying out a controlled and coordinated movement.

[ISO/IEC Guide 71:2001, 9.3.3.2]

Design considerations

Some people with movement difficulties are assisted by equipment such as wheelchairs or walking aids; others may require personal help. In both cases, extra space is needed around them to allow for approach and manoeuvring.

[ISO/IEC Guide 71:2001, 9.3.3.3]

Risks and hazards

People with impaired movement are particularly at risk during emergency evacuation of vehicles or buildings.

[ISO/IEC Guide 71:2001, 9.3.3.4]

9.3.3.1 General

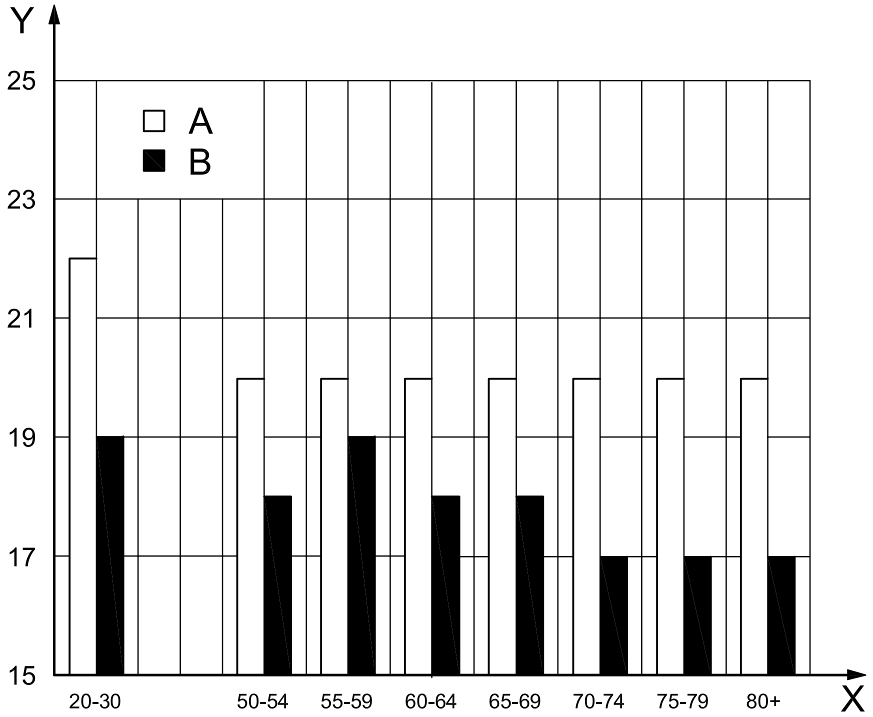
Movement involves coordination of the actions with the neural system, while the body needs to maintain balance in order to remain static or move. Balance can be disturbed, for example, as a result of circulatory problems, leading to unsteadiness when standing and walking. Paralysis or loss of limbs can also cause balance and mobility problems due to a lack of muscular power or because of neuronal complications.

Walking aids, walking frames and wheelchairs support mobility. Construction features with support systems and the provision of sufficient opportunity to be seated provide more independence and safety.

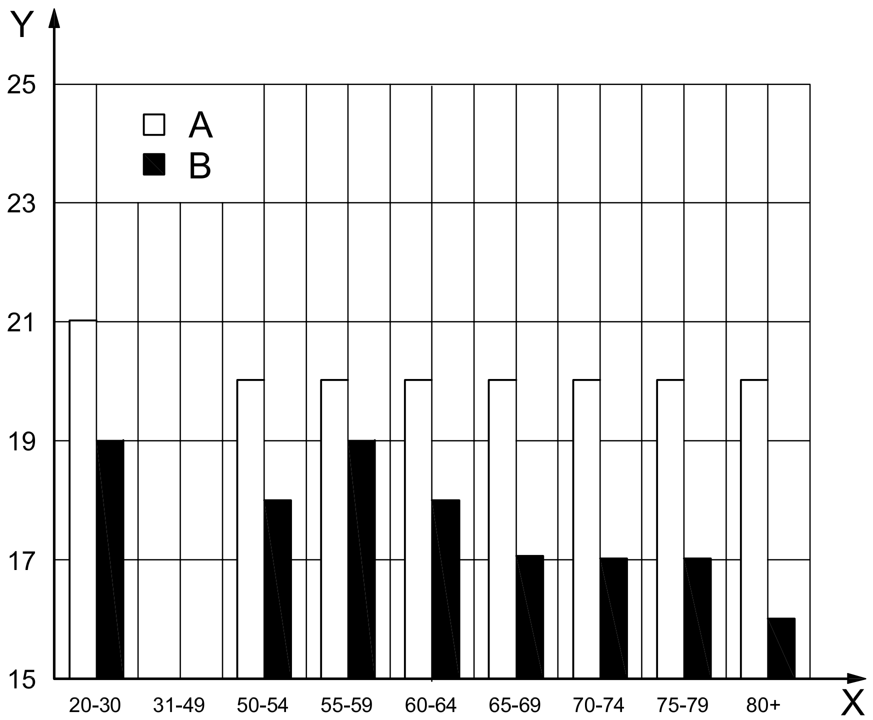
A threshold-free layout, e.g. in buildings and traffic spaces, is preferable. Small differences in level can be overcome by persons who use wheelchairs, walking frames, etc., with the help of gently sloping ramps. Lifts or mechanical progress systems become necessary to overcome greater level differences. Buildings, public spaces, traffic facilities and parks that are reachable or usable without thresholds increase accessibility.

Steenbekkers and van Beijsterveldt [107] undertook tests indicating different patterns of ageing for different types of human ability. Step length and walking speed at a normal and at a hurried pace both reduce with age.

Figures 57 and 58 [107] show the step height of ascending and descending at comfortable and at maximum condition, respectively. In both cases, the step height decreases with age, especially for females.



a) Comfortable step height, ascending

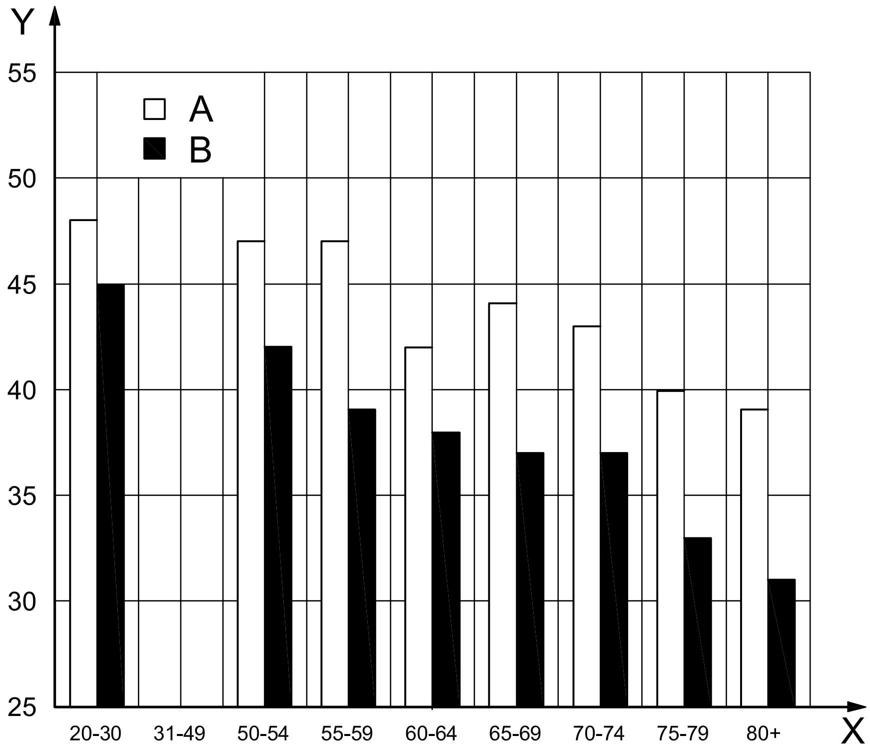


b) Comfortable step height, descending

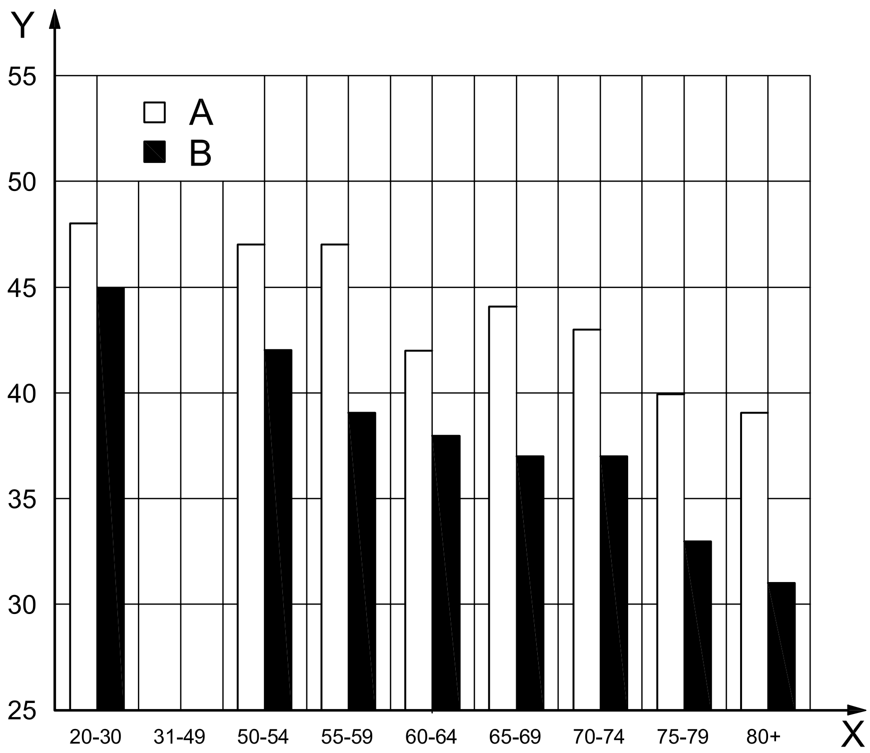
Key

X age group, years
Y step height, cm
A men
B women

Figure 57 — Comfortable step height for different age groups



a) Maximum step height, ascending



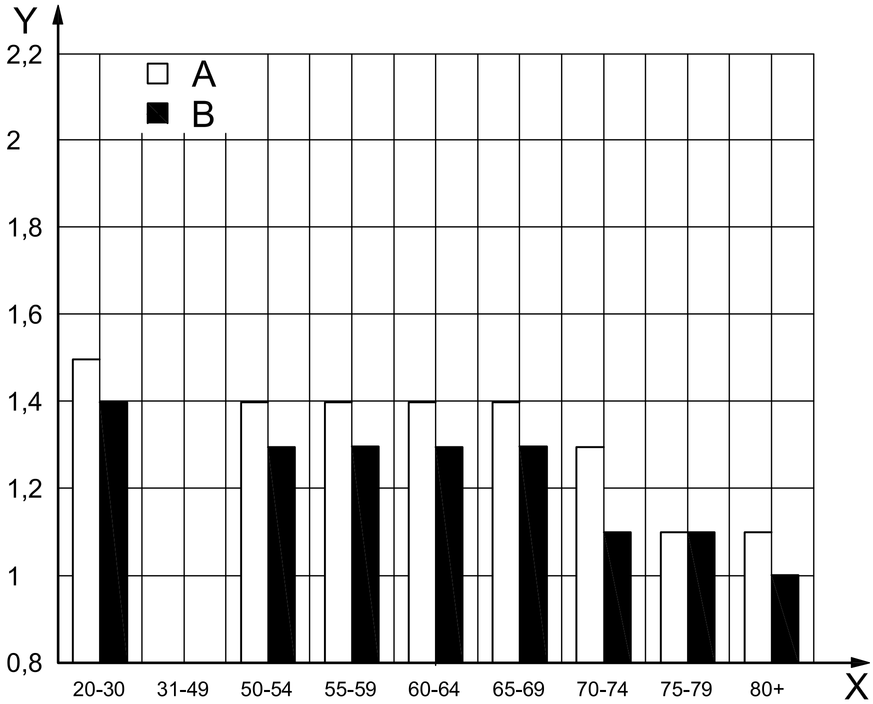
b) Maximum step height, descending

Key

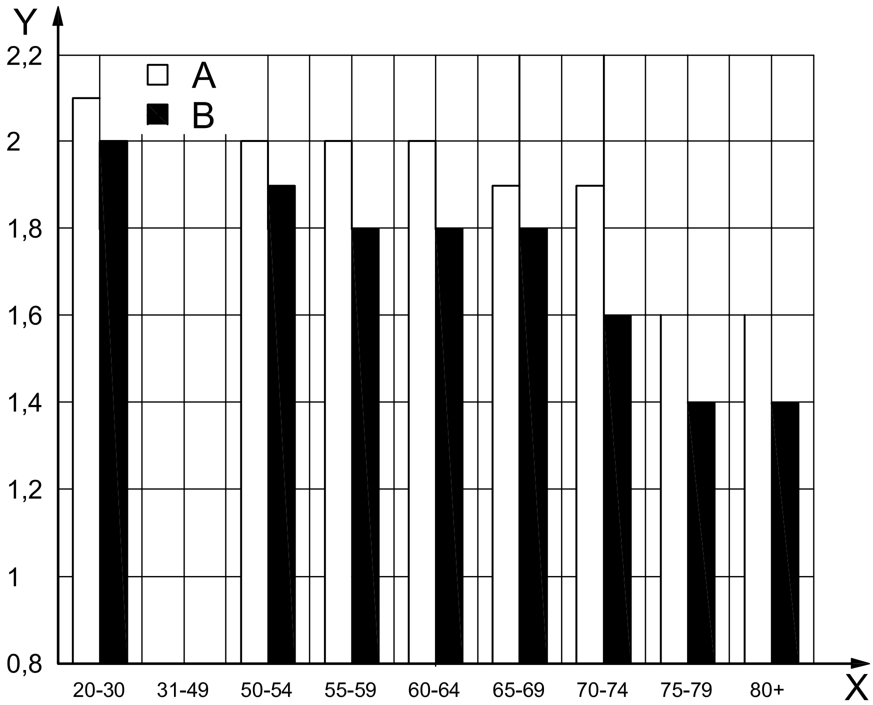
X age group, years
Y step height, cm
A men
B women

Figure 58 — Maximum step height for different age groups

Speed of motion is also one of the most important criteria of movement. Walking velocity also decreases with age both at a normal and a hurried pace, as is shown in Figure 59.



a) Normal pace



b) Hurried pace

Key

X age group, years

Y walking velocity, m/s

A men

B women

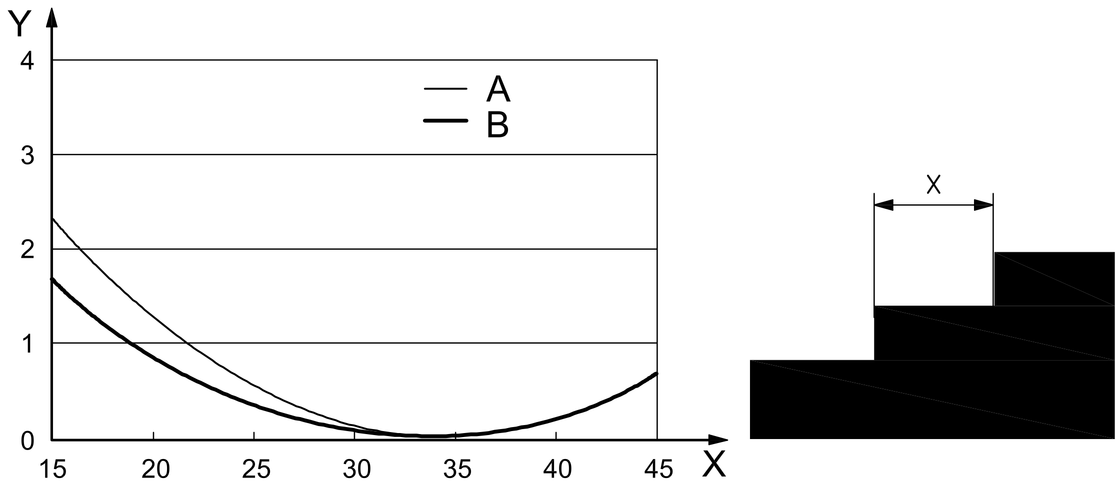
Figure 59 — Walking speed

9.3.3.2 Ease of moving

Walking is an integral part of many activities in daily life. Step length, step height and walking velocity decrease with age. Older people need, for example, a smaller distance between separate stepping stones. They also need more time to pass automatic doors and to make use of pedestrian crossings. It is very unpleasant for them to be forced to walk at a pace other than their normal pace.

Older people require an optimal step height (e.g. 170 mm). When ascending or descending stairs, the slope of the stairs becomes an important factor. A regular flight of stairs allows a certain rhythm of body movement. Older people have a reduced sense of balance. Therefore, it is necessary to design banisters or hand grips alongside stairs.

Appropriate stair dimensions can be estimated in terms of human factors, e.g. the relationship between subjective evaluation on the difficulty of walking on stairs and tread dimension. As shown in Figure 60 [110], relationships between tread dimension and subjective evaluation of difficulty can be approximated by quadratic polynomials ($p < 0{,}001$), with the lowest intensity at 300 mm to 350 mm of tread for both young and older people. Using Figure 60, the subjective load, i.e. the *difficulty*, can be known when tread dimension is given.



Key

X tread (cm)

Y walking difficulty (none at “0” and great at “4”)

A young

B elderly

Figure 60 — Relationship between tread dimension and subjective evaluation of stair-walking difficulty

Generally speaking, older people take smaller steps. To determine the walking space required, use the median or average values as a reference point. To determine the space which has to be covered by taking one step, use a smaller value.

The walking width required for people with walking aids is between 800 mm and 900 mm.

A great number of construction features and ergonomic factors need to be considered in order to enable wheelchair users to move independently. Some factors are dealt with in 8.12.7 and 8.16.

The handling of wheelchairs becomes difficult as the slope of ramps increases. Figure 61 [109] gives an example of the effect of the ramp slope on the handling of a wheelchair. Ramps tend to be difficult for older people when the slope becomes steeper.

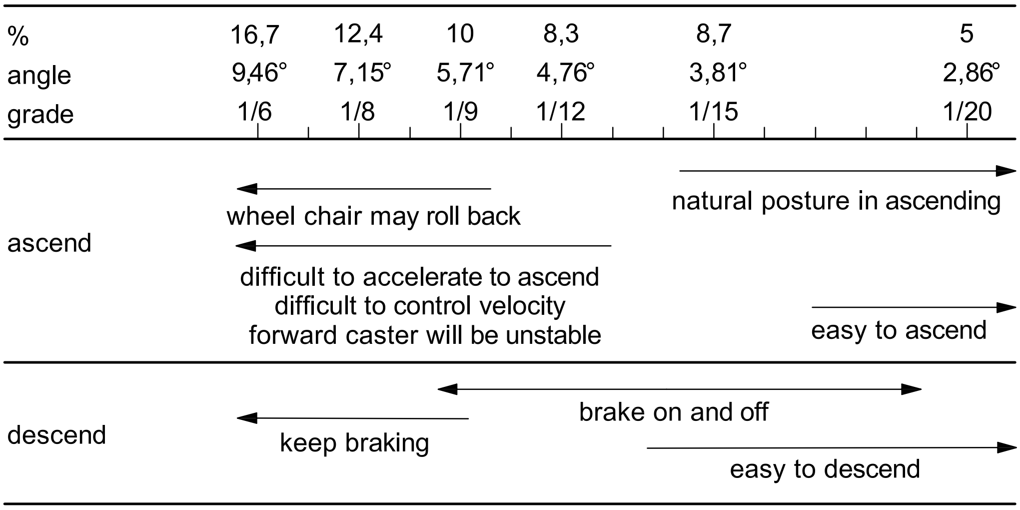


Figure 61 — Relationships between slope of ramps and ease of operation of wheelchair

9.3.4 Strength and endurance

Description

Strength relates to the force generated by contraction of a muscle, or muscle group, when carrying out an activity. Strength can be the force exerted with a specific part of the body in a specific action (e.g. pushing) or applied to a specific object (e.g. opening bottle tops). Activities include pulling, lifting, pressing, gripping, pinching, and twisting.

Strength also depends on endurance, the capacity to sustain force. This can be related to heart and lung function. Limited strength is common to many physically disabling conditions and is a common reason for being unable to operate equipment.

[ISO/IEC Guide 71:2001, 9.3.4.1]

Effects of ageing

Reductions in muscle power and stamina are common in older age resulting in impairment of strength. Impairment of grip strength can make it difficult or painful to operate an appliance against resistance or torque. Limitations of stamina will cause fatigue when use of a product requires prolonged activity. Control of passive movement (i.e. when an external force such as gravity causes the motion) can be impaired resulting in difficulties, e.g. lowering a heavy object to the ground or sitting down on a chair.

[ISO/IEC Guide 71:2001, 9.3.4.2]

9.3.4.1 General

Older persons and persons with disabilities can exert less force, e.g. when operating products. Elderly females are only two-thirds as strong as males of the same age on average. In a healthy population, there is an eight-fold difference in gripping force between the strongest and weakest groups of persons.

Older persons are also less strong than younger persons when pushing with two hands or pulling with one hand. For the strength of constructions, it is recommended that the strongest individual be used as the criterion. For handling products, the weakest individual should be used.

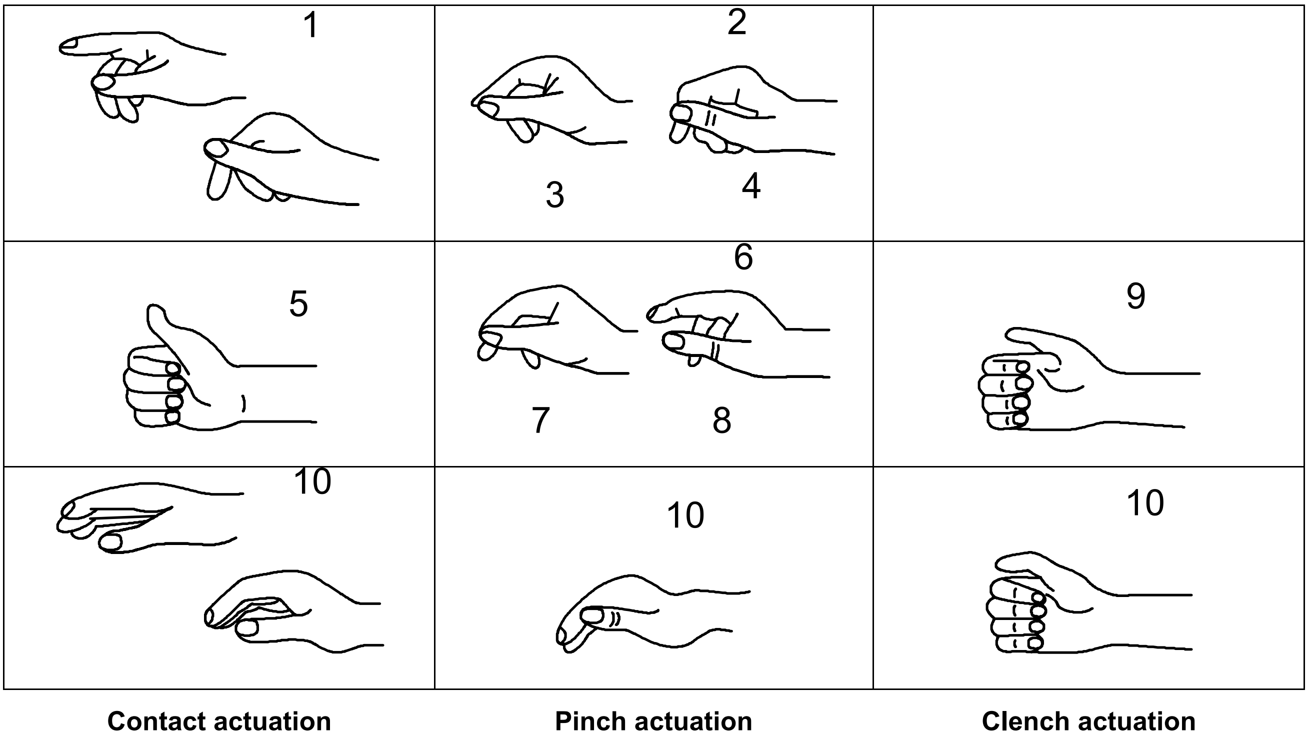
The ability to exert force decreases with age. Several studies have investigated the exertion of static forces [100], [111]. In these studies, gripping forces, lifting forces, pulling forces and torque forces were investigated in different ways. When physical condition and individual capabilities were taken into account, there was a negative correlation between static forces and age. For example, the maximum static torque of two hands for older people is less than for younger people. When making products opened by torque, less strength of muscle in older people can be taken into account. Sufficient grip strength in these products can increase accessibility.

The measurement method was described in detail in the specific studies. Several aspects were taken into account when deciding which method of measurement to use. For example, Steenbekkers and van Beijsterveldt [107] took dominant hand (pulling and gripping force of both hands; the writing hand not always being the dominant hand, etc.), building-up force (building-up and holding times, etc.), number of measurements, time between measurements, clothing (imitated daily-life situations), motivation/encouragement, position (standing or sitting, elbows flexed at 90°, etc.), apparatus (Jamar hydraulic hand-dynamometer, lifting forces with initial weights of 0,5 kg–1,5 kg, etc.).

Steenbekkers' and van Beijsterveldt's results are based on a sample of approximately 750 people. Some of their data are shown as an example of the results of research for gripping force, pushing force, and static torque together with other sources of the data.

9.3.4.2 Grip strength

Three types of grip exist in handling controls. Figure 62 illustrates the different types of grip between the operator's hand and the control. *Contact grip* is one where a unidirectional force is applied by a finger, the thumb or hand to the control. *Pinch grip* is one where the control is held by fingers and/or thumb without clenching the fist. *Clench grip* uses all fingers wrapped around the control (see ISO 9355-3). The size suitable for a control depends on the type of grip used. See 8.12.3.1.



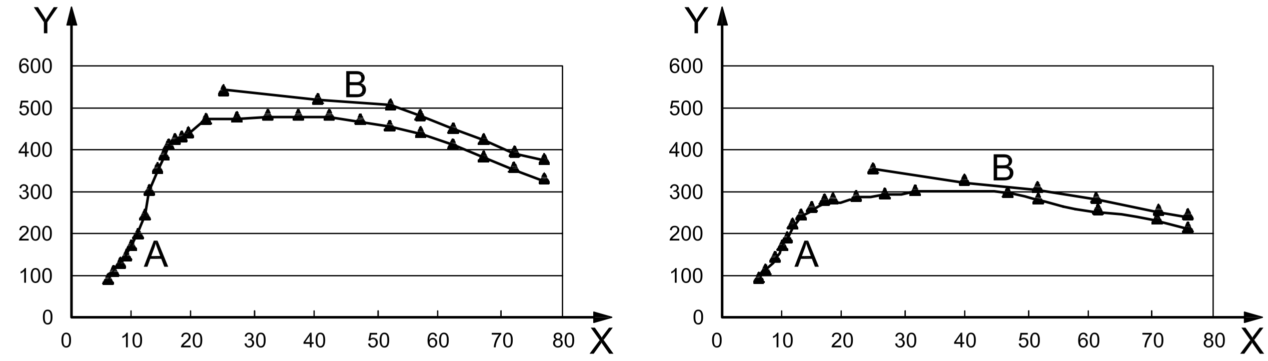
Key

1 finger
2 two fingers
3 thumb opposed
4 thumb at right angle
5 thumb
6 three fingers
7 evenly spaced
8 thumb opposed
9 finger
10 hand

Figure 62 — Types of contact (ISO 9355-3)

When designing caps for jars, bottles and other packaging that needs to be gripped or rotated, the maximum gripping force of a hand should be taken into account. Exertion of a gripping force depends on size, length, and texture of surface.

Figures 63 provides the maximal grip strength for Japanese males and females as a function of age [101]. Grip strength data were obtained for both right and left hands as maximal-effort contraction. Measurements were made on the right and left side, with two trials on each side in a standing position. The results of Steenbekkers and van Beijsterveldt [107] are also shown for comparison.



a) Men **b) Women**

Key

X age, years

Y grip strength, N

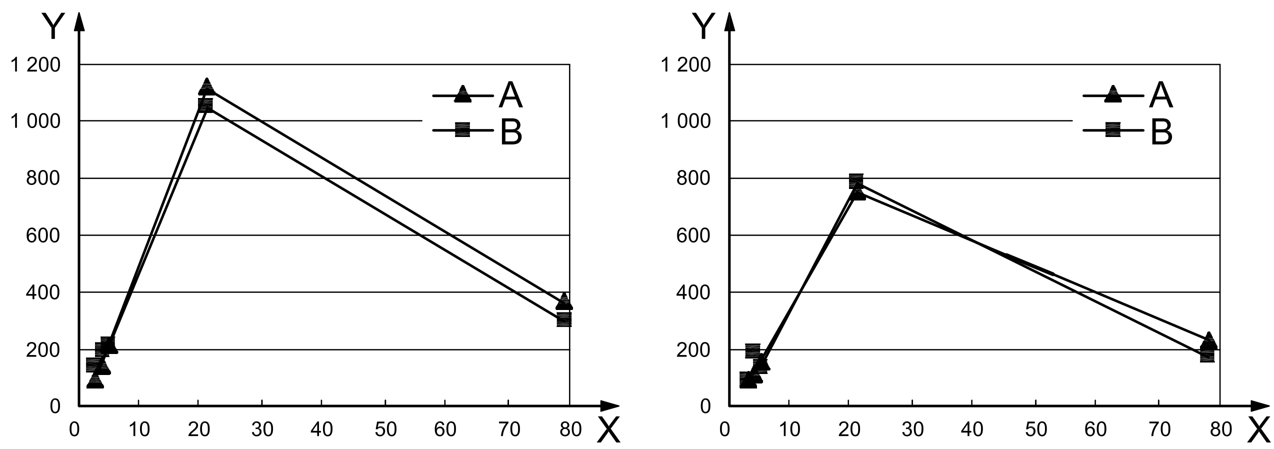
A Japan [101]

B Netherlands [107]

Figure 63 — Grip strength for males and females as function of age for two national data sources

9.3.4.3 Lifting strength

Figure 64, Table 23 and Figure 65 show the lifting strength data for healthy Japanese [112] and German [102] males and females. Individuals lifted a metal pipe or a plate from underneath by gripping with both hands. Bending of knees was allowed and the position of the feet was decided by the individuals.



a) Men **b) Women**

Key

X age, years

Y lifting strength, N

A height = 600 mm

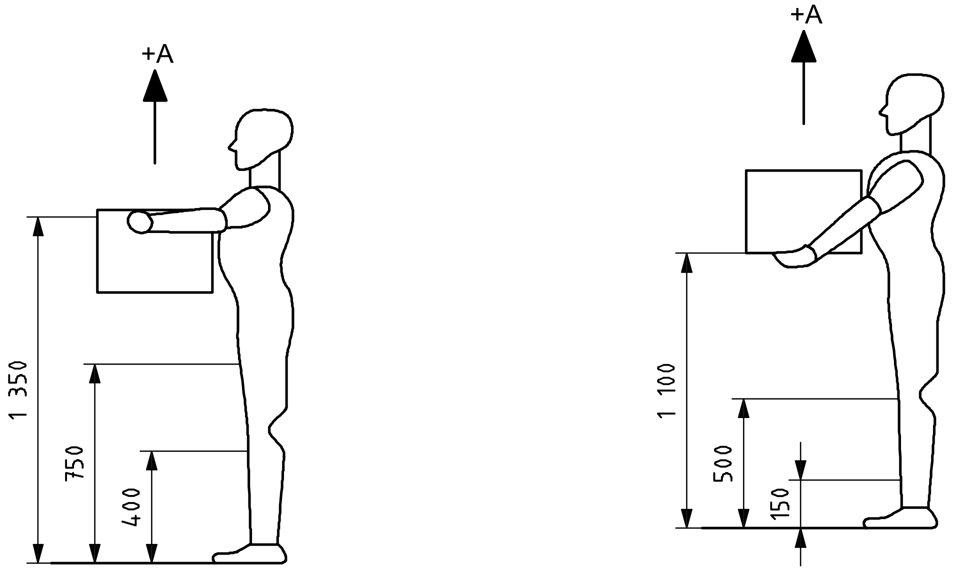
B height = 800 mm

Figure 64 — Lifting strength data for healthy Japanese men and women during childhood, youth and old age

Table 23 — Two-handed force that can be exerted to lift a crate (width 500 mm) [102]

Force direction	Point of force application mm	Force percentiles	Gender-related force values	
			Female	Male
A (vertical)	1 350 Side-gripping	5	123	268
		10	134	305
		15	144	323
		50	166	417
		95	268	570
	1 110 Bottom-gripping	5	153	353
		10	176	393
		15	190	419
		50	248	541
		95	353	764
	750 Side-gripping	5	294	642
		10	345	739
		15	375	821
		50	528	1 274
		95	353	764
	500 Bottom-gripping	5	284	617
		10	339	718
		15	383	774
		50	507	991
		95	724	1 329
	400 Side-gripping	5	261	603
		10	326	687
		15	349	762
		50	490	1 108
		95	770	1 651
	150 Bottom-gripping	5	256	456
		10	301	678
		15	338	738
		50	470	971
		95	689	1 324

Dimensions in millimetres



a) Gripped from side

b) Gripped from bottom

Key

+A vertical force direction

Figure 65 — Measurement of two-handed force to lift a crate of width 500 mm [102]

9.3.4.4 Pushing force with two hands

The following data provide pushing and pulling strength values for Japanese [109], German [108], and Dutch [107] people. The pushing and pulling strength data were obtained by isometric “make” tests in the sagittal plane using a force measurement system with a load cell. They were measured during maximal-effort contraction in expiration in order to prevent strokes caused by sudden changes in blood pressure.

NOTE The “make” test is a muscular strength testing method for measuring the force exerted by individuals against an unmoving object such as a wall. *Isometric* means that the muscle length is kept constant without joint movement during testing.

The data given in Table 24 and shown in Figure 66 provide the maximum pushing force using both arms and hands together, exerted for 3 s. The data can be applied to situations in which maximum pushing force with two hands is required. It also gives an indication of the required solidity of vertical constructions [107].

Table 24 — Pushing force with two hands as function of age

Age	Men		Women	
(years)	*n*	Mean N	*n*	Mean N
20–30	54	508	68	333
31–49	—	490	—	317
50–54	35	459	35	307
55–59	46	485	49	294
60–64	44	424	53	288
65–69	50	409	51	250
70–74	59	361	62	230
75–79	36	349	37	219
80+	33	295	34	165

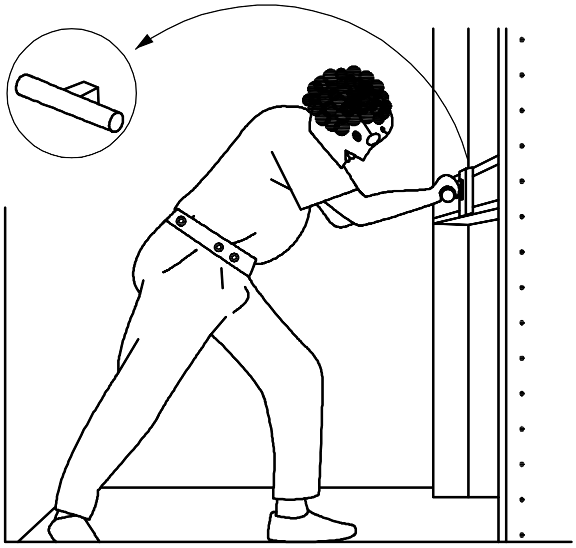


Figure 66 — Measurement of pushing force with two hands

9.3.4.5 Pulling force with one hand

The data given in Table 25 and shown in Figure 67 provide the maximum pulling force of one hand, exerted for 3 s. The data can be applied to situations in which maximum pulling force with one hand is required. It also gives an indication of the required solidity of vertical constructions [107].

Table 25 — Pulling force with one hand as function of age

Age (years)	Men		Women	
	n	Mean N	*n*	Mean N
20–30	55	349	68	240
31–49	—	354	—	247
50–54	35	342	35	247
55–59	46	374	50	262
60–64	44	330	53	238
65–69	50	321	51	212
70–74	59	288	62	194
75–79	36	287	37	184
80+	33	258	35	155

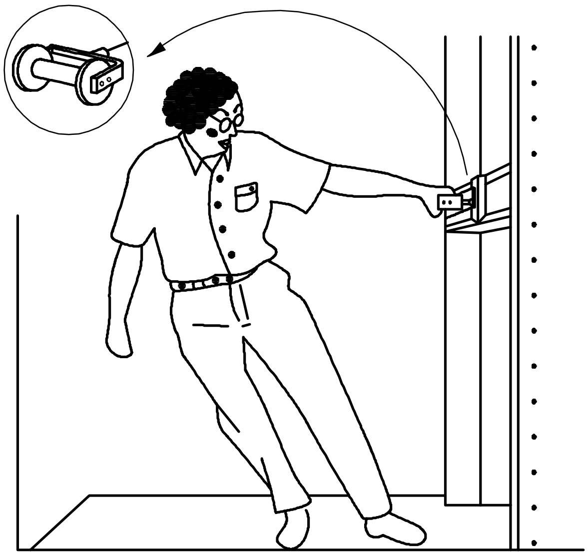


Figure 67 — Measurement of pulling force with one hand

9.3.4.6 Static torque with two hands

The data given in Table 26 and shown in Figure 68 provide the maximum static torque of two hands and both arms, exerted for 3 s. The data can be applied to products that require two-handed manipulation, e.g. one part has to be turned relative to the other. It also gives an indication of the solidity required of products that have to withstand torque [107].

Table 26 — Static torques with two hands as function of age

Age (years)	**Men** *n*	**Men Mean** N	**Women** *n*	**Women Mean** N
20–30	55	8.7	68	5.6
31–49	—	8.2	—	5.2
50–54	35	7.7	35	4.8
55–59	46	7.5	50	4.7
60–64	44	6.4	53	4.8
65–69	50	6.5	51	4.0
70–74	59	5.3	62	3.7
75–79	36	5.1	37	3.5
80+	33	4.9	35	3.4

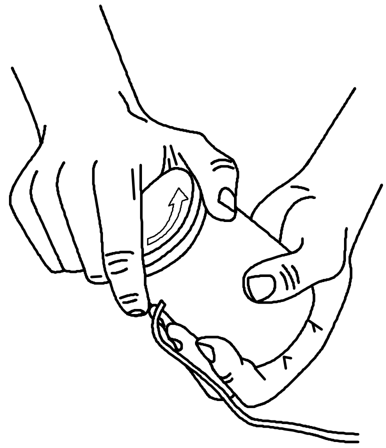
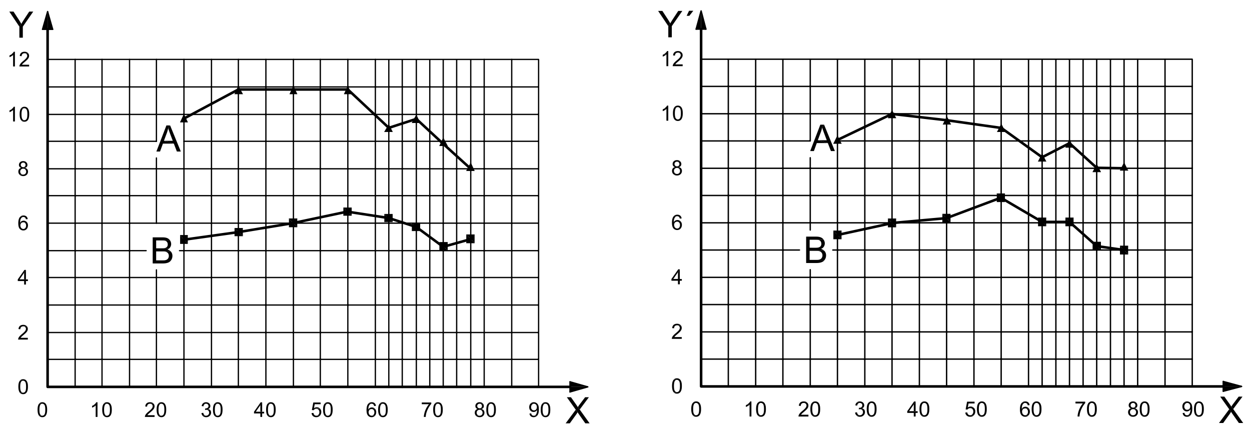


Figure 68 — Measurement of static torque

9.3.4.7 Extremity muscle strength

Muscle strength in the limbs has a great impact on activities of daily living and on the quality of life. The following data provide the extremity muscle strength torque taken from about 1 000 Japanese males and females. The extremity muscle strength data were obtained as the data of gravity-compensated extremity joint torque (EJT) values. The EJT values were obtained by isometric "make" tests in the sagittal plane with a hand-held dynamometer (HHD).

Figures 69, 70 and 71 are data on joint torque of flexion and extension for wrist, elbow and shoulder. The data were taken for more than 300 Japanese men and women ranging in age from about 20 to 80 years [113]. Joint torque of any kind shown here has a slight peak at middle age and decreases with age.



a) Wrist flexion

b) Wrist extension

Key

X age, years

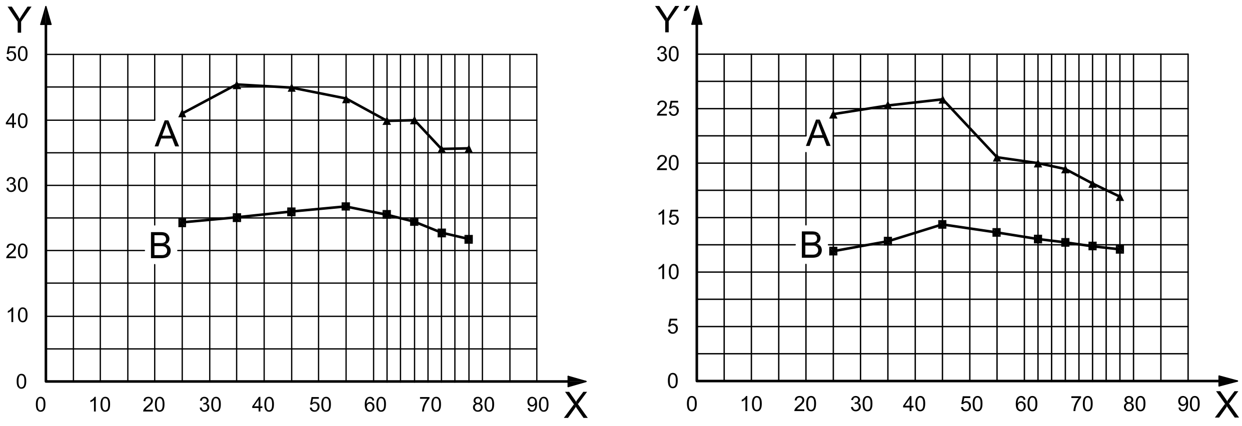
Y wrist flexion torque (palmar flexion), N·m

Y′ wrist extension torque (dorsiflexion), N·m

A men

B women

Figure 69 — Torque data for wrist flexion and extension for Japanese people as function of age



a) Elbow flexion **b) Elbow extension**

Key

X age, years

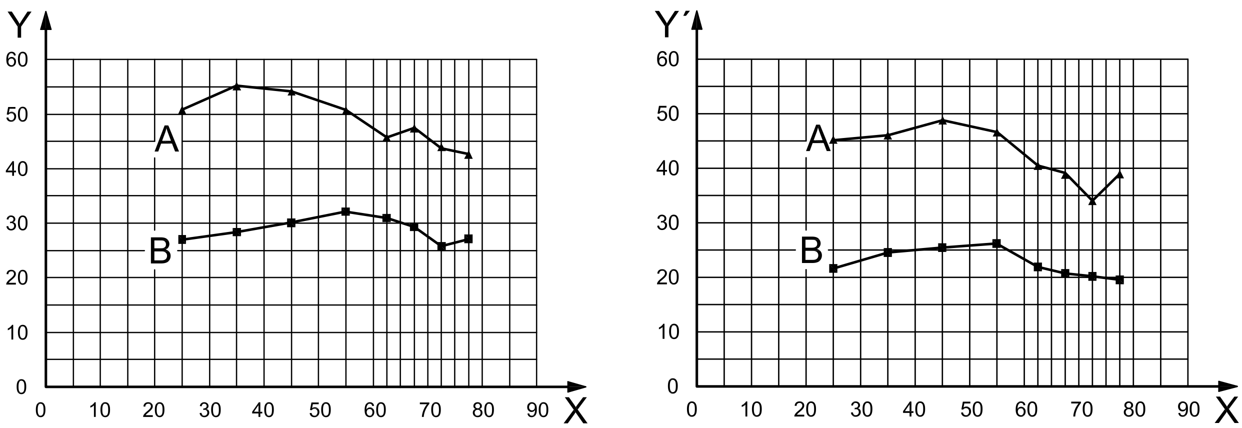
Y elbow flexion torque, N·m

Y′ elbow extension torque, N·m

A men

B women

Figure 70 — Torque data for elbow flexion and extension for Japanese people as function of age



a) Shoulder flexion **b) Shoulder extension**

Key

X age, years

Y shoulder flexion torque (forward elevation), N·m

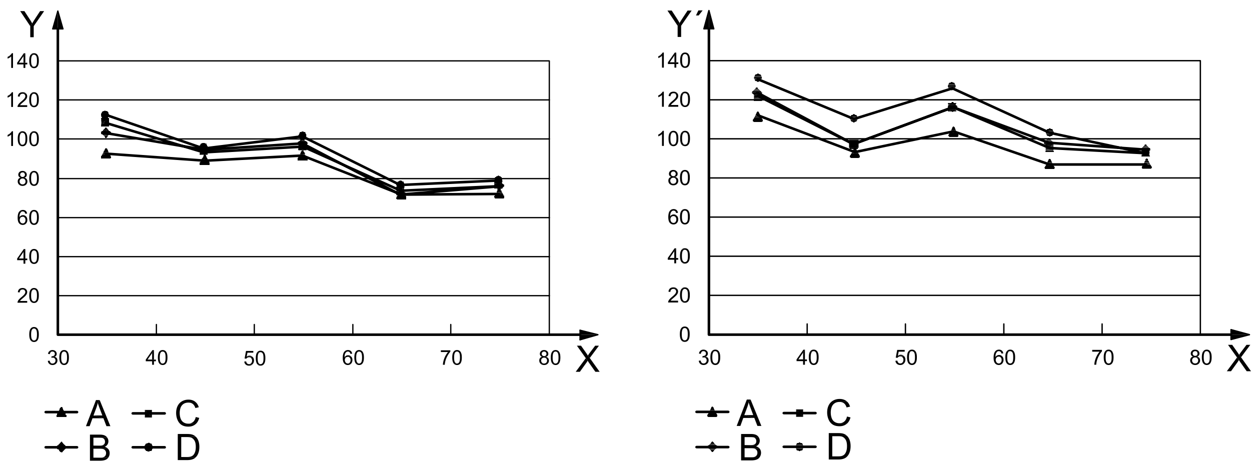
Y′ shoulder extension torque, N·m

A men

B women

Figure 71 — Torque data for shoulder flexion and extension for Japanese people as function of age

Figure 72 indicates the relationship between the height of the grip and the pushing and pulling strength values. The pushing and pulling strength values were taken from about 200 Japanese males. Measurements were performed when standing. The pushing and pulling strength values were obtained by isometric “make” tests in the sagittal plane using a force measurement system with load cells, and were measured during maximal-effort contraction in expiration in order to prevent strokes caused by sudden changes in blood pressure. Data were normalized by the height of the elbow joint of each person [113], [114].



a) Pushing strength **b) Pulling strength**

Key

X age, years

Y pushing strength, N

Y′ pulling strength, N

A relative height = 1,2

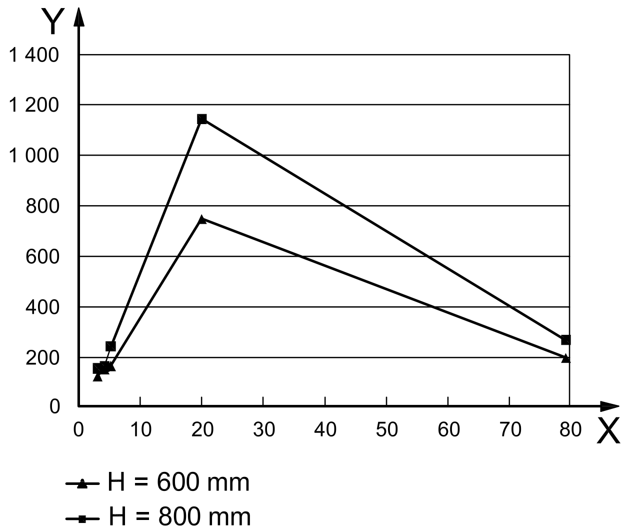
B relative height = 1,0

C relative height = 0,9

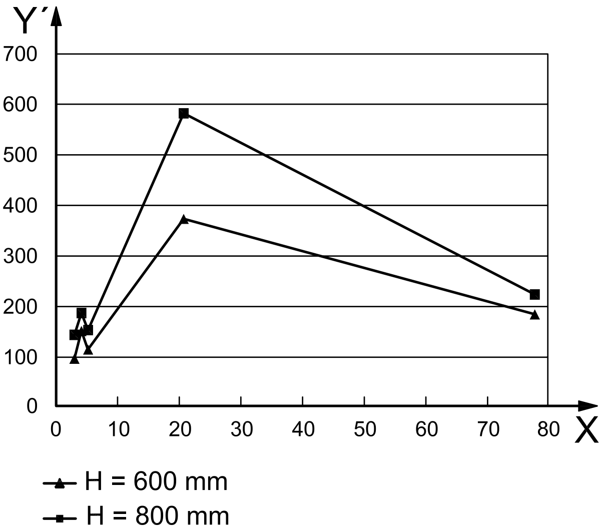
D relative height = 0,8

Figure 72 — Age-related difference of pushing/pulling strength in healthy Japanese men

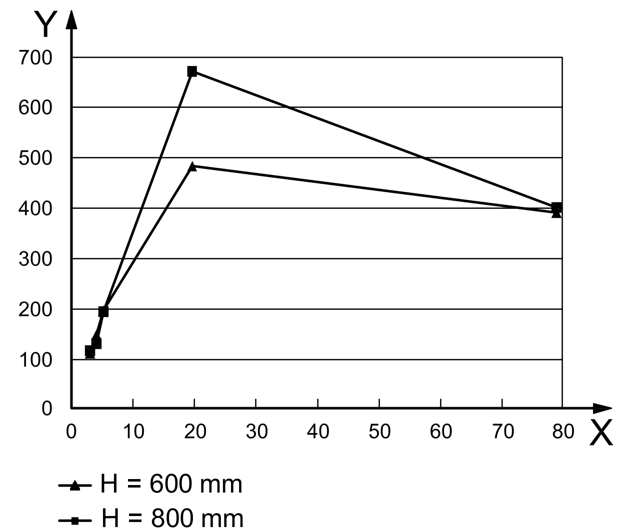
Figure 73 provides the relationships between height of the grip and pushing and pulling strength. The pushing and pulling strength values were taken from standing Japanese people. The pushing and pulling strength values were obtained by isometric “make” tests in the sagittal plane using a force measurement system with load cells, and were measured during maximal-effort contraction [112].



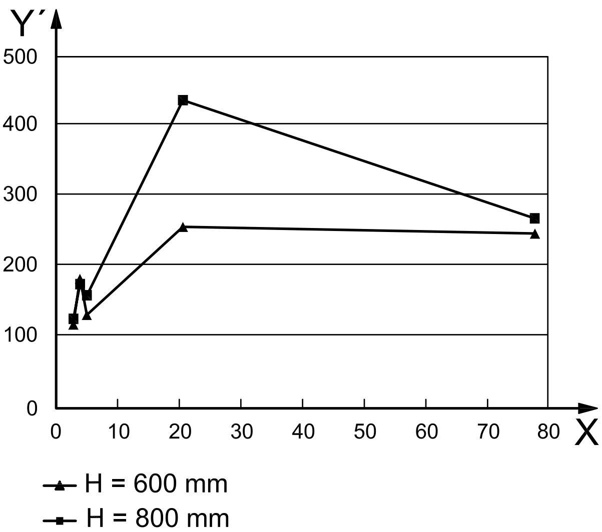
a) Pushing strength, men



b) Pushing strength, women



c) Pulling strength, men



d) Pulling strength, women

Key

X age, years

Y pushing strength, N

Y′ pulling strength, N

H relative height

Figure 73 — Age-related difference of pushing/pulling strength in healthy Japanese men and women

9.3.5 Voice

Description

Voice relates to the sound produced by the vocal organs, usually as speech. Speech impairments may influence speech in a general way, or only certain aspects of it such as articulation, volume, fluency, speed, melody and rhythm.

[ISO/IEC Guide 71:2001, 9.3.5.1]

Design considerations

The principal consequence of speech impairment is the barrier to communication and social interaction. Alternative forms of communication, such as sign language, or devices such as speech amplification, speech synthesis, or use of facsimile or key boards, may assist.

[ISO/IEC Guide 71:2001, 9.3.5.2]

No further guidance is offered.

9.4 Cognitive abilities

9.4.1 General

Cognition is the understanding, integrating and processing of information. The information includes abstraction and organization of ideas and time-management.

[ISO/IEC Guide 71:2001, 9.4.1.1]

People with a cognitive impairment may have trouble learning new things, making generalizations and associations, and expressing themselves through spoken and written language. These impairments can produce anxiety, loneliness, depression, delusions, obsessions and compulsions. Such disorders may result in reduced ability to concentrate on a task.

[ISO/IEC Guide 71:2001, 9.4.1.2]

Cognitive abilities are those concerned with central information processing, such as recalling from memory, directing attention, perception through sensory information, thinking, decision making, problem solving and language. *Cognition* refers to mental activities involved in acquiring and processing information. A general decline in cognitive performance can be observed with age.

When designing a product, consideration of cognitive limitations in respect of the acquiring, processing and storing of information, as summarized in Table 27, can increase accessibility.

Table 27 — Potential effects of cognitive impairment

Cognitive aspect	Potential effect of cognitive impairment	Relevant subclauses of this Technical Report
Intellect	Slower information processing	9.4.2, 8.7.4.2
Memory	Reduced ability to remember, increased forgetfulness	9.4.3, 8.10.1, 8.16.8
Language and literacy	Reduced ability to express thought in words or to process speech	9.4.4, 8.7.6.2
Time needed to acquire and process information	Time to process is increased	9.4.2.1, 8.10.1 to 8.10.3, 8.12.6
Recognition and comprehension of new information	Impaired	9.4.2.1, 8.20.1, 8.16.8
Reactions	Speed reduced	9.4.2.2, 8.12.6
Carrying out complex tasks	More difficult to complete	9.4.2.2, 8.17.1 to 8.17.4, 8.7.2
Sensitivity to disturbance	Increased when subjected to over-stimulation and distraction	8.16.8, 8.16.9, 8.7.4.4, 8.7.4.1, 8.8
Tendency toward irritation	Increased	8.17, (8.16), (8.20.1)
Psycho-motor coordination	Reduced	8.16.1 to 8.16.9, 8.18.1 to 8.18.3

Although the potential effects of cognitive impairment are evident, it is considered that variability among persons with cognitive impairment is very high and some cognitive aspects do not necessarily affect many people.

9.4.2 Intellect

Description

Intellect is the capacity to know, understand and reason.

[ISO/IEC Guide 71:2001, 9.4.2.1]

Effects of ageing

As people get older they may have more difficulty concentrating and in continuing to pay attention to a task. Changes in sleep/wake rhythm may mean older persons are sleepy and thus less alert during the day. Conditions such as dementia and Alzheimer's disease, which are more predominant among older persons, lead progressively to intellectual decline, confusion and disorientation.

[ISO/IEC Guide 71:2001, 9.4.2.2]

Design considerations

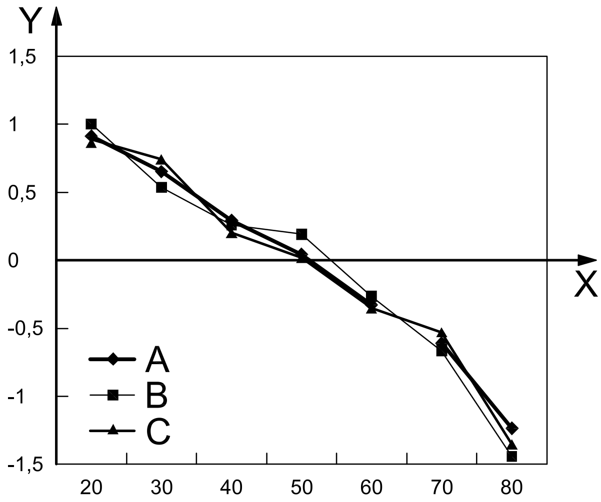
Impairment leads to perception problems, which include difficulty taking in, attending to, and discriminating sensory information. Difficulties in problem-solving include recognizing the problem, identifying, choosing ad implementing solutions, and evaluating the outcome.

[ISO/IEC Guide 71:2001, 9.4.2.3]

9.4.2.1 Processing speed and capacity

Age differences in comprehension and memory are mainly caused by reduction in processing capacity, which is believed to be caused by a decline in working memory capacity. This decline in processing capacity is expressed through a reduced information processing speed.

Older people can acquire new knowledge and master new skills, but doing so takes longer than it does for younger people. Generally speaking, the performance of learned mental tasks and skills will take longer than for younger people. Figure 74 [115] shows how processing speed decreases with age, for example, for digit symbol, pattern comparison, and letter comparison tasks. This “cognitive slowing” occurs at all stages of information processing, and increases both the time taken to perceive incoming information and the time required to process it and make decisions as to what response(s) to make. Training and application of strategies can improve older persons’ cognitive performance.



Key

X age by decade

Y Z score

A digit symbol

B pattern comparison

C letter comparison

NOTE Z score is the normalized standard score, the mean and standard deviation of which are converted to become zero and unity, respectively.

Figure 74 — Processing speed of intellectual activities as function of age

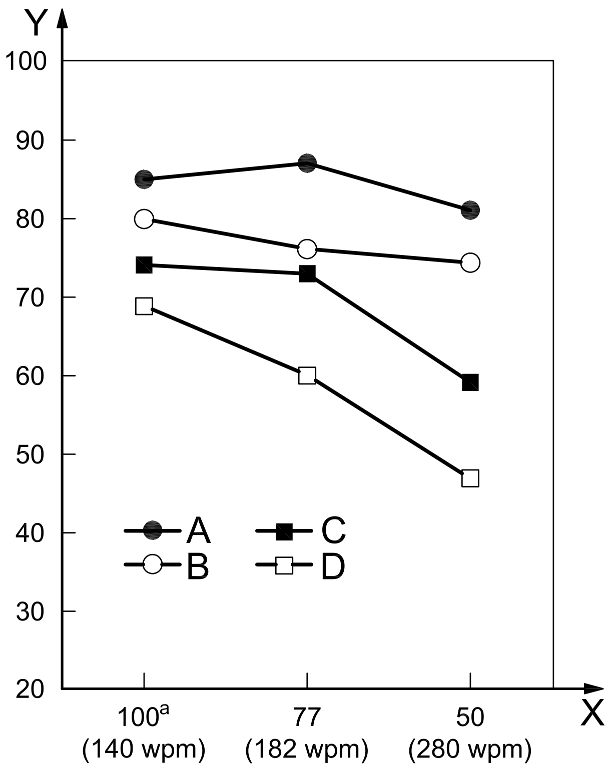
9.4.2.2 Task complexity

Performance is generally better when individuals perform a single task rather than when they are required to divide their attention among multiple tasks. For some tasks, such as those involving visual attention and reaction time, older people perform less well than younger people [116], [117].

For other tasks, such as those in studies employing meaningful speech [118], [119], there appear to be no age effects; the decline under dual task conditions were similar for older and younger people.

In some studies [118] the dual-task conditions involved the recall of words in spoken text, presented at three different rates, and recognition of pictures on a computer screen, which either had or had not been presented previously. Figure 75 shows the experimental results and a clear decline in the percentage of correctly recalled words by older people (but not younger people) as the speech rate increased. However, although the performance for both younger and older people declined under dual-task conditions, relative to single-task conditions, the decline was similar in both age groups.

The decline in the performance of older people with increasing speech rates is thought to reflect a "cognitive slowing" of information processing for older people, such that they need more time to process information presented at fast rates. Similarly, older people have difficulty processing sentences with especially complex syntax (see, for example, Reference [121]).



Key

X percent of original speech rate, %

Y percent correct recall

wpm words per minute

A young: single-task

B young: dual-task

C elderly: single-task

D elderly: dual-task

[a] Original.

Figure 75 — Percent of original speech rate

9.4.3 Memory

Description

Memory relates to specific mental functions of registering and storing information and retrieving it as needed.

[ISO/IEC Guide 71:2001, 9.4.3.1]

Effects of ageing

Failing memory affects people's ability to recall and learn things and may also lead to people being confused. Short-term or long-term memory can be affected. Short-term memory is more important for product use. People can forget what they should be doing before they complete a task.

[ISO/IEC Guide 71:2001, 9.4.3.2]

Risks and hazards

Memory impairment can lead to a hazard if an uncompleted task results in a dangerous situation such as the gas supply turned on but not ignited. Design needs to ensure that systems are "fail-safe".

[ISO/IEC Guide 71:2001, 9.4.3.3]

9.4.3.1 General

Memory refers to a multitude of human capacities. A central aspect of memory is preserving information, involving processes of encoding, storage and retrieval. There are many kinds of memory, as shown in Table 28 [120]. An often-used distinction of memory is based on the storage duration of information.

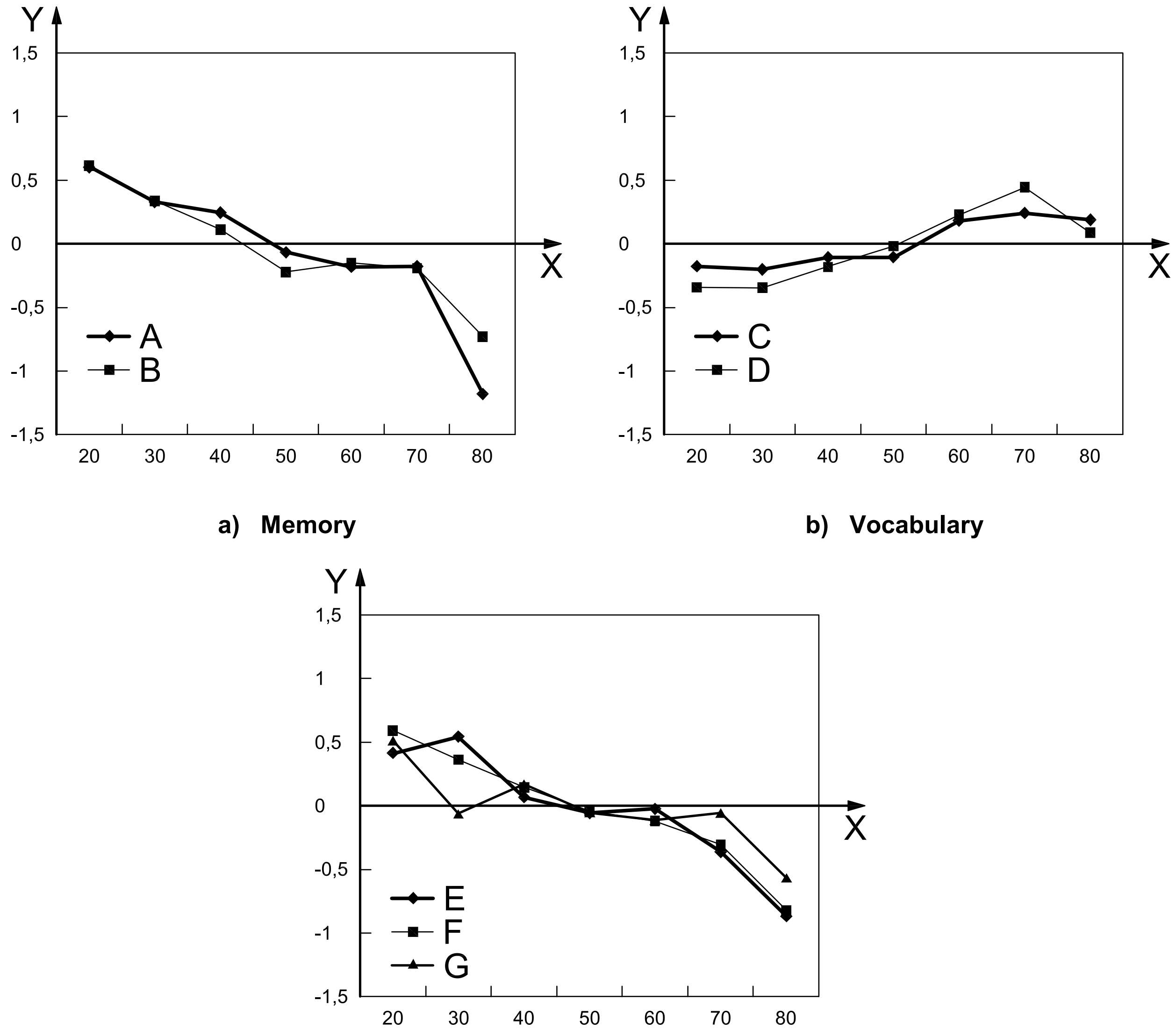
Table 28 — Classification of memory

Type of memory	Specification
Sensory memory	Retention of sensory information after the original stimulus has ceased (last < 2 s).
Working memory (short-term memory)	Manipulation and storage of information for a short period of time. Information storage capacity is approximately 4 discrete units (i.e.chunks). Information loss within 10 s–15 s if information not actively attended and rehearsed.
Long-term memory	Long-term storage of information over many years. Storage capacity is theoretically unlimited.
Episodic memory	Type of long-term memory that refers to the memory of events, such as the birth of a child, a tragic accident or a trip to a place one has never visited before.
NOTE *Chunk* is defined in cognitive science as a block of information processed as if it were a single piece of information even though it consists of several separate pieces. For example, a series of numbers comprising a telephone number.	

9.4.3.2 Effect of ageing on memory

Ageing is accompanied by a reduction in processing capacity. All forms of memory generally decrease as a function of age for nearly everyone, as shown in Figure 76 [115]. This memory decline accelerates after the age of about 75. Working memory seems to be most strongly affected by the process of ageing. The decline of working memory is believed to affect performance in many tasks, such as recalling information, information processing, language fluency, and understanding grammatical complexity, as well as multi-task performance. However, it is noted that vocabulary memory actually increases with age until at least age 80. Certain cognitive impairments and medical conditions have similar effects on memory.

In addition, persons with cognitive impairments often have difficulty in remembering the exact sequencing of multi-step procedures, or lose their orientation in a long sequence of steps. They rely more heavily on external memory aids and have problems holding a large amount of information in working memory.



a) Memory

b) Vocabulary

c) Working Memory

Key

X age by decade

Y Z score [a]

A free recall

B cued recall

C WAIS R (Wechsler adult intelligence scale, revised) vocabulary

D Shipley vocabulary (Shipley vocabulary test)

E computation span

F reading span

G backward digit span

[a] Normalized standard score: see Figure 74.

Figure 76 — Memory activities as function of age

9.4.4 Language/literacy

Description

Language and literacy are the specific mental functions of recognizing and using signs, symbols and other components of a language.

[ISO/IEC Guide 71:2001, 9.4.4.1]

Effects of ageing

Ageing sometimes affects a person's language ability, for example as the result of a stroke. When people have a stroke, their language ability may be affected. They may be able to think in the same manner but be unable to express their thoughts in words. Language impairment may cause difficulty in any, some or all of comprehension or expression of written or spoken language. People of all ages with dyslexia have difficulties in reading and writing.

[ISO/IEC Guide 71:2001, 9.4.4.2]

Risks and hazards

People with a language impairment may be put at risk if they are unable to comprehend written warnings or significant instructions.

[ISO/IEC Guide 71:2001, 9.4.4.3]

9.4.4.1 General

As noted in 9.4.3, the effects of age alone on language and literacy is limited, unless accompanied by sensory impairments or other medical conditions (e.g. stroke) that interfere with tasks involving speaking or writing. Limitations in working memory capacity seem to affect processing time, verbal fluency and resolution of grammatical complexity. These effects are especially apparent in multi-task situations (see 9.4.2.2). Moreover, there are many individuals of all ages who have difficulties reading, writing or speaking, due to sensory or cognitive impairments (e.g. dyslexia, dysgraphia, aphasia). In addition, levels of literacy are low in many countries. Many people have difficulties with languages other than their native language.

9.5 Allergies

9.5.1 Description

An allergy is an immunological reaction to a substance which may be serious and, in some circumstances, life-threatening. Allergies are also disabling when the need to avoid contact with an allergen (the substance to which their body is hypersensitive), imposes limitations on an individual's activities. In view of the implications for products, particularly labelling and warnings, information is provided on this topic.

[ISO/IEC Guide 71:2001, 9.5.1.1]

Types of allergens that cause allergic reactions include pollens, dust particles, mould spores, food, latex rubber, insect venom and certain medicines. Many products and devices unnecessarily contain substances, such as nickel, which cause allergic responses.

[ISO/IEC Guide 71:2001, 9.5.1.2]

Allergic reactions can range from mild and annoying to sudden and life-threatening. An example of sudden reaction is swollen throat and acute difficulties in breathing for people allergic to a certain foodstuff.

[ISO/IEC Guide 71:2001, 9.5.1.3]

9.5.1.1 General

Persons who have been sensitized by certain substances and who develop an allergy or already have an allergy are at a higher risk and are inconvenienced compared to the general public, and are therefore considered to have a disability. Allergies affect an increasing number of people in all age groups; therefore, it is important to avoid known allergens.

9.5.1.2 Allergic reaction

An allergy is an excessive immunological reaction to a foreign substance. A cross-reaction can also occur when immune cells come into contact with a substance that has a chemical structure similar to that of a sensitizer.

These phenomena are important for products in such fields as the textile, clothing, photography and hairdressing industries.

In general, allergic reactions are classified into four types (Types I, II, III, and IV). The allergic reactions related to product design are Type-I (anaphylaxis) and Type-IV (cell-mediated immunity) reactions.

Proteins are the major allergens for Type-I allergies. Type-I allergic reactions are common, with symptoms including allergic rhinitis (hay fever), allergic bronchial asthma and urticaria (skin rash), which arise from contact with such substances.

9.5.1.3 Importance of labelling

The use of warning labels (see 8.14) is important for products and services involving proteins, drugs or antibiotics that can induce systemic anaphylaxis through a Type-I allergic reaction. With rubber gloves or other products made of natural rubber, it is important to warn users with expressions such as, “Contains natural rubber”.

As far as Type-IV allergic reactions are concerned, because many people are sensitized to nickel and chrome, it is important to label products that contain, or are plated with, these by such warnings as, “Contains nickel”. Due to the risk of cross-sensitization, it is necessary to caution persons who have had related types of allergies. Certain dyes and p-Phenylenediamine (PPD) in hair dyes cross-react with some garments, making it necessary to label garments that have been made using such dyes with, for example, “This garment should not be worn by those who have had allergic reactions to a hair dye.”

EXAMPLE Allergic contact dermatitis caused by nickel (Ni) and chromium (Cr) in wristwatches.

Wristwatches and wristwatch bands made of stainless steel can cause allergic contact dermatitis when small amounts of nickel and chromium are eluted, due to sweat. It is therefore important to warn those who wear wristwatches about metal allergies.

9.5.2 Contact allergies

> Contact allergies are caused by allergens that enter the body through the skin. They are particularly contained in powders, lotions, perfumes, scented products, cosmetics, household chemicals, some metals or latex, and may be found in many household, building and electrical appliances. Contact allergy is prevalent among about 15 % of the population and is often life-long.
>
> [ISO/IEC Guide 71:2001, 9.5.2]

9.5.2.1 General information

There are two types of contact allergy, contact urticaria (Type-I allergic reaction) and allergic contact dermatitis (Type-IV allergic reaction).

Allergens are included in some metallic materials, plastics, synthetic rubbers, fibres, building materials, natural aromatic substances and latex. Contact allergies are occasionally caused by jewellery, watches, everyday items, cosmetics, garments, household chemicals, electrical products or buildings containing allergens. Fifteen percent of the population experiences some form of contact allergy, which in most cases lasts a lifetime. The major allergen for contact urticaria is a protein contained in latex, sometimes used in natural rubber gloves. The major allergens for allergic contact dermatitis vary, and include metals, macromolecular rubber additives, macromolecular monomers and dyes. Annex E presents case reports of allergic contact dermatitis.

9.5.3 Food allergies

A food allergy is a reaction or intolerance to one or more foodstuffs. A great number of foods can cause allergic reactions, the most common being milk, wheat, soy, egg, peanuts and fish. Food colours, preservatives and additives are also a major cause of allergy. [ISO/IEC Guide 71:2001, 9.5.3]

No further guidance is offered.

9.5.4 Respiratory allergies

Airborne allergens cover those that are inhaled, such as dust, pollen, mites, moulds and animal detritus. The most typical respiratory allergy is asthma, which results in constriction of the respiratory channels and breathlessness. [ISO/IEC Guide 71:2001, 9.5.4.1] For the purpose of this Guide, this clause includes chemical sensitivities, i.e. reactions to chemicals in the human environment. These allergy-like reactions may result from exposure to a wide variety of synthetic and natural substances, such as those found in paints, carpeting, building, materials, plastics, perfumes, cigarette smoke and plants. [ISO/IEC Guide 71:2001, 9.5.4.2]

Respiratory allergy is a Type-I allergic reaction. Bronchial asthma is one of the main diseases of respiratory tract allergy, and house dust is the cause in many cases. The symptoms of bronchial asthma can also result from contact with volatile organic compounds, such as formaldehyde.

Chemical sensitivity is considered to be different from a Type-I allergic reaction. The cause is not known well. The case of reacting to many chemicals is called “Multiple chemical sensitivity (MCS)”. The cause of these reactions, volatile organic compounds (VOC) such as formaldehyde and toluene, which are diffused from building materials, *is* known.

NOTE 1 Measuring of formaldehyde and VOC has been standardized (ISO/IEC 16000).

NOTE 2 Air quality guidelines for Europe, Copenhagen: WHO-Regional Office for Europe, WHO Regional Publications, European series No. 23/1987.

Annex A
(informative)

Principles of accessible design

When designing accessible products, the following principles published by the Center for Universal Design [44] should be considered, preferably during the early design stages:

Principle 1: Equitable use

The design is useful and marketable to persons with diverse abilities.

a) Provide the same means of use for all users: identical whenever possible; equivalent when not.

b) Avoid segregating or stigmatizing any users.

c) Provisions for privacy, security and safety should be equally available to all users.

d) Make the design appealing to all users.

Principle 2: Flexibility in use

The design accommodates a wide range of individual preferences and abilities.

a) Provide choice in methods of use.

b) Accommodate right- or left-handed access and use.

c) Facilitate the user's accuracy and precision.

d) Provide adaptability to the user's pace.

Principle 3: Simple and intuitive use

Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.

a) Eliminate unnecessary complexity.

b) Be consistent with user expectations and intuition.

c) Accommodate a wide range of literacy and language skills.

d) Arrange information consistently by its importance.

e) Provide effective prompting and feedback during and after task completion.

Principle 4: Perceptible information

The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.

a) Use alternative formats to present essential information, e.g. pictorial, verbal, and tactile modes.

b) Provide adequate contrast between essential information and its surroundings.

c) Maximize “legibility” of essential information.

d) Differentiate elements in ways that can be described (i.e. make it easy to give instructions or directions).

e) Provide compatibility with a variety of methods or devices used by persons with sensory limitations.

Principle 5: Tolerance for error

The design minimizes hazards and the adverse consequences of accidental or unintended actions.

a) Arrange elements to minimize hazards and errors: most used elements, most accessible, with hazardous elements eliminated, isolated or shielded.

b) Provide warnings of hazards and errors.

c) Provide fail safe features.

d) Discourage unconscious action in tasks that require vigilance.

Principle 6: Low physical effort

The design can be used efficiently, comfortably, and with a minimum of fatigue.

a) Allow user to maintain a neutral body position.

b) Use reasonable operating forces.

c) Minimize repetitive actions.

d) Minimize sustained physical effort.

Principle 7: Size and space for approach and use

Appropriate size and space is provided for approach, reach, manipulation, and use regardless of user’s body size, posture, or mobility.

a) Provide a clear line of sight to important elements for any seated or standing user.

b) Make reach to all components comfortable for any seated or standing user.

c) Accommodate variations in hand and grip size.

d) Provide adequate space for the use of assistive devices or personal assistance.

Annex B
(informative)

Data on spectral sensitivity of the eye as a function of age and application

B.1 Data

Table B.1 shows the spectral sensitivity of the eye measured by flicker photometry for a total of 91 people ranging in age from 11 years to 78 years [81]. The data are classified into seven decades and geometrically averaged over each group. The averaged data are normalized at 555 nm and represented in the table in 5 nm steps from 400 nm to 700 nm. See 9.2.1.1.

Table B.1 — Spectral sensitivity data

Wavelength	Spectral sensitivity of the eye						
nm	10–19 years	20–29 years	30–39 years	40–49 years	50–59 years	60–69 years	70–79 years
400	0,015	0,010	0,006	0,004	0,002	0,002	0,001
405	0,022	0,014	0,009	0,006	0,004	0,002	0,002
410	0,029	0,020	0,013	0,009	0,006	0,004	0,003
415	0,038	0,026	0,018	0,012	0,008	0,006	0,004
420	0,048	0,033	0,023	0,016	0,011	0,008	0,006
425	0,057	0,041	0,029	0,021	0,015	0,011	0,008
430	0,064	0,047	0,034	0,025	0,018	0,014	0,010
435	0,071	0,053	0,040	0,030	0,022	0,017	0,012
440	0,076	0,058	0,045	0,034	0,026	0,020	0,015
445	0,081	0,063	0,049	0,038	0,030	0,023	0,018
450	0,085	0,068	0,054	0,043	0,034	0,027	0,022
455	0,090	0,073	0,059	0,048	0,039	0,032	0,026
460	0,097	0,080	0,066	0,055	0,045	0,037	0,031
465	0,106	0,089	0,075	0,063	0,053	0,044	0,037
470	0,116	0,099	0,085	0,072	0,062	0,053	0,045
475	0,129	0,112	0,097	0,084	0,073	0,063	0,055
480	0,144	0,127	0,112	0,099	0,087	0,076	0,067
485	0,164	0,146	0,131	0,117	0,104	0,093	0,083
490	0,191	0,173	0,156	0,142	0,128	0,116	0,105
495	0,232	0,212	0,194	0,178	0,163	0,150	0,137
500	0,292	0,271	0,251	0,233	0,216	0,200	0,186
505	0,384	0,360	0,337	0,316	0,296	0,278	0,260
510	0,501	0,474	0,449	0,425	0,402	0,381	0,361
515	0,621	0,593	0,567	0,541	0,517	0,494	0,472
520	0,729	0,703	0,677	0,653	0,629	0,606	0,584
525	0,813	0,790	0,767	0,745	0,723	0,702	0,682
530	0,876	0,857	0,838	0,819	0,801	0,783	0,766
535	0,929	0,914	0,899	0,884	0,870	0,856	0,842
540	0,969	0,958	0,948	0,937	0,927	0,917	0,906
545	0,994	0,988	0,981	0,975	0,968	0,962	0,956
550	1,003	1,001	1,000	0,995	0,992	0,989	0,986
555	1,000	1,000	1,000	1,000	1,000	1,000	1,000
560	0,987	0,989	0,991	0,993	0,995	0,997	0,999
565	0,964	0,967	0,970	0,974	0,977	0,980	0,984
570	0,932	0,936	0,940	0,943	0,947	0,951	0,955
575	0,892	0,896	0,899	0,902	0,906	0,909	0,913
580	0,820	0,828	0,836	0,845	0,853	0,861	0,870
585	0,751	0,762	0,774	0,786	0,799	0,811	0,824
590	0,684	0,698	0,713	0,728	0,744	0,760	0,776
595	0,620	0,637	0,654	0,671	0,689	0,708	0,727
600	0,560	0,578	0,596	0,615	0,635	0,655	0,676
605	0,500	0,519	0,538	0,558	0,579	0,600	0,622
610	0,440	0,458	0,478	0,498	0,519	0,540	0,563
615	0,381	0,399	0,417	0,437	0,457	0,478	0,501
620	0,325	0,341	0,359	0,377	0,396	0,417	0,438
625	0,272	0,287	0,303	0,320	0,338	0,357	0,376
630	0,225	0,238	0,252	0,267	0,283	0,300	0,318
635	0,183	0,194	0,207	0,220	0,234	0,248	0,264
640	0,146	0,156	0,166	0,178	0,189	0,202	0,216
645	0,115	0,123	0,132	0,141	0,151	0,162	0,173
650	0,089	0,096	0,103	0,110	0,119	0,127	0,137
655	0,068	0,074	0,079	0,085	0,092	0,099	0,106
660	0,052	0,056	0,061	0,065	0,070	0,076	0,082
665	0,039	0,042	0,046	0,050	0,054	0,058	0,063
670	0,029	0,032	0,034	0,037	0,040	0,044	0,047
675	0,022	0,024	0,026	0,028	0,030	0,033	0,036
680	0,016	0,017	0,019	0,021	0,022	0,024	0,026
685	0,012	0,013	0,014	0,015	0,016	0,018	0,019
690	0,008	0,009	0,010	0,011	0,012	0,013	0,014
695	0,006	0,007	0,007	0,008	0,009	0,009	0,010
700	0,004	0,005	0,005	0,006	0,006	0,007	0,007

B.2 Application

Quantitative evaluation of luminance contrast of any two coloured lights for an observer of age a can be estimated by using spectral sensitivity of the eye.

Equation (B.1) defines age-related luminance contrast, C_a, that expresses apparent contrast of two lights seen by an observer of age a, where the spectral sensitivity function corresponding to the age is used.

$$C_a = \frac{\sum_{400}^{700} L_{1e,\lambda} V(\lambda)_a \Delta\lambda - \sum_{400}^{700} L_{2e,\lambda} V(\lambda)_a \Delta\lambda}{\sum_{400}^{700} L_{2e,\lambda} V(\lambda)_a \Delta\lambda} \tag{B.1}$$

where

C_a is the age-related luminance contrast of age a,

$L_{1e,\lambda}$ is the spectral radiance of one part of the two lights to be compared

$W \cdot m^{-2} \cdot sr^{-1} \cdot nm^{-1}$,

$L_{2e,\lambda}$ is the spectral radiance of the other part of the two lights to be compared

$W \cdot m^{-2} \cdot sr^{-1} \cdot nm^{-1}$,

$V(\lambda)_a$ is spectral sensitivity function of a person of age a,

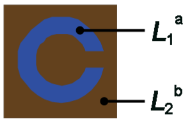
$\Delta\lambda$ is the wavelength width (5 nm).

C_a is expressed, for example, as C_{20} for the observer in his/her twenties. $L_{1e,\lambda}$ and $L_{2e,\lambda}$ is the value measured in the range of 400 nm to 700 nm in 5 nm for the abridged calculation. $V(\lambda)_a$ is expressed, for example, as $V(\lambda)_{20}$ for an observer in his/her twenties, and appears as a suitable value from the age-related spectral luminous efficiency given in Table B.1.

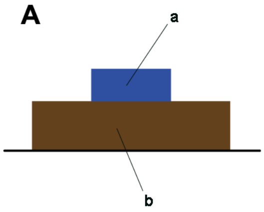
The quantity, $\sum_{400}^{700} L_{1e,\lambda} V(\lambda)_a \Delta\lambda$ corresponds to a relative value of luminance or as defined by CIE where the standard luminous efficiency function, $V(\lambda)$ and the maximum luminous efficacy K_m (683 lm/W) are applied. This means the quantity represents the perceived brightness of a light.

For a given visual sign with spectral radiant distribution as shown in Figure B.1, the age-related luminous contrast is calculable for the sign and the background for two observers different in age, e.g. those in their 20s and those in their 60s, by using their corresponding spectral sensitivity. The results of calculation show that the age-related contrast for an individual in his/her 20s is 0,51, and that for an individual in his/her 60s is 0,18. This means the sign is clearly visible for younger people but much less visible for older.

The calculation method can be applied to any sign/symbol and background of any colour, for example in traffic or public signs, products labels, lamps and lighting installations. See also 8.2.3.1 and 8.5.1 to 8.5.4.



A

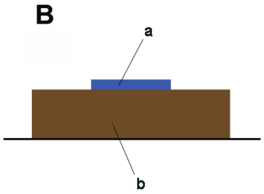


$$C_{20} = \frac{\sum L_{1e,\lambda}\, 1V(\lambda)_{20}\, \Delta\lambda - \sum L_{2e,\lambda}\, V(\lambda)_{20}\, \Delta\lambda}{\sum L_{2e,\lambda}\, V(\lambda)_{20}\, \Delta\lambda}$$

$$= \frac{0{,}238 - 0{,}158}{0{,}158} = 0{,}51$$

Contrast 51 %

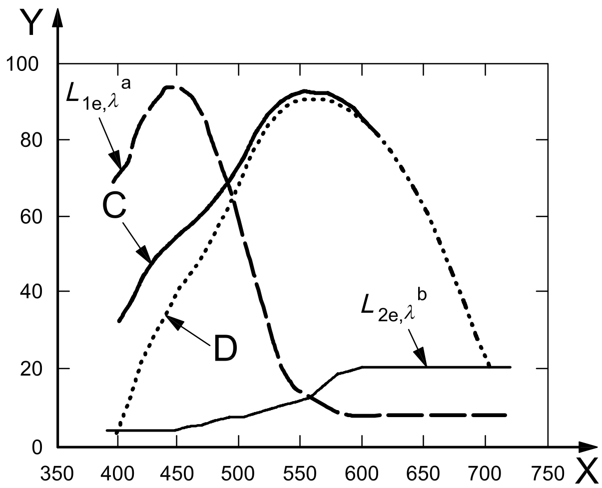
B



$$C_{60} = \frac{\sum L_{1e,\lambda}\, 1V(\lambda)_{60}\, \Delta\lambda - \sum L_{2e,\lambda}\, V(\lambda)_{60}\, \Delta\lambda}{\sum L_{2e,\lambda}\, V(\lambda)_{60}\, \Delta\lambda}$$

$$= \frac{0{,}193 - 0{,}163}{0{,}163} = 0{,}18$$

Contrast 18 %



Key

X wavelength, nm

Y spectral radiance, mW/m^{2}sr

A for an individual in his/her 20s

B for an individual in his/her 60s

C $V(\lambda)_{20}$

D $V(\lambda)_{60}$

[a] Blue symbol.

[b] Dark brown background.

Figure B.1 — Example of calculation of the age-related relative luminous efficiency and visual contrast

Annex C
(informative)

Visual acuity data as a function of viewing distance for different age groups

C.1 General

Table C.1 shows visual acuity measured using a Landolt ring chart printed black on a white background, i.e. an insufficiently high contrast. The luminance of the background is 100 cd/m^2. The individual's eye was corrected by an optical lens so as to obtain the best acuity at the furthest (5 m) point. Visual acuity is here defined so that 80 % of the correct response of orientation of the gap is in a Landolt ring.

The data were measured for a total of 111 individuals ranged in age from 11 to 78 years at five viewing distances (0,3 m, 0,5 m, 1 m, 2 m, 5 m) and the data were smoothed and interpolated along with age and viewing distance. The data are presented in 2 year steps in age and in appropriate steps in viewing distance [82].

Table C.1 — Visual acuity as function of viewing distance and age (at 100 cd/m^2)

Age years	Viewing distance m											
	0,2	0,3	0,5	1	2	3	5	10	20	30	50	100
10	1,237	1,411	1,567	1,696	1,764	1,787	1,806	1,792	1,785	1,783	1,780	1,779
12	1,124	1,316	1,493	1,641	1,721	1,748	1,770	1,754	1,746	1,743	1,741	1,739
14	1,022	1,228	1,423	1,589	1,679	1,710	1,735	1,717	1,707	1,704	1,701	1,700
16	0,929	1,146	1,356	1,538	1,638	1,673	1,701	1,680	1,670	1,666	1,663	1,661
18	0,844	1,069	1,292	1,489	1,598	1,636	1,667	1,644	1,633	1,629	1,626	1,623
20	0,767	0,998	1,231	1,441	1,559	1,600	1,634	1,609	1,597	1,593	1,590	1,587
22	0,697	0,931	1,173	1,395	1,521	1,565	1,602	1,575	1,562	1,557	1,553	1,551
24	0,634	0,869	1,118	1,350	1,484	1,531	1,570	1,542	1,527	1,522	1,519	1,516
26	0,576	0,810	1,065	1,307	1,448	1,498	1,539	1,509	1,493	1,488	1,484	1,481
28	0,524	0,756	1,015	1,265	1,412	1,465	1,509	1,477	1,461	1,455	1,451	1,448
30	0,476	0,706	0,967	1,224	1,378	1,433	1,479	1,445	1,428	1,423	1,418	1,415
32	0,433	0,658	0,921	1,185	1,344	1,402	1,450	1,415	1,397	1,391	1,386	1,383
34	0,393	0,614	0,878	1,147	1,311	1,371	1,421	1,385	1,366	1,360	1,355	1,352
36	0,357	0,573	0,836	1,110	1,280	1,341	1,393	1,355	1,336	1,330	1,325	1,321
38	0,325	0,535	0,797	1,075	1,248	1,312	1,366	1,326	1,307	1,300	1,295	1,291
40	0,295	0,499	0,760	1,040	1,218	1,284	1,339	1,298	1,278	1,271	1,266	1,262
42	0,268	0,466	0,724	1,007	1,188	1,256	1,312	1,270	1,250	1,243	1,237	1,233
44	0,244	0,434	0,690	0,975	1,159	1,228	1,286	1,243	1,222	1,215	1,209	1,205
46	0,222	0,405	0,657	0,944	1,131	1,201	1,261	1,217	1,195	1,188	1,182	1,178
48	0,200	0,378	0,626	0,913	1,103	1,175	1,236	1,190	1,169	1,161	1,156	1,151
50	0,180	0,353	0,596	0,884	1,077	1,150	1,211	1,166	1,143	1,136	1,130	1,125
52	0,160	0,329	0,568	0,856	1,050	1,124	1,188	1,141	1,118	1,110	1,104	1,100
54	0,151	0,307	0,541	0,828	1,025	1,100	1,164	1,117	1,093	1,086	1,079	1,075
56	0,137	0,287	0,516	0,802	1,000	1,076	1,141	1,093	1,069	1,061	1,055	1,050
58	0,125	0,267	0,492	0,776	0,975	1,052	1,119	1,070	1,046	1,038	1,031	1,027
60	0,114	0,250	0,468	0,751	0,952	1,029	1,096	1,047	1,023	1,014	1,008	1,003
62	0,103	0,233	0,446	0,727	0,928	1,007	1,075	1,025	1,000	0,992	0,985	0,981

Table C.1 (*continued*)

Age years	Viewing distance m											
	0,2	0,3	0,5	1	2	3	5	10	20	30	50	100
64	0,094	0,217	0,425	0,704	0,906	0,985	1,054	1,003	0,978	0,970	0,963	0,958
66	0,085	0,203	0,405	0,681	0,884	0,964	1,033	0,982	0,956	0,948	0,942	0,937
68	0,077	0,189	0,386	0,660	0,862	0,943	1,012	0,961	0,935	0,927	0,920	0,916
70	0,070	0,176	0,368	0,638	0,841	0,922	0,992	0,940	0,915	0,906	0,900	0,895
72	0,064	0,165	0,351	0,618	0,821	0,902	0,973	0,920	0,895	0,886	0,879	0,875
74	0,058	0,154	0,334	0,598	0,801	0,882	0,953	0,901	0,875	0,866	0,860	0,855
76	0,053	0,143	0,318	0,579	0,781	0,863	0,935	0,882	0,856	0,847	0,840	0,835
78	0,048	0,134	0,303	0,561	0,762	0,844	0,916	0,863	0,837	0,828	0,821	0,816
80	0,044	0,125	0,289	0,542	0,743	0,826	0,898	0,844	0,818	0,810	0,803	0,798

C.2 Visual acuity data as function of luminance level

Table C.2 shows visual acuity data for different luminance levels. The dependency of visual acuity on luminance is not affected by age.

The data presented in Table C.2 mean that the luminance is defined by a ratio of visual acuity to the reference data at 100 cd/m^2. The data are presented from 0,01 cd/m^2 to 3 000 cd/m^2 [82].

Table C.2 — Visual acuity as function of luminance relative to 100 cd/m^2 value (luminance factor)

Luminance cd/m^2	Luminance factor for acuity
0,01	0,028
0,02	0,101
0,03	0,143
0,04	0,174
0,05	0,198
0,06	0,217
0,07	0,233
0,08	0,248
0,09	0,260
0,1	0,271
0,2	0,344
0,3	0,387
0,4	0,417
0,5	0,441
0,6	0,460
0,7	0,476
0,8	0,491
0,9	0,503
1	0,514
2	0,587
3	0,630
4	0,660
5	0,683
6	0,703
7	0,719
8	0,734
9	0,746

Luminance cd/m^2	Luminance factor for acuity
10	0,757
20	0,830
30	0,873
40	0,903
50	0,927
60	0,946
70	0,962
80	0,977
90	0,989
100	1,000
200	1,036
300	1,057
400	1,071
500	1,083
600	1,093
700	1,101
800	1,108
900	1,114
1 000	1,119
2 000	1,155
3 000	1,176

C.3 Estimation of a minimum legible font size

The minimum legible font size of a single character, P, in points, can be estimated as a function of visual acuity by introducing a size factor, S, as shown in Equation (C.1):

$$P = (a \times S) + b \qquad \text{(C.1)}$$

where

P is the minimum legible font size of the character;

a, b are parameters depending on the type of font (see Table C.3).

The size factor is defined by viewing distance, D (in metres), and visual acuity, V, as shown in Equation (C.2):

$$S = D/V \qquad \text{(C.2)}$$

Visual acuity, V, can be obtained as a function of viewing distance D, luminance level, L (in cd/m^2) and age of the person. Annex C.1 provides visual acuity data as a function of viewing distance and age at a fixed luminance condition of 100 cd/m^2. To determine the visual acuity at any other luminance level, C.2 provides a multiplication factor, called the *luminance factor* on visual acuity, as in Equation (C.3):

$$V = V_0 \times k \qquad \text{(C.3)}$$

where

V_0 is the visual acuity at 100 cd/m^2;

k is the luminance factor.

From Equations (C.1) to (C.3), the minimum legible font size is calculable. For example, for a given condition such as age = 68 years old, viewing distance (D) = 0,5 m, luminance (L) = 10 cd/m^2, the font size is obtained as follows:

Table C.1 shows that the visual acuity, V_0, for a 68 year old person, at 0,5 m and at 100 cd/m^2 is 0,386.

Table C.2 shows that the luminance factor on visual acuity, k, at 10 cd/m^2 is 0,757.

Visual acuity adjusted to 10 cd/m^2 is obtained from Equation (C.3) as, $V = V_0 \times k$ = 0,386 × 0,757 = 0,292.

The size factor is calculable from Equation (C.2) as, $S = D/V$ = 0,5/0,292 = 1,71.

Assuming a plain font, the parameters a = 8,2 and b = 2,6 are selected from Table C.1 and are used in the calculation of the minimum legible size, P, from Equation (C.1) as:

$$P = (a \times S) + b = (8{,}2 \times 1{,}71) + 2{,}6 = 16{,}6 \text{ (point)}$$

Table C.3 — Coefficients a and b of Equation (C.1) for plain and gothic alphanumeric fonts

Font type	a	b
Plain(with serifs)	8,2	2,6
Gothic(sans-serif)	6,4	3,0

A 16,6 point plain font is the minimum legible size for an individual aged 68 in the 10 cd/m^2 condition from a viewing distance of 0,5 m.

As the P means the “minimum” legible size, the comfortable reading size could be set larger than this minimum, depending on the purpose.

Font size in points, P, can be expressed by the Equation (C.4):

$$M = 0{,}3514 \times P \qquad \text{(C.4)}$$

Luminance of the background can be calculated from illuminance, E (in lux), and reflectance, ρ, of the background of diffused material by following Equation (C.5):

$$L = \rho \times E/\pi \qquad (\text{cd/m}^2) \qquad \text{(C.5)}$$

Annex D
(informative)

Span of fundamental colours

D.1 Definition and principle of measurement of colour category

Colour is perceived in the central part of the brain by the formation of a family of similar colours. Berlin and Kay [122] found a limited number of basic colours for such families denoted as categorical colours from a linguistic point of view (red, yellow, green, etc.). This concept is applied in the measurement of the span of fundamental colours on the basis of similarity of colours.

Colour category can be measured experimentally by presenting a pair of colours and asking the individual to judge whether or not the pair of colours looks similar in appearance. By fixing one component of the pair as a reference and changing the other throughout the human colour space in respect of variable hue, chroma, lightness, along with entire human colour space (e.g. Munsell Colour Space), a group of similar colours can be measured against the reference. By changing the reference to a number of fundamental colours, it is possible to draw a set of similar colour groups for the fundamental colours in the human colour space.

Using a number of individuals, the similarity judge for a pair of colours can be expressed as a probability of those who judged colours to be “similar” among the total individuals participating in the experiment. Then, metric treatment of the span of similarity is possible by setting the probability at, say, 50 %.

D.2 Data

The span of categorical colours was measured extensively using subjective judgment of colour similarity for a total of 50 younger (18–26 years) and 50 older (60–76 years) people, and the 50 % and 10 % similarity data were presented [83], [123]. Considering the change of colour perception with luminance level and age groups, the data were given in four different conditions:

— younger persons at the photopic (moderate to high illuminance) level;

— older persons at the photopic level;

— younger persons at the mesopic (low illuminance) level;

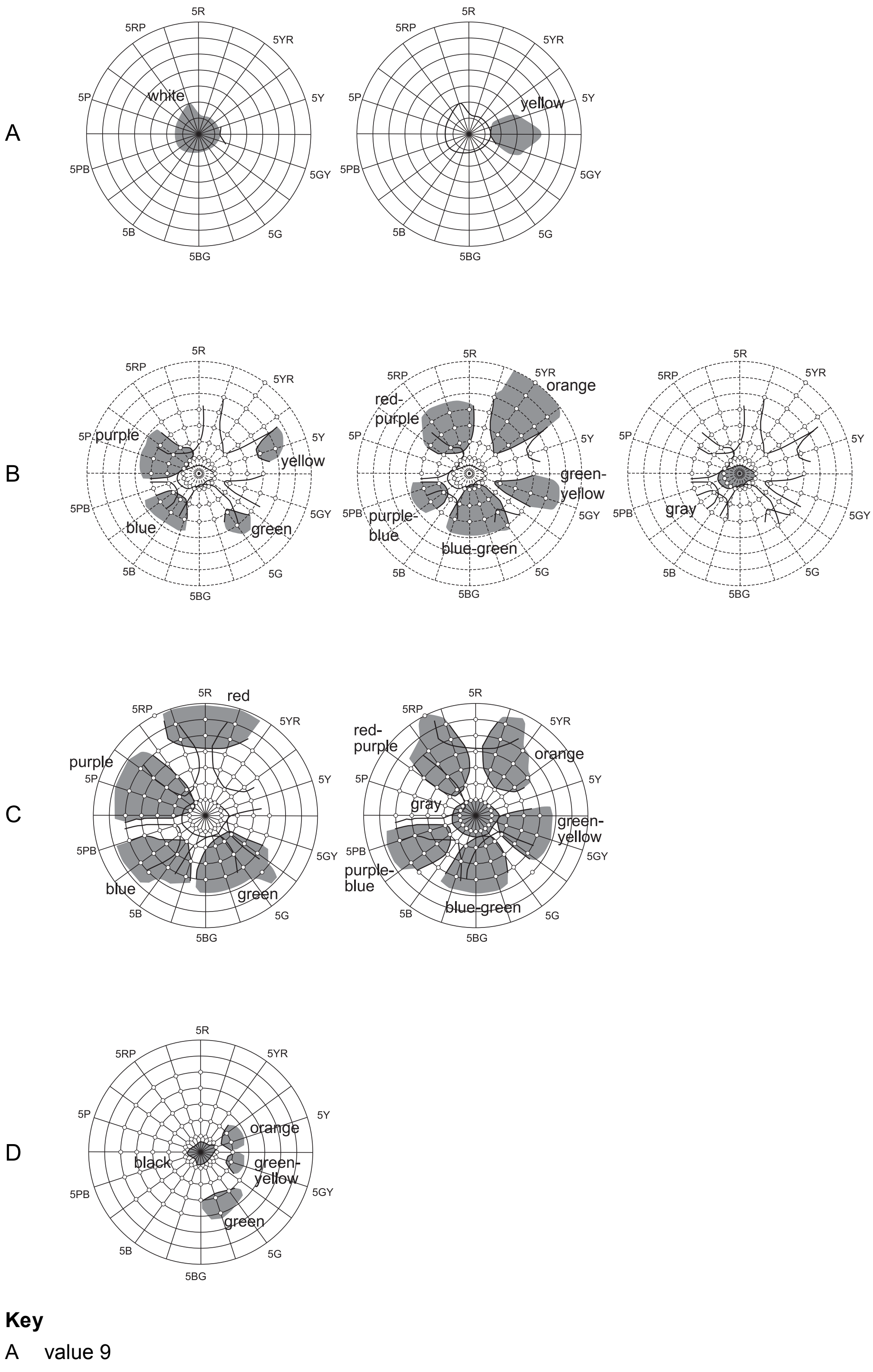
— older persons at the mesopic level.

NOTE In the experiment, photopic and mesopic levels are defined as 500 lx and 0,5 lx, respectively.

In Figure D.1, the data for younger people at the photopic level are shown. Noting the three-dimensional structure of the test colour in the Munsell colour space, the data were shown at four levels of lightness scale, i.e. values 9, 7, 5 and 3. The span of each of the 13 fundamental colours (red, orange, yellow, yellow-green, green, green-blue, blue, blue-purple, purple, red-purple, white, grey and black) is shown as the filled area in Figure D.1. For some colours, the span extends to a few different lightness levels.

Data for older people in photopic conditions are shown in Figure 32 together with an example of how to use the data.

Figures D.2 and D.3 show the data taken at dark (mesopic) conditions for younger and older people. The span is larger than, and the shape differs from, that of the photopic condition for almost all of the fundamental colours.



Key

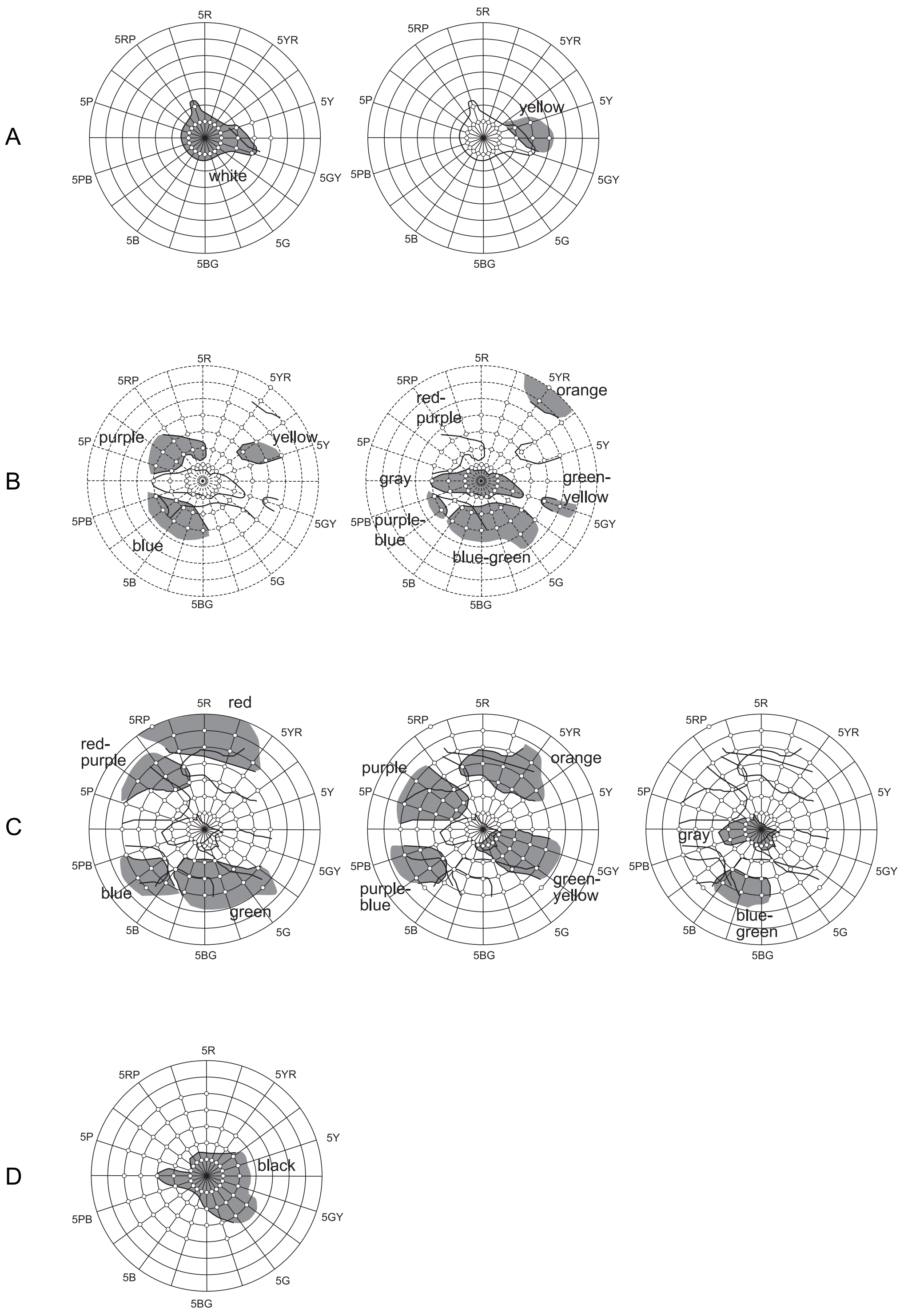
A value 9

B value 7

C value 5

D value 3

Figure D.1 — Span of fundamental colours for younger people at photopic level



Key

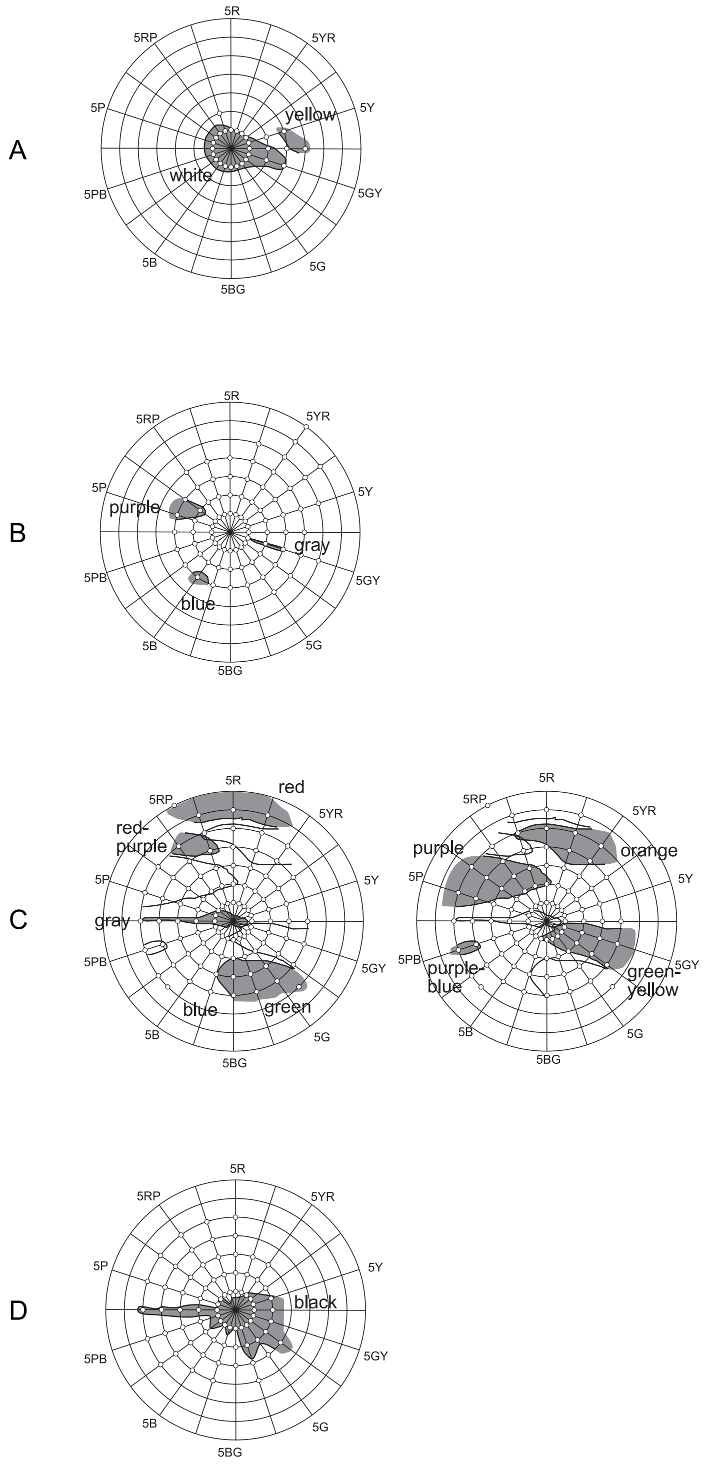
A value 9

B value 7

C value 5

D value 3

Figure D.2 — Span of fundamental colours for younger people at mesopic level



Key

A value 9

B value 7

C value 5

D value 3

Figure D.3 — Span of fundamental colours for older people at mesopic level

Annex E
(informative)

Cases of allergy

E.1 Metal allergens

Nickel, chromium, cobalt and mercury are common allergens. Nickel and chromium plating allows plated materials to appear glossy and attractive, and provides them with superior rust-prevention properties. As a result, these metals are used in jewellery, household goods and machine tools. Stainless steel is an alloy comprising iron, nickel and chromium, and is very stable. As a result, it is used in household goods, building materials and machine tools. In metallic form, nickel and chromium do not cause allergies. However, nickel and chromium may dissolve into metallic salt, and thereby cause allergic contact dermatitis. As for the source of sensitization, occupational allergies caused by cement were common in the past, but allergies caused by the wearing of jewellery are more common today.

a) Allergic contact dermatitis caused by nickel (Ni) and chromium (Cr) in wristwatches

Target products: wristwatches.

Allergens: nickel (Ni) and chromium (Cr).

Corresponding ICS code: ICS 39.040.10 (Watches).

Wristwatches and wristwatch bands made of stainless steel can cause allergic-contact dermatitis when small amounts of nickel and chromium are eluted, due to sweat. In the past, chrome salts were used for the tanning of leather, and allergic contact dermatitis was caused by chromium in leather watchbands.

As metals can cause an allergic reaction, research was conducted to develop wristwatch materials that do not cause allergic reactions. As a result, titanium watches were introduced, and are now sold as hypoallergenic products. Those with an allergy to metal sometimes wear wristwatches with resin watchbands, or wrap their wrist in a bandage so that the metal does not come in contact with the wrist; however, these measures actually have little effect. It is therefore important to warn those who wear wristwatches about metal allergies, and to suggest that those with metal allergies use hypoallergenic products.

b) Allergic contact dermatitis caused by nickel-plated jewellery

Target product: jewellery.

Allergen: nickel (Ni).

Corresponding ICS code: ICS 39.060 (Jewellery).

When nickel elutes from nickel-plated jewellery that comes in direct contact with skin — a factor affected by the shape and usage — allergic contact dermatitis can occur. For example, the gold plating of necklaces, bracelets and pendants is rubbed off due to abrasion, which exposes the inner nickel plating layer covering the brass. This can cause allergic contact dermatitis. If information as to how jewellery is made and what substances are used is given, then those with metal allergies can be prevented from developing allergic contact dermatitis. Those with metal allergies are advised to avoid wearing jewellery wherever possible, or wear jewellery made of less sensitizing metals, such as gold and platinum.

c) **Allergic contact dermatitis caused by gold earring pins**

Target products: earrings.

Allergen: gold (Au).

Corresponding ICS code: ICS 39.060 (Jewellery).

While gold is a relatively low sensitizing metal, when used for an earring pin that goes through the earlobe, sensitization occasionally occurs and allergic contact dermatitis can occur. Allergic contact dermatitis caused by an earring is severe, and when gold remains inside the earlobe, the dermatitis is less likely to heal. In the worst-case scenario, the earlobe needs to be amputated. Today, more earring pins are being made of titanium. As gold sensitization is not widely known, it is important to provide effective information. It is also necessary to exercise caution as regards the use of gold for connectors in jewellery, as this has been known to cause allergies.

d) **Allergic contact dermatitis caused by nickel (Ni) in cupronickel coins**

Target product: coins.

Allergen: nickel (Ni).

Corresponding ICS code: 03.060 (Finance, Banking, Monetary systems and Insurance).

Many countries use cupronickel coins. Cupronickel is an alloy comprising copper, tin and nickel. With European monetary integration, new coins put into use have begun to cause allergic contact dermatitis. This is due to the use of naturally sensitizing nickel. However, cupronickel coins in Japan have not caused allergic contact dermatitis, and this is due to the different degree of bleeding used. Therefore, those who set standards for each country need to consider the ratio of the population who are sensitized to nickel, and also take nickel bleeding into account.

e) **Allergic contact dermatitis caused by chromium in leather goods**

Target products: wristwatches (leather watchbands) and shoes (leather shoes).

Allergen: chromium (Cr).

Corresponding ICS codes: ICS 39.040.10 (Watches), ICS 59.140 (Leather technology), and ICS 61.060 (Footwear).

Chrome salts are used as leather tanning agents, and allergic contact dermatitis can be caused by leather watchbands, leather shoes, or leather gloves.

As leather tanning agents, chromium, tannin and formaldehyde have been used to tan white leather. Although high-quality leather can be made using sodium bichromate, chromium is troublesome to handle, and as a result this tanning agent is not used as frequently. With leather goods that come in direct contact with the skin, standards developers can prevent allergic contact dermatitis caused by chromium by directing that leather be made using non-chrome tanning agents. Those with an allergy to chromium can avoid the onset of allergic contact dermatitis by choosing synthetic leather products.

f) **Allergic contact dermatitis caused by chromium (Cr) and cobalt (Co) in cement**

Target product: cement.

Allergen: chromium (Cr) and cobalt (Co).

Corresponding ICS codes: ICS 13.100 (Occupational safety. Industrial hygiene), ICS 91.100.10 (Cement. Gypsum. Lime. Mortar), ICS 91.010 (Construction industry), and ICS 91.100.30 (Concrete and concrete products).

Cement contains chrome and cobalt salts, and was previously the leading cause of chromium-induced allergic contact dermatitis (cement dermatitis).

Due to the development of a technique for eliminating chromium from cement, chromium sensitization has decreased. However, cobalt sensitization continues to occur.

Standards developers for construction, cement and concrete are advised to recognize chromium (Cr) and cobalt (Co) as allergens, and set standards to prevent cement from coming into direct contact with the skin, for example, by making construction workers aware of the fact that cement contains allergens.

g) Allergic contact dermatitis caused by chromium (Cr) and cobalt (Co) in biological materials made of stainless steel

Target products: implants.

Allergen: chromium (Cr) and cobalt (Co).

Corresponding ICS codes: ICS 11.040.40 (Implants for surgery, prosthetics and orthotics), and ICS 13.180 (Ergonomics).

Stainless steel is an alloy comprising iron, nickel and chromium, and is very stable. As a result it has been used to make biological implants. However, once an implant is placed in the body, it is attacked by immune cells. Nickel and chromium sometimes elute from the implant to cause allergic contact dermatitis at the location of the implant. Additionally, in those who are sensitized to nickel and chromium, an allergic reaction sometimes occurs at the time of the insertion of the implant.

As a result of implant research and development, implants made of pure titanium, biocompatible titanium alloys and surface-treated titanium alloys are now available.

Standards developers of medical implants, surgery and ergonomics are advised to recognize that chromium (Cr) and cobalt (Co) are allergens, and set standards that encourage the development and use of biologically inactive materials. For example, make medical professionals and those receiving medical care aware of the fact that stainless steel contains allergens.

h) Synthetic resin and resin monomer allergens

Synthetic resins are polymers that are made by binding low-molecular-weight substances, and are often used in plastics. With synthetic resins, during polymerization, monomers and oligomers that are made of several monomers sometimes remain. Polymers with molecular weights of more than 1 000 cannot penetrate the skin and are not sensitizers, but monomers and oligomers are relatively low-molecular-weight substances, and some penetrate the skin and act as allergens. Allergic contact dermatitis can be caused by nylon monomers, acrylic monomers, and formaldehyde. With p-tert-butylphenol formaldehyde and epoxy resins, allergic contact dermatitis can be caused by residual oligomers.

i) Allergic contact dermatitis caused by formaldehyde in textile products

Target products: textile products.

Allergen: formaldehyde.

Corresponding ICS code: 59.080.01.

Formaldehyde is a common allergen. In the past, urea-formalin and melamine resins were used to maintain the shape and pleats in textile products, and allergic contact dermatitis was caused by formaldehyde released from these resin-processing agents. In Japan, for example, the use of formaldehyde in textile products is now legally regulated, thus the incidence of formaldehyde-induced allergic contact dermatitis has markedly decreased.

Resin-processing agents without formaldehyde have been developed, and are in use today. However, formaldehyde released from building materials can contaminate textile products, and measures such as separating the distribution of baby clothes from that of other clothes and not opening packaging until purchase have been taken.

j) Allergic contact dermatitis caused by ε-Caprolactam in nylon stockings

Target products: textile products.

Allergen: ε-Caprolactam.

Corresponding ICS code: 59.080.01.

Nylon is a synthetic resin made by polymerizing diamine and dicarboxylate compounds. In clothing items, 6-Nylon and 6,6-Nylon are generally used. While 6-Nylon is synthesized by ring-opening polymerization of ε-Caprolactam, several percent of ε-Caprolactam monomers remain.

While rare, some people do develop ε-Caprolactam-induced allergic contact dermatitis while wearing 6-Nylon stockings. Not being able to wear stockings can present a significant problem for women.

Those who are allergic to 6-Nylon stockings can suppress the onset of allergic contact dermatitis by wearing 6,6-Nylon stockings.

Standards developers of textile products are advised to recognize that ε-Caprolactam, which is a monomer in 6-Nylon, is a sensitizer. It is fairly easy to warn people about the possibility of an allergy to 6-Nylon, or to suggest that such people use 6,6-Nylon stockings. In addition, the reverse is also true: those who are allergic to 6,6-Nylon stockings can suppress the onset of allergic contact dermatitis by wearing 6-Nylon stockings.

k) Dye, pigment, and additive allergens

Of the dyes and pigments used to colour resins or dye fabrics and hair, some compounds with molecular weights of or lower than 1 000 can penetrate the skin and act as allergens. Disperse dyes that are used to stain acetate, polyester, and nylon fibres, as well as oil-soluble dyes that are used to colour nylon and acetate resins, have been known to cause allergic contact dermatitis. While high-molecular-weight additives used in antibacterials have been known to cause allergic contact dermatitis, many of the actual causative substances have not yet been identified.

l) Allergic contact dermatitis caused by p-Phenylenediamine (PPD) in hair dyes

Target products: hair dyes.

Allergen: p-Phenylenediamine.

p-Phenylenediamine (PPD), a substance used in hair dyes, is a known sensitizer. PPD, an oxidation dye, is oxidized by oxygen in air, turning black as a result. Allergic contact dermatitis caused by PPD causes hand eczema in hairstylists who handle hair dyes.

Because PPD is a sensitizer, studies have been conducted to develop non-sensitizing hair dyes. However, it has been shown that the substitutes are also sensitizers. At present, there are no non-sensitizing agents that can take the place of PPD.

When sensitized to PPD, persons can become allergic to other azo-disperse dyes having similar chemical structures (cross-reaction). Because other hair dyes are not durable, and hair dyes containing PPD are often used, it is difficult to prevent PPD-induced allergic contact dermatitis.

m) Allergic contact dermatitis caused by disperse dyes in textile products

Target products: textile products.

Allergens: Disperse dyes.

Corresponding ICS codes: 59.080.01 and 59.120.50.

Allergic contact dermatitis can be caused by disperse dyes that are used to stain acetate, polyester, and nylon fibres.

Since skin-patch test reagents (Disperse dyes: C. I. Disperse Blue 106 and C.I. Disperse Blue 124) first became available, positive reactions have been detected around the world. Persons that have been sensitized to the dyes used to dye clothing items, as well as those who are sensitized to PPD can cross-react with C. I. Disperse Blue 106 and C.I. Disperse Blue 124. The combination of the two leads to high positive rates. Those who develop an allergy as a result of wearing clothing items and garments that have been dyed black or dark blue often test positive to C. I. Disperse Blue 106 and C.I. Disperse Blue 124. However, some develop an allergy to clothing items that have not been dyed using C. I. Disperse Blue 106 or C.I. Disperse Blue 124, and as a result it is difficult to determine whether allergic reactions are caused by a disperse dye or a cross-reaction caused by PPD sensitization.

There is a system for listing sensitizing disperse dyes, including C. I. Disperse Blue 106 and C.I. Disperse Blue 124, and labelling products that do not contain such dyes. With such a system, used mainly in Europe, it is possible for those who are sensitized to disperse dyes and PPD to choose appropriate products.

n) Allergic contact dermatitis caused by Naphthol dyes that are used to dye textile products

Target products: textile products.

Allergen: Naphthol dyes.

Corresponding ICS codes: 59.080.01 and 59.120.50.

Allergic contact dermatitis can be caused by Naphthol dyes that are used to dye cotton dark colours. Initially, Naphthol AS was identified as the cause of a mass outbreak of allergic contact dermatitis among employees of a dye plant, but consumers who used products made at the plant did not develop allergic contact dermatitis.

In Japan, many people who wore cotton pyjamas developed allergic contact dermatitis, and the results of a study showed that the causative agent was Naphthol AS, which was used to dye the pyjamas. The study clarified that when a change was made in dyeing equipment, a large amount (over 1 000 µg/g) of Naphthol AS remained in the fabric, causing sensitization. Thorough quality management has since lowered the amount of residual Naphthol AS and led to a lowered incidence of allergic contact dermatitis caused by Naphthol dyes. Since the above-mentioned mass outbreak, several cases of allergic contact dermatitis caused by clothing items made of fabrics without quality management have been reported. This shows that allergic contract dermatitis can be caused by clothing items containing residual Naphthol AS.

Those who are sensitized to Naphthol AS can also be allergic to dyes similar to Naphthol AS (cross-reaction).

o) Allergic contact dermatitis caused by decomposition of Naphthol dyes used to dye textile products

Target products: textile products.

Allergen: phosgen (2,5-Dichlorophenyl) hydrazone (PCPH).

Corresponding ICS codes: 59.080.01 and 59.120.50.

In Japan, many people developed severe allergic contact dermatitis as a result of wearing a summer sweater that had been dyed yellow. Dermatitis developed over the entire upper body, and patients were hospitalized. A total of 51 sweaters were sold, and 12 persons developed dermatitis. Hence, allergic reactions were induced at a high rate.

These sweaters were made by dyeing cotton yellow using Naphthol AS-G and 2,5-dichloroaniline, and then bleaching using sodium hypochlorite. C. I. Pigment Yellow 16, a pigment produced through Naphthol dyeing, was subjected to decomposition and chlorination by sodium hypochlorite, which caused the formation of Phosgene (2,5-Dichlorophenyl) hydrazone (PCPH). PCPH is a potent sensitizer that is even more potent than 2,5-Dinitrochlorobenzene (DNCB), a compound used to induce allergic reactions. The Japanese Government has issued a notice instructing that safety must be confirmed when textile products are bleached using sodium hypochlorite (household bleach).

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