



BSI Standards Publication

Ergonomics data for use in the application of ISO/IEC Guide 71:2014

National foreword

This Published Document is the UK implementation of CEN ISO/TR 22411:2021. It is identical to ISO/TR 22411:2021. It supersedes PD CEN ISO/TR 22411:2011, which is withdrawn.

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Ergonomics data for use in the application of ISO/IEC Guide 71:2014 (ISO/TR 22411:2021)

Données ergonomiques destinées à être utilisées dans
le cadre de l'application du Guide ISO/IEC 71:2014
(ISO/TR 22411:2021)

Ergonomische Daten und Leitlinien für die Anwendung
des ISO/IEC Guide 71 für Produkte und
Dienstleistungen zur Berücksichtigung der Belange
älterer und behinderter Menschen (ISO/TR
22411:2021)

This Technical Report was approved by CEN on 26 December 2020. It has been drawn up by the Technical Committee CEN/TC 122.

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European foreword

This document (CEN ISO/TR 22411:2021) has been prepared by Technical Committee ISO/TC 159 "Ergonomics" in collaboration with Technical Committee CEN/TC 122 "Ergonomics" the secretariat of which is held by DIN.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document supersedes CEN ISO/TR 22411:2011.

Endorsement notice

The text of ISO/TR 22411:2021 has been approved by CEN as CEN ISO/TR 22411:2021 without any modification.

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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.

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

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

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

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

This document was prepared by Technical Committee ISO/TC 159, *Ergonomics*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 122, *Ergonomics*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO/TR 22411:2008), which has been technically revised.

The main change compared to the previous edition is the replacement of ergonomics data on human abilities and capabilities with new or more elaborated data for use in the application of ISO/IEC Guide 71:2014.

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

Introduction

This document is intended to help standards developers by providing ergonomics data related to human characteristics and capabilities to support ISO/IEC Guide 71:2014. This document is supposed to be used mainly by standards developers, but also by those responsible for design. 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 people with a widest range of capabilities. This idea, called accessibility, has been spreading all over the world.

ISO/IEC Guide 71 was first published in 2001 to successfully address the importance of being aware of the needs of older persons and persons with disabilities and to direct the attention of standards developers to these needs when they draft or revise standards. In response to the publication of ISO/IEC Guide 71, ISO/TR 22411:2008 was developed to fulfil the gap between the concept and practice with offering ergonomic knowledge and data on human abilities.

After more than 10 years from the publication of ISO/IEC Guide 71 and ISO/TR 22411, together with new knowledge and experience in implementing these documents, ISO/IEC Guide 71 was revised into a more elaborated one and consequently the revision of ISO/TR 22411 was required.

This document provides updated ergonomics data as well as newly available data which are all publicly available and can be used to support standards developers in applying ISO/IEC Guide 71:2014 in their individual standards. These ergonomics data help standards developers to understand characteristics and capabilities of diverse users to be served by requirements and recommendations in a standard. The data provided in this document apply mainly to persons with disabilities and older persons. The intention in using these data is to formulate requirements and recommendations in standards that include the widest possible range of users. It can also be used by designers in order to increase accessibility as part of accessible design or universal design.

While the data covers a wide area of human abilities related to accessibility, data for some part of the area, for example cognitive abilities, is still missing. Furthermore, new data emerged or were updated during the development of this document, which is not included in this document either. This document, due to scientific reasons, does not necessarily adopt the ICF terminology but established terms in ergonomics.

Ergonomics data for use in the application of ISO/IEC Guide 71:2014

IMPORTANT — The electronic file of this document contains colours which are considered to be useful for the correct understanding of the document. Users should therefore consider printing this document using a colour printer.

1 Scope

This document provides ergonomics data for standard developers to use in applying ISO/IEC Guide 71:2014 to address accessibility in standards. These data can also be used by ergonomists and designers to support the development of more accessible products, systems, services, environments, and facilities.

The ergonomics data include quantitative data and knowledge about basic human characteristics and capabilities as well as context-specific and task-specific data, all being based on ergonomics research. The data focused on the effects of ageing and/or consequences of various types of human sensory, physical, and cognitive disabilities. It does not contain general ergonomics data that have no direct relation to ageing or disabilities.

The data presented in this document are not exhaustive due to no available data for some aspects of human characteristics and capabilities with regard to ageing and disabilities.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1 accessibility

extent to which products, systems, services, environments and facilities can be used by people from a population with the widest range of user needs, characteristics and capabilities to achieve identified goals in identified contexts of use

Note 1 to entry: Context of use includes direct use or use supported by assistive technologies.

[SOURCE: ISO 9241-112:2017, 3.15]

3.2 accessible design

design focused on diverse users to maximize the number of potential users who can readily use a system in diverse contexts

Note 1 to entry: This aim can be achieved by (1) designing systems that are readily usable by most users without any modification, (2) making systems adaptable to different users (by providing adaptable user interfaces) and (3) having standardized interfaces to be compatible with assistive products and assistive technology.

Note 2 to entry: Terms such as universal design, accessible design, design for all, barrier-free design, inclusive design and transgenerational design are often used interchangeably with the same meaning.

[SOURCE: ISO/IEC Guide 71:2014, 2.19]

3.3 impairment

problem in body function or structure related to a significant deviation or loss

Note 1 to entry: Impairments can be temporary or permanent; progressive, regressive or static; intermittent or continuous.

[SOURCE: ICF 2001, WHO]

3.4 system

product, service, or built environment or any combination of them with which the user interacts

[SOURCE: ISO/IEC Guide 71:2014, 2.1]

3.5 universal design

design of products, environments, programmes and services to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design

Note 1 to entry: Universal design shall not exclude assistive devices for particular groups or persons with disabilities where this is needed.

Note 2 to entry: Terms such as universal design, accessible design, design for all, barrier-free design, inclusive design and transgenerational design are often used interchangeably with the same meaning.

[SOURCE: ISO/IEC Guide 71:2014, 2.18]

3.6 user

individual who accesses or interacts with a system

[SOURCE: ISO 9241-11:2018, 3.1.5, modified — In the definition, "person" has been changed to "individual", "accesses or" has been added, and "product or service" has been removed.]

4 Supporting ISO/IEC Guide 71 with human data

ISO/IEC Guide 71:2014 provides standards developers with guidance on addressing accessibility in standards through two approaches, as shown in [Figure 1](#):

- 1) the first approach defines accessibility goals for the product or system under development and the user accessibility needs associated with fulfilling those goals (denoted by Clause 6 in [Figure 1](#));
- 2) the second approach provides accessibility-related design considerations, based on an understanding of human abilities and characteristics (denoted by Clause 7 in [Figure 1](#)).

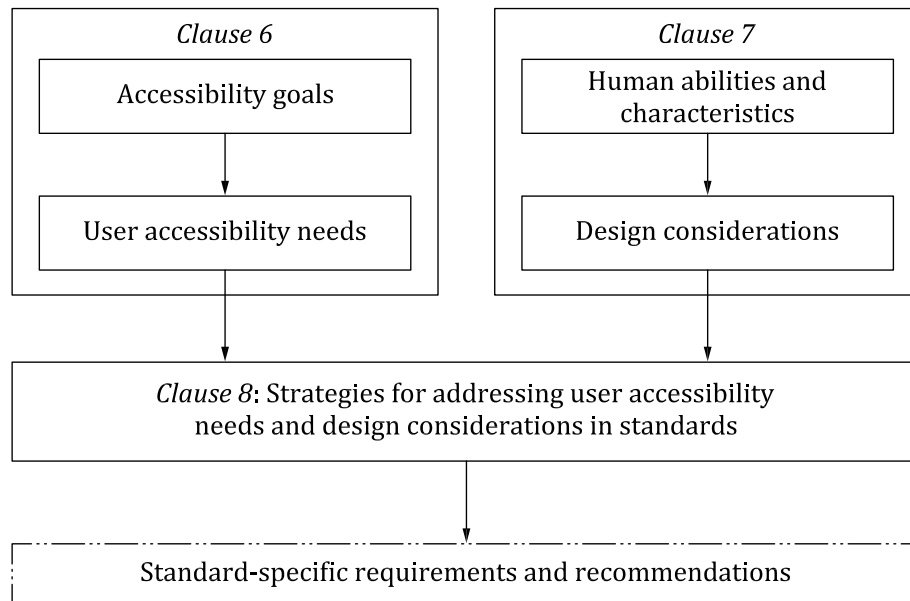


Figure 1 — Two approaches to address accessibility in standards described in ISO/IEC Guide 71:2014

The user accessibility needs (first approach) or design considerations (second approach) can serve as the basis for accessibility requirements and recommendations in standards. Regardless of which approach is used, the accessibility requirements and recommendations in the standards are derived through the appropriate selection of strategies (denoted by Clause 8 in [Figure 1](#)) that can meet the accessibility needs or address the design considerations.

Ergonomics data are relevant throughout both approaches and especially important in determining which strategies are the most effective in a situation. In some cases, the data can provide a source of nominal values or numerical specifications which can be included in the requirements and recommendations of standards. In other cases (especially with respect to cognitive variables), the available data are qualitative in nature and/or reflect small sample sizes, but can still be used to evaluate the feasibility of applying particular strategies to meet accessibility needs or to address design considerations.

In addition to the role that ergonomics data play in standards development, these data are directly relevant to the product and system designers, who are attempting to fulfil accessibility requirements and recommendations by developing and implementing technical solutions that make use of the existing data.

One of the challenges for standards developers and designers is that ergonomics data relevant to specific populations is distributed across multiple standards and other guidance documents, as well as in published research reports, papers and books from a variety of academic disciplines. The purpose of this document is to bring the most valid and applicable data together in one document. This will assist standards developers to address accessibility and consider the widest range of user needs when formulating requirements and recommendations. Having a single source of information will also be of value to designers.

5 Data selection and format

5.1 Data selection

The data in this document were selected from various sources existing in scientific books and journals, standards, as well as databases of universities, research institutes or projects. They are all relevant for demonstrating effects of ageing and disabilities and the committee regards valid and worth citing in this document. Most of the data are well-supported in academia and related technical fields or based on

a sufficient number of samples to provide statistical meaningful results. Some of the data, especially in cognitive field, have a limited number of samples but the committee regards qualitatively relevant for application.

5.2 Data format of this document

Data in this document are presented in a common format for easy and correct understanding of the data. It contains following items. If no information is available for some items, they are left blank.

— Title

This item describes the title of the data. The title has an additional information on the type of data either for the effect of ageing or the effect of some specific disability.

— General

This item describes background and outline of data, implications in designing, as well as why the data is important and included in this document. Some scientific information necessary to understand the data is also included.

— Sampled population

This item describes samples from which the data have been obtained. Number of people who participated in the experiments or measurements, their age and gender distribution, and any other attributes of samples necessary for understanding the data are presented.

— Methods and conditions of data collection

This item describes methods and conditions of the measurement used for data collection. Technical information necessary for understanding the figures and tables in the data section is provided depending on the types of human characteristics and capabilities. Limitations associated with the methods or conditions are also provided.

— Data

This item describes typical data given in figures and tables picked up from the data source(s) that would be most suitable for understanding the human characteristics and capabilities expressed in the title of the data. The data is also selected as the most useful one for design considerations.

— Limitations

This item describes constraints or cautions for use of the data. As the human data largely depends on the methods and conditions of the measurement, it would be safe and useful to show the limitations in applying the data to actual situations.

— Application examples

This item gives a general idea for applying the data and implication of the data for design with some examples. This includes not only specific design examples but also how to use the data in general.

— References

This item provides a list of:

- Data sources: sources of information on the data presented in the data item, including relevant literature (standards, academic journals, books, other reports) and website;
- Cross-references: relevant sections in this document for cross-referencing and better understanding of the section;
- Other references: relevant literature and website, not directly related to the data but useful for understanding them.

5.3 How to use the data

This document provides data on a large variety of human characteristics and capabilities that can be applied to product design, as well as some aspects of the design of services and environments.

[Clause 6](#) provides data items on sensory characteristics and capabilities covering modalities of vision, hearing, touch, and the thermal sense. No data is provided on smell and taste as no relevant data source was found, though ISO/IEC Guide 71 does address these senses in a general way.

[Clause 7](#) provides data items on physical characteristics and capabilities, covering body size, fine motor coordination of the hand, movement of upper body structures, movement of lower body structures, and muscle power and muscle endurance. No data is provided on physical characteristics and capabilities related to speech production.

[Clause 8](#) provides data items on cognitive characteristics and capabilities related to attention, information processing and memory. Although cognitive abilities are especially relevant to accessibility, little data of quantitative nature exists because cognitive disabilities vary markedly in their effects and can involve many unique combinations of attentional, information processing, memory, decision-making and affective impairments for any given individual.

The data provided in this document can be used, directly or indirectly, when standard developers and products designers consider accessibility in the context of developing standards or designing products, services or environments. Depending on the nature of experimental data provided, it may or may not be relevant to a specific design issue. Therefore, users of this document should consider whether the data provided in this document can be applied in their specific situation, given how it was collected (i.e. the population tested and the method used), as well as the limitations of the data, as described in subclauses.

In addition, much of the data related to physical and sensory capabilities can be directly applied because numerical values are provided in tables, charts, formulas and graphics. These data may be directly used to set limit values in standards (e.g. weight-lifting limit), or specifications of certain design parameters (e.g. the grip span for a tool). Alternatively, much of the data related to cognitive abilities simply is in the form of task-specific trends, as a function of age and/or disability, and cannot be applied directly. In these cases, designers and standards developers are limited to interpreting the implications of the trends in light of their particular design or standards development situation. It is also extremely important that users of the cognitive data maintain awareness of the significant variance in cognitive capabilities and limitations, generally, and the limited sample sizes involved for some populations for which data is provided.

6 Sensory characteristics and capabilities

6.1 Overview of sensory characteristics and capabilities

Every sensory characteristic and capability can be affected by ageing: abilities to detect, discriminate or perceive sensory stimuli of vision, hearing, touch or thermal sense. How the change occurs varies depending on the sensory function.

Various types of disabilities in sensory characteristics and capabilities are caused by medical disorders or impairments in the structure or the function, which result in low vision, colour defect, hardness of hearing, etc. In addition, disabilities can be caused by environmental factors such as illumination, noise, temperature, etc.

Most of the sensory characteristics and capabilities do not vary depending on the gender or ethnicity. However, in the case of hearing, for example, a large gender difference can be found in the sensitivity of older ears although the reason for that is not known.

[Table 1](#) shows a brief summary of sensory characteristics and capabilities with regard to ageing effects. Details are described in [6.2](#) to [6.5](#). The sense of taste and olfaction is missing in this document because of a lack of data useful for ergonomic design.

An online database can be used to investigate the ageing effects and effects of disabilities in sensory characteristics and capabilities (see Reference [77]). Some of the data referenced in this document have been taken from the database.

Overview of ageing effects on vision is also available in Reference [59].

Table 1 — List of major sensory functions and effects of aging

Sensory functions	Particular effects of age
Vision	
Spectral sensitivity	Declines at short-wave region (blue light)
Colour discrimination	Worsened
Colour identification/colour category	Span of colour category reduced
Contrast sensitivity	Declines at high spatial frequencies
Temporal sensitivity (flicker sensitivity)	Declines at high temporal frequencies
Visual acuity	Worsened at high spatial frequencies and at short viewing distance
Legibility (of symbols and letters)	Worsened for complex symbols and letters
Field of view	Narrowed
Dark/light adaptation	Slightly affected
Lighting level	Slightly affected
Glare	Increased
Hearing	
Hearing sensitivity	Declines especially at high frequencies
Sensitivity to extremely high frequency (above 10 000 Hz)	Declines or completely lost
Sensitivity to low frequency (below 100 Hz)	Moderately affected
Loudness	Becomes smaller especially at high frequencies; in some cases, accompanies abnormal growth called “recruitment”
Tone perception	Worsened especially in noisy conditions
Speech perception	Worsened especially in noisy conditions
Touch	
Tactile pressure sense	Sensitivity decreased
Spatial resolution	Declines at high spatial frequencies
Temporal sensitivity (for vibration)	Sensitivity decreased especially for high temporal frequencies
Legibility (for tactile symbols and characters)	Worsened
Thermal sense	
Sensitivity to surface temperature	Decreased
Sensitivity to air temperature	Decreased
Thermal sensation for comfort	Reduced

6.2 Vision

6.2.1 Visual sensitivity to colour (spectral sensitivity of the eye: ageing effect)

6.2.1.1 General

The human eye responds to electro-magnetic radiation of the wavelength range from about 380 nm to 780 nm. The overall sensitivity to the radiation throughout the range is called spectral sensitivity or spectral luminous efficiency. This spectral sensitivity changes with age so that it becomes less sensitive

to light in the short-wavelength region approximately from 400 nm to 500 nm (coloured purplish and bluish). Therefore, a bluish as well as a purplish light looks darker to older persons than it does to young persons. Taking account of this ageing effect can increase visibility of signs and displays for older people.

NOTE This ageing effect disappears if an older person has had his/her lens replaced with an artificial eye lens surgically implanted, as the effect is caused mainly by yellowing of the lens.

6.2.1.2 Sampled population

Data were collected from 91 participants ranged in age from 12 years to 78 years. The distribution of ages of the participants were 6 people in 10–19 years, 11 people in 20–29 years, 10 people in 30–39 years, 10 people 40–49 years, 10 people in 50–59 years, 28 people in 60–69 years, and 16 people in 70–79 years. The numbers of male and female participants were nearly equal.

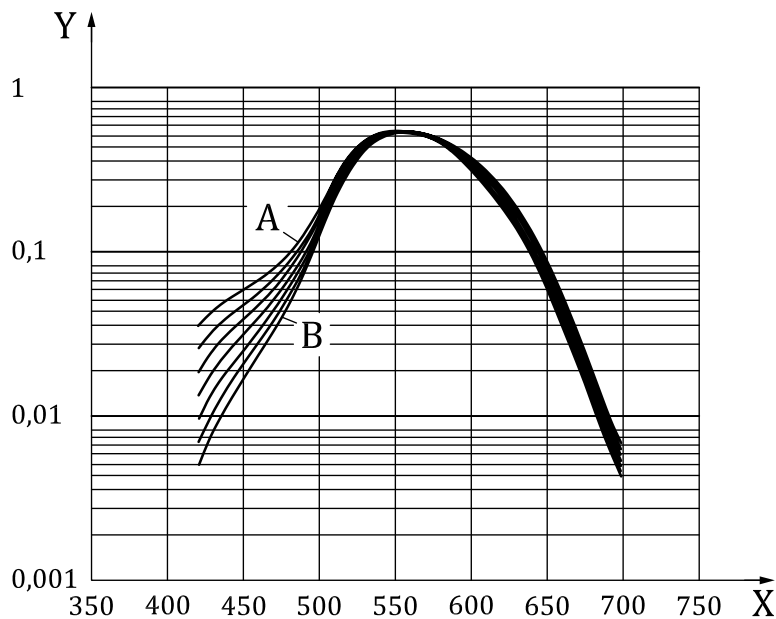
6.2.1.3 Methods and conditions of data collection

The data were measured by the conventional method for visual sensitivity called flicker photometry. In this measurement, a test light and a reference light, both of which were subtended at a visual angle of about 2° at the same location on the retina, were temporally alternated with a fixed frequency of 12 Hz. A non-flicker or a minimum flicker point was determined by adjusting the intensity of the test light, in most cases, while that of the reference light was fixed. The minimum flicker point was regarded as the equal luminance of the test and reference light to the eye. The test light was chosen from a range of 420 nm to 700 nm in 10 nm steps. The amount of each test light needed to reach to the equal luminance level gives the reciprocal of spectral sensitivity data.

6.2.1.4 Data

[Figure 2](#) shows the spectral sensitivity data measured for 91 people by flicker photometry with a foveally fixed 2-degree target field at a photopic level. The data are classified into seven age groups in 10-year steps and the geometric average over all the participants in a decade is expressed as a solid line.

The data shows clear reductions of sensitivity in the short-wave region (blue light) with ageing, while there is almost no change at middle-wave (green light) and long-wave (red light) regions. This means that blue light, which contains a short-wave component, looks darker to older people than it does to young people. This age-related change occurs gradually and smoothly from the youngest age, and the maximum difference reaches about one tenth (or 10 times) when the data of 10–19 years old and 70–79 years old are compared.



Key

- X wavelength (nm)
- Y relative sensitivity
- A average of people in their 10s
- B average of people in their 70s

Figure 2 — Spectral sensitivity curves of the human eye for seven age groups from 11 to 78 years

6.2.1.5 Limitations

The data presented here are only for people with normal colour vision, and do not apply to people with defective colour vision nor with low vision.

6.2.1.6 Application examples

The main application of human spectral sensitivity is in the measurement of light in terms of visual sensation of lights or objects (photometry or visually meaningful measurement of light), i.e. brighter or darker. The sensitivity data for young people without any visual impairment has been standardized by the International Commission on Illumination (CIE) and has been traditionally used in the measurement of light which is visually meaningful. The age-related change in the sensitivity shown in [Figure 2](#) has not been officially established yet in the field of photometry, but can be practically used in evaluating lights for people in any range of age, in particular for older people, in the same manner as it is used in photometry.

Evaluating the visibility of blue lights for older people in traffic signs, emergency signs and other critical displays, in particular, can increase the accessibility of those signs. Designers should increase light intensity when possible if they use blue lights (blue LEDs, for example) against dark backgrounds in signage used by older people.

[Figure 3](#) shows an example of visual sign composed of blue letters on a dark yellow (brown) background. Using spectral sensitivity curves of people in their 20s and 70s respectively, the contrast ratio of this sign is much lower for older people (1,13 for those in their 70s) than for young people (2,07 for those in their 20s). Nearly twice as much luminance of blue light is needed for older people to achieve the same contrast as young people. This colour combination example is a typical one regarded as hard to see for older people but not to young people. For other colour combinations, this contrast difference may be smaller, but care should be taken for any colour combination when blue light is used in a sign.

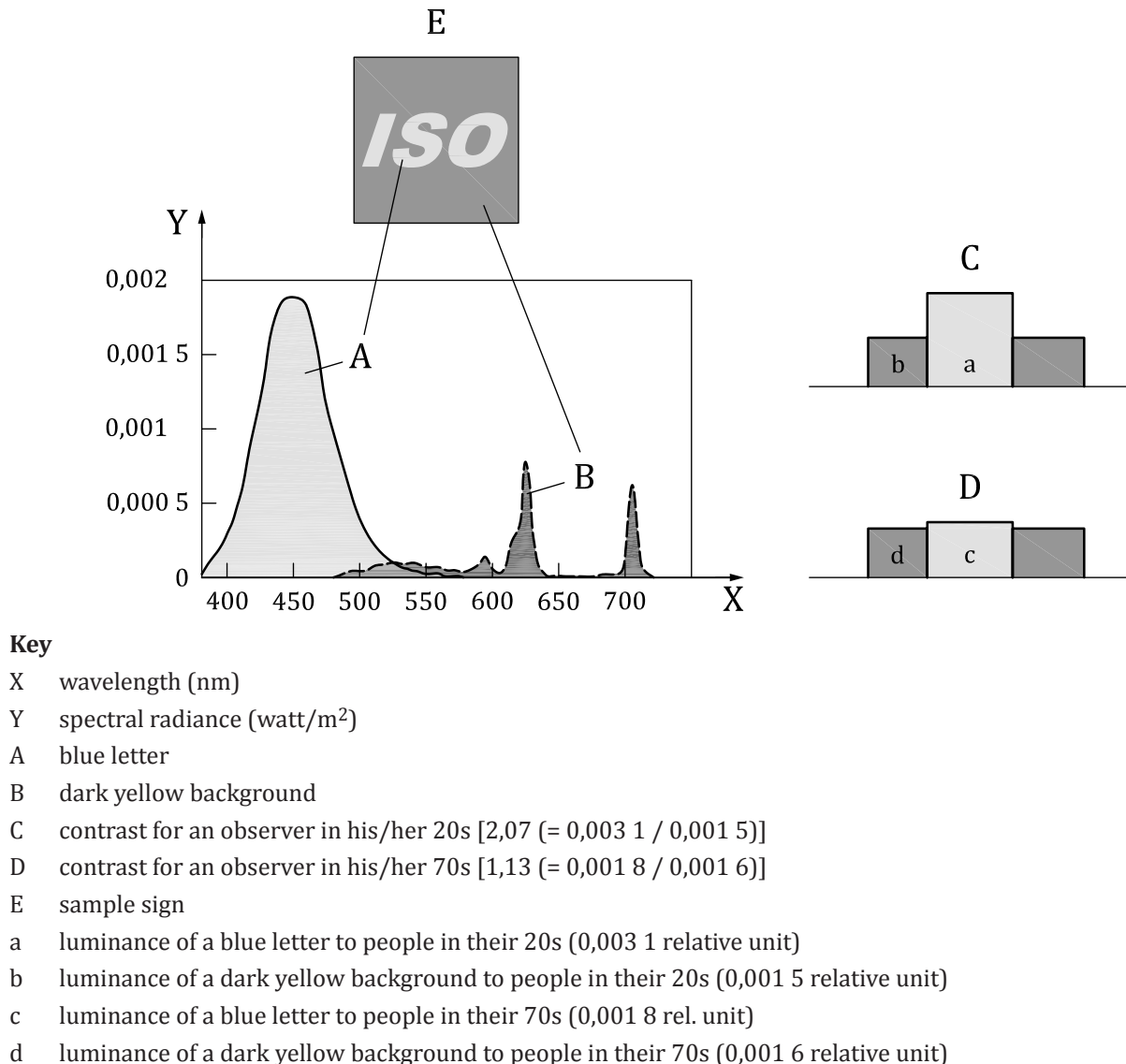


Figure 3 — An application of spectral sensitivity for calculating contrast of a coloured sign

More information on the implication and use of the spectral sensitivity data are presented in ISO 24502.

6.2.1.7 References

- Data source: Reference [31];
- Cross-references in this document: none;
- Other references: Reference [86].

6.2.2 Colour category (spans of fundamental colour, young people, older people, and people with low vision)

6.2.2.1 General

Colour is coded in the central brain, but not in the retina in the eye, as a number of groups of similar colours. This is called categorical colour perception or colour categories. Orangish-red and purplish-red, for example, are both perceived as a colour in the red category in the brain. There are a number of

colour categories, 11 or 13 depending on academic studies. Each category corresponds to a fundamental or a basic colour term linguistically, such as red, green or blue.

As the colour category is closely related to colour terms (i.e. language), it is useful to know the span of each fundamental colour in the colour space when colour is used in daily life. Knowing how many colour categories exist, and which colour belongs to which category, is a basic question when selecting and applying colour in any type of design that contains colour.

Knowledge on colour categories is also useful for creating a colour combination in particular. The theory of categorical colour perception says that colours appear distinctive from each other if they are selected from different colour categories. Conversely, colours selected from the same category are likely to be confused.

This clause provides spans of colour categories expressed in the Munsell colour space for different types of people in colour vision: young people, older people, people with defective colour vision and people with low vision. Colour combinations based on colour categories with different distinctiveness are also presented in a tabular form.

NOTE The Munsell colour space is a three-dimensional system to specify colour by hue, chroma (or saturation, meaning how close to or far from grey the colour is) and value (the lightness or darkness of the colour).

6.2.2.2 Sampled population

Data were collected from the following participants groups shown in [Table 2](#).

Table 2 — Participants groups for the measurement of colour category

Participants group	Number of participants	Age (years)	Notes
Young people	50	19–26	
Older people	50	60–76	
People with defective colour vision	59	14–66	Protanope (29) Deutanope (30)
People with low vision	69	19–79	Retinitis pigmentosa (13) Glaucoma (8) Cataract (8) Optic atrophy (6) Aphakia (3) Others (31)

6.2.2.3 Methods and conditions of data collection

The definition of colour category is based on the subjective judgement of colour similarity. A pair of colours was presented to the participant and he/she judged whether the two colours looked similar or not. Carrying out this similarity judgement, the percentage of similar judgements among the total number of participants was obtained. The similarity data is high when the two colours are close, but low when the two colours are apart from each other.

In the experiment shown in [Figure 4 a\)](#), a pair of colours consisting of a reference colour and a test colour was presented. The reference colour was selected from one of the thirteen fundamental colours (red 5R5/12, yellow-red 5YR7/14, yellow 5Y8/12, green-yellow 5GY5/8, green 5G5/8, blue-green 5BG5/8, blue 5B5/8, purple-blue 5PB5/8, purple 5P5/10, red-purple 5RP5/10, white N9.5, grey N5, and black N1), and the test colour was randomly picked from a set of 286 test colours distributed in the Munsell colour space while the reference was kept constant. This measurement gave the similarity data against the reference colour, and a contour map was obtained [see [Figure 4 b\)](#) for the case of red fundamental colour]. This was repeated for all the thirteen reference colours.

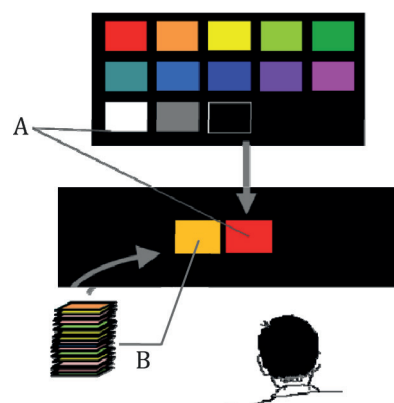
The number of test colours was reduced to 103 for the experiment on low vision taking account of the relatively low colour discrimination ability of those participants.

The similarity data were obtained for each test colour of 286 (or 103 for low vision) samples against the 13 fundamental colours respectively, and a category was defined for each fundamental colour with regard to the similarity data as shown in [Figure 4 b](#)). Finally, the 50 % contour [i.e. half of the participants judged as similar (category 3 in [Figure 4](#))], was used as a span of colour category for a fundamental colour.

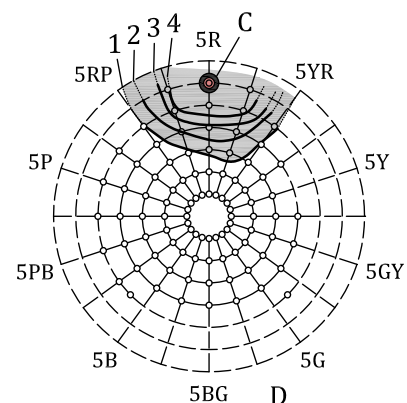
This span of colour category was measured at 4 different lightness level [value 9 (very light), value 7 (light), value 5 (moderate), and value 3 (dark)] for each fundamental colour and the span is expressed in the four levels.

NOTE Other spans can be defined with a different ratio, e.g. a contour of 70 %, 30 %, or 10 % similarity.

All the colour category data were obtained using Munsell colour chips illuminated at a moderate illuminance level (500 lx) supporting photopic vision. A lower illuminance level of 0,5 lx called mesopic vision was also employed in the study, but the data is not included here (see [6.2.2.7](#)).



a) Colour similarity measurement



b) Definition of colour category

Key

- A reference colours (13 fundamental colours)
- B test colours (286 or 200 samples)
- C red fundamental colour
- D Munsell value 5 plane
- 1 category 1 (10 % similarity)
- 2 category 2 (30 % similarity)
- 3 category 3 (50 % similarity)
- 4 category 4 (70 % similarity)

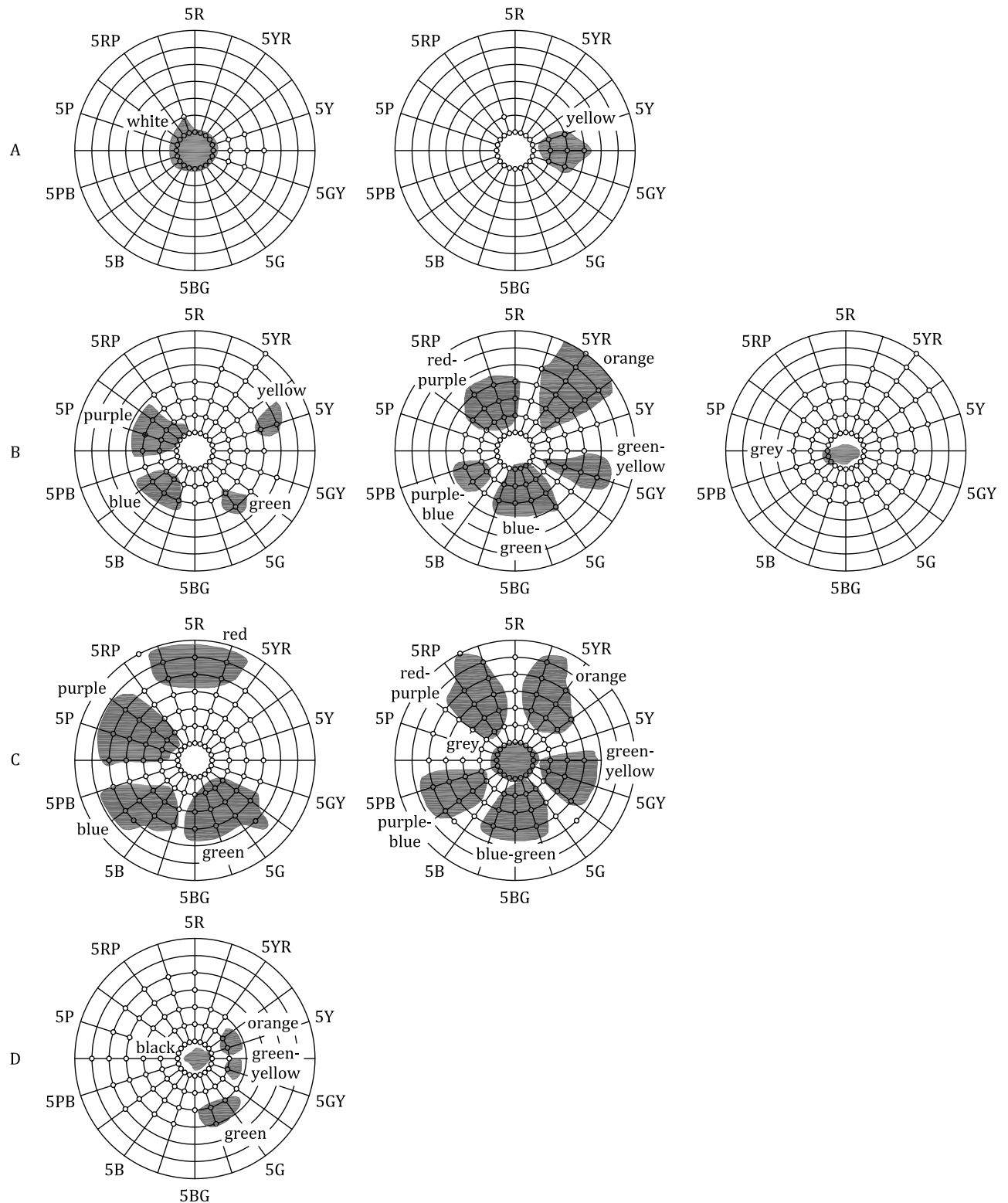
Figure 4 — Measurements of colour similarity and definition of colour category (in case of red fundamental colour)

6.2.2.4 Data (spans of fundamental colours and colour combination tables)

6.2.2.4.1 Young people

[Figure 5](#) shows the span of colour category for each of the 13 fundamental colours expressed in the Munsell colour space for young people at a moderately bright illuminance level (500 lx). The colour category data were obtained and shown at four different lightness levels in the Munsell colour space of values 3, 5, 7, and 9. The spans coloured grey in the figure show the colour categories of the 13 fundamental colours. In some cases, the spans of two or more fundamental colours overlapped.

in that case, the data are shown in another cross-section separately so that the spans would be visible more clearly. However, contours were still drawn in that case to indicate the overlap. The small open circles in the colour charts mean the test colours used in the experiment.



Key

- A Munsell value 9 (very light level)
- B Munsell value 7 (light level)
- C Munsell value 5 (moderately light level)
- D Munsell value 3 (dark level)

Figure 5 — Spans of fundamental colours for young people at photopic level (50 % similarity level)

Table 3 was derived from the data shown in Figure 5 to show possible two-colour combinations and their distinctiveness. The degree of distinctiveness of the colour combination is classified into the three levels (high, moderate and low), depending on the mutual relationship of similarity areas with regard to the situation overlapped or separated. Using the 50 % areas as well as the 10 % ones, the three levels are defined as:

- 1) both the 50 % areas and the 10 % areas are separated (high distinctiveness);
- 2) the 50 % areas are separated but the 10 % areas are overlapped (moderate distinctiveness);
- 3) both the 50 % and the 10 areas are overlapped (low distinctiveness).

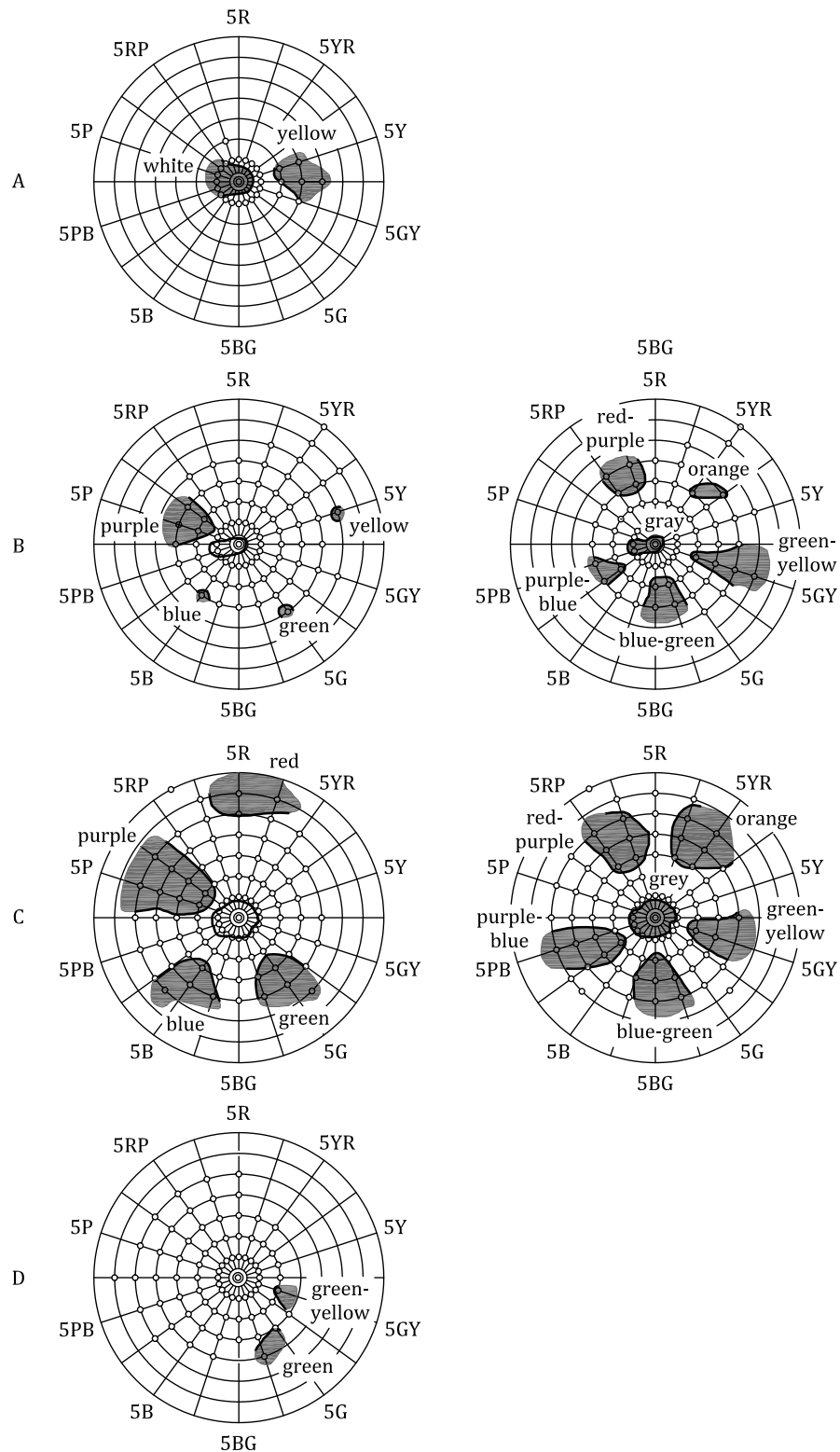
Table 3 can be used firstly for the choice of any two fundamental colours depending on the user's preference of the distinctiveness of colour combination. Once the two fundamental colours are chosen from Table 3, a specific colour that belongs to each of the categories of fundamental colours can be selected from Figure 5. For example, a red colour from the red category in Figure 5. Finally, those selected colours are used for the colour combination. When more than two colours are used, this procedure is repeated for any possible two-colour combination.

Table 3 — Colour combinations and their distinctiveness for young people at photopic level

	R	YR	Y	GY	G	BG	B	PB	P	RP	GRE	WHT	BLK
R	—	+	++	+++	+++	+++	+++	+++	++	+	+++	+++	+++
YR	+	—	++	++	+++	+++	+++	+++	++	++	++	+++	++
Y	++	++	—	++	++	+++	+++	+++	+++	+++	++	+	+++
GY	+++	++	++	—	+	++	+++	+++	+++	+++	++	++	++
G	+++	+++	++	+	—	+	++	++	+++	+++	++	++	++
BG	+++	+++	+++	++	+	—	+	++	+++	+++	++	++	++
B	+++	+++	+++	+++	++	+	—	+	++	+++	++	++	++
PB	+++	+++	+++	+++	++	++	+	—	++	+++	++	++	++
P	++	++	+++	+++	+++	+++	++	++	—	+	+	++	++
RP	+	++	+++	+++	+++	+++	+++	+++	+	—	++	++	+++
GRE	+++	++	++	++	++	++	++	++	+	++	—	++	++
WHT	+++	+++	+	++	++	++	++	++	++	++	++	—	+++
BLK	+++	++	+++	++	++	++	++	++	++	+++	++	+++	—
+++ High distinctiveness ++ Moderate distinctiveness + Low distinctiveness NOTE The names of fundamental colours that define colour categories are: (R) red, (YR) orange or yellow-red, (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.													

6.2.2.4.2 Older people

Figure 6 shows the spans of colour categories for older people expressed in the same way as those for young people (see Figure 5). Most of the spans are smaller than those obtained for young people. This means the choice of a colour for each of the fundamental colours is limited in colour space.



Key

- A Munsell value 9 (very light level)
- B Munsell value 7 (light level)
- C Munsell value 5 (moderately light level)
- D Munsell value 3 (dark level)

Figure 6 — Spans of fundamental colours for older people at photopic level (50 % similarity level)

Table 4 shows a colour combination table for older people derived from the colour category data of Figure 6. Note that spans of these categories of older people are different from those of young people. Table 4 should be used in conjunction with the category data of Figure 6.

Table 4 — Colour combinations and their distinctiveness for older people at photopic level

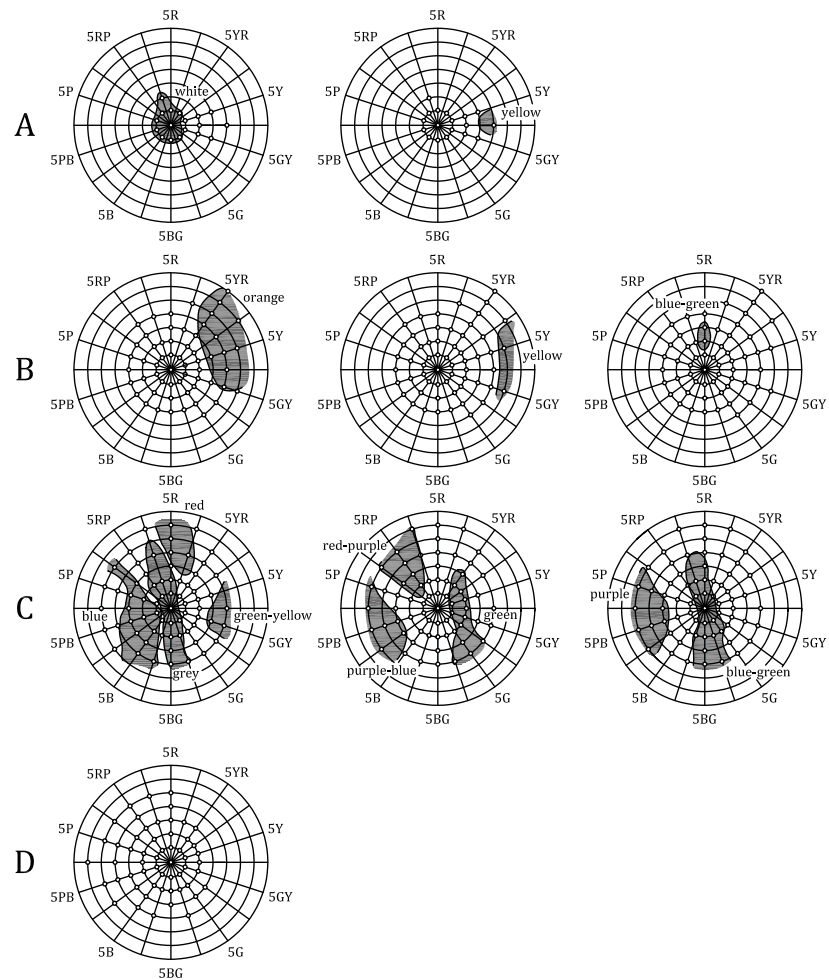
	R	YR	Y	GY	G	BG	B	PB	P	RP	GRE	WHT	BLK
R	—	+	+++	+++	+++	+++	+++	+++	++	++	+++	+++	+++
YR	+	—	++	+++	+++	+++	+++	+++	++	++	++	+++	+++
Y	+++	++	—	++	+++	+++	+++	+++	+++	+++	+++	++	+++
GY	+++	+++	++	—	++	++	+++	+++	+++	+++	++	++	++
G	+++	+++	+++	++	—	+	++	+++	+++	+++	++	+++	++
BG	+++	+++	+++	++	+	—	+	++	+++	+++	++	++	++
B	+++	+++	+++	+++	++	+	—	+	++	+++	++	+++	++
PB	+++	+++	+++	+++	+++	++	+	—	++	+++	++	+++	++
P	++	++	+++	+++	+++	+++	++	++	—	+	++	+++	++
RP	++	++	+++	+++	+++	+++	+++	+++	+	—	++	++	+++
GRE	+++	++	+++	++	++	++	++	++	++	++	—	++	+++
WHT	+++	+++	++	++	+++	++	+++	+++	+++	++	++	—	+++
BLK	+++	+++	+++	++	++	++	++	++	++	+++	+++	+++	—

+++ High distinctiveness
 ++ Moderate distinctiveness
 + Low distinctiveness

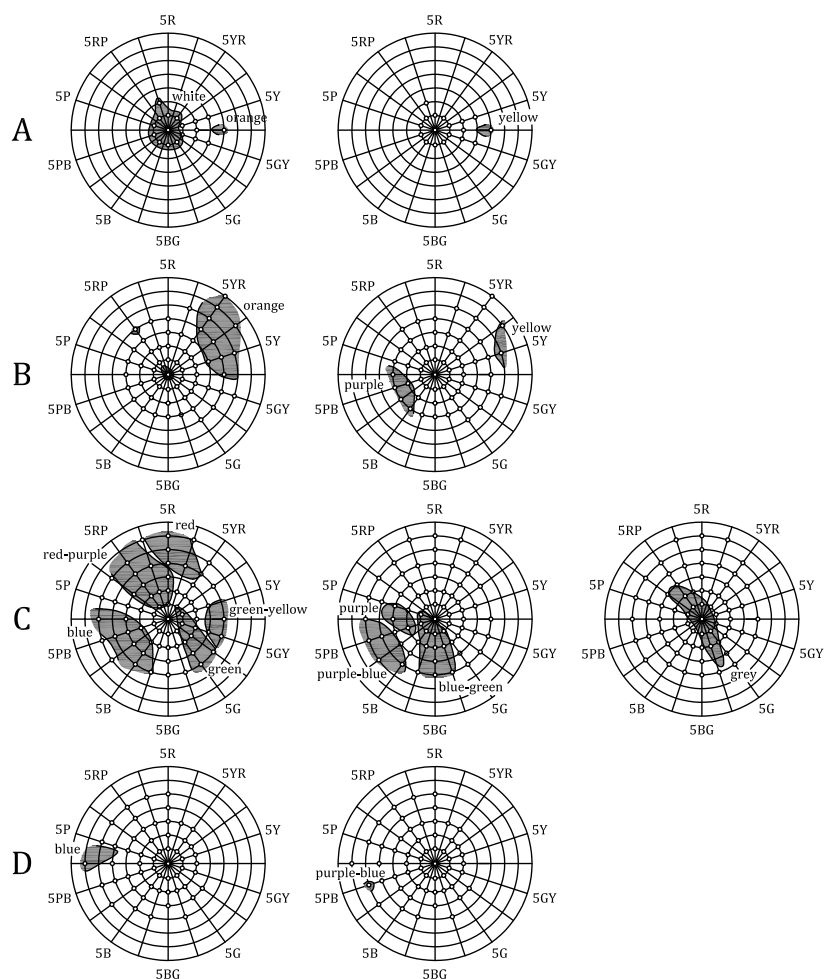
NOTE The names of fundamental colours that define colour categories are: (R) red, (YR) orange or yellow-red, (Y) yellow, (GY) green-yellow, (G) green, (BG) blue-green, (B) blue, (PB) purple-blue, (P) purple, (RP) red-purple, (GRE) grey, (WHT) white, (BLK) black.

6.2.2.4.3 People with defective colour vision

Figure 7 a) and b) shows the spans of colour category for people with defective colour vision, protanope and deuteranope respectively, measured and expressed in the same way as in young and older people. Due to largely different characteristic of colour vision, spans of colour categories are largely different from those of young or older people. Differences are also seen between the data of protanope and deuteranope. The spans of colour categories for both protanope and deuteranope are extended to the direction of red-green colour axis and the distinction of red and green colours become worse for those colour deficiencies.



a) Protanope



b) Deuteranope

Figure 7 — Spans of fundamental colours for people with defective colour vision at photopic level (50 % similarity level)

Table 5 and Table 6 show colour combination tables for protanope and for deuteranope derived from the colour category data of Figure 7 a) and b), respectively. Note that spans of these categories of older people are different from those of young or older people. Table 5 and Table 6 should be used in conjunction with the category data of Figure 7 a) and b), respectively.

Table 5 — Colour combinations and their distinctiveness for people with defective colour vision, protanope

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

Table 5 (continued)

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

+++ High distinctiveness
 ++ Moderate distinctiveness
 + Low distinctiveness

NOTE The names of fundamental colours that define colour categories are: (R) red, (YR) orange or yellow-red, (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.

Table 6 — Colour combinations and their distinctiveness for people with defective colour vision, deuteranope

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

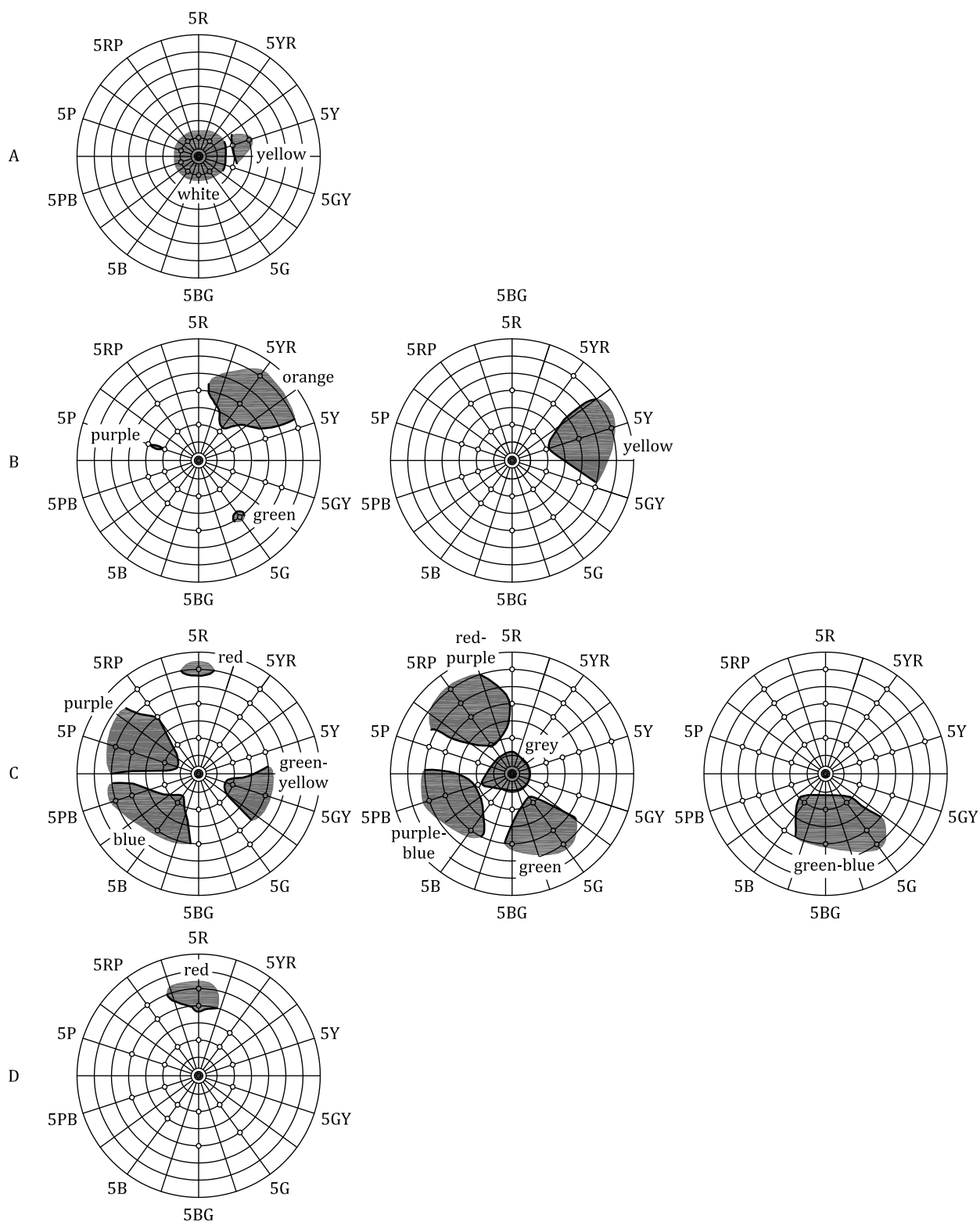
+++ High distinctiveness
 ++ Moderate distinctiveness
 + Low distinctiveness

NOTE The names of fundamental colours that define colour categories are: (R) red, (YR) orange or yellow-red, (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.

6.2.2.4.4 People with low vision

Low vision is physiologically, but not optically, impaired vision with an extremely low visual acuity and/or a restricted visual field, which is caused in most cases by an eye disease or disorder such as cataract, retinitis pigmentosa and glaucoma. Low vision cannot be corrected by spectacles or other optical means of imaging. As colour appearance for people with these visual impairments is different from that of people without any visual impairment, spans of categorical colours also differ for these groups of people. This clause gives data on the span of categorical colours and a colour combination table for people with low vision.

Figure 8 shows the data for colour categories measured for people with low vision. The spans of 50 % level of similarity are rather smaller than those for young people (see Figure 5). However, the spans of the 10 % similarity (not shown here) become larger for almost all fundamental colours, which means colours are perceived as widely spread for low vision and not sharply localized in a colour space.



Key

- A Munsell value 9 (very light level)
- B Munsell value 7 (light level)
- C Munsell value 5 (moderately light level)
- D Munsell value 3 (dark level)

Figure 8 — Spans of fundamental colours for people with low vision at photopic level (50 % similarity level)

Table 7 shows a colour combination table derived from the data in Figure 8.

Table 7 — Colour combination and their distinctiveness for people with low vision at photopic level

	R	YR	Y	GY	G	BG	B	PB	P	RP	GRE	WHT	BLK
R	—	++	++	++	+++	+++	+++	+++	++	+	++	+++	+++
YR	++	—	+	++	++	++	+++	+++	++	++	++	++	+++
Y	++	+	—	++	++	++	+++	++	++	++	++	++	+++
GY	++	++	++	—	+	+	++	+++	+++	+++	++	++	++
G	+++	++	++	+	—	+	++	++	++	+++	++	++	++
BG	+++	++	++	+	+	—	+	+	++	++	++	++	++
B	+++	+++	+++	++	++	+	—	+	++	++	++	++	++
PB	+++	+++	++	+++	++	+	+	—	+	++	++	++	++
P	++	++	++	+++	++	++	++	+	—	+	++	++	++
RP	+	++	++	+++	+++	++	++	++	+	—	++	++	++
GRE	++	++	++	++	++	++	++	++	++	++	—	++	++
WHT	+++	++	++	++	++	++	++	++	++	++	++	—	+++
BLK	+++	+++	+++	++	++	++	++	++	++	++	++	+++	—

+++ High distinctiveness
 ++ Moderate distinctiveness
 + Low distinctiveness

NOTE The names of fundamental colours that define colour categories are: (R) red, (YR) orange or yellow-red, (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.

6.2.2.5 Limitations

All the data presented in this document are basically applicable to reflected colour samples illuminated at a photopic level at moderately high illuminance levels. Colours appearing in a self-luminous mode such as lamps or displays should be converted into the Munsell colour system, or vice versa, before being applied.

Data in dim lighting condition called mesopic vision are also available (see references in 6.2.2.7).

6.2.2.6 Application examples

6.2.2.6.1 Identification by a single colour

Colour is used to identify a thing or an object by associating it with a specific single colour. For example, a colour is used for the uniform of a sports team to identify this team by the colour. Categorical colours can be used for this purpose effectively, and the choice of colour can be done along with the data on spans of categorical colours.

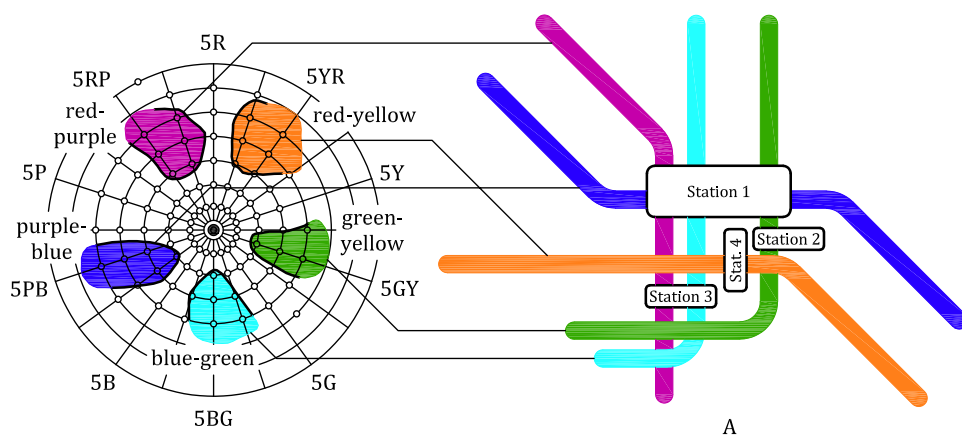
For example, when orange is used for the uniform of a sports team, the colour should be selected from the span of the orange area expressed in one of Figure 5 to Figure 8, depending on the users involved, so that the people can easily identify the uniform colour as “orange” and consequently the group.

6.2.2.6.2 Colour combination

When a set of colours is used to enable identification of different categories of information presented together, the combination is chosen to ensure they can be differentiated. For example, when colouring 5 subway lines on a network map, a set of 5 fundamental colours can be selected by referring to Figure 5 to Figure 8, depending on the users who involved.

In [Figure 9](#), 5 fundamental colours (red-yellow, green-yellow, blue-green, purple-blue, and red-purple) are selected as an example of colour set for older people under photopic viewing condition. Using the 5 fundamental colour groups selected, any 5 colours within the respective span of the colour can be picked to use for colouring the 5 subway lines. This colour combination is distinctive as all 5 colours belong to different categories, not overlapping, and are therefore clearly distinctive.

Different sets of fundamental colours and exact colours for the combination can be created if they belong to a category of those fundamental colours. The choice of colours gives designers freedom and ease of use.



Key

A traffic 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 level.

Figure 9 — Example of colour combination for older people under photopic condition

6.2.2.7 References

- Data sources: References [\[43\]](#) and [\[33\]](#);
- Cross-references in this document: [6.2.3](#);
- Other references: Reference [\[87\]](#).

6.2.3 Colour category (international comparison)

6.2.3.1 General

Colour category is considered to reflect cognitive and language-related nature and its span may vary depending on a location in the world. This clause presents data on the spans of categorical colours collected in several countries in the same experimental context to identify regional or language-related differences in the spans of categorical colours.

6.2.3.2 Sampled population

Six countries (China, Germany, Japan, Republic of Korea, Thailand and the USA) participated in the experiment for collecting data on categorical colours. Each country had 20 young (age range 20–29 years) and 20 older (age range 60–79 years) participants. They were all confirmed not having defective colour vision by a test using the Ishihara colour-test chart.

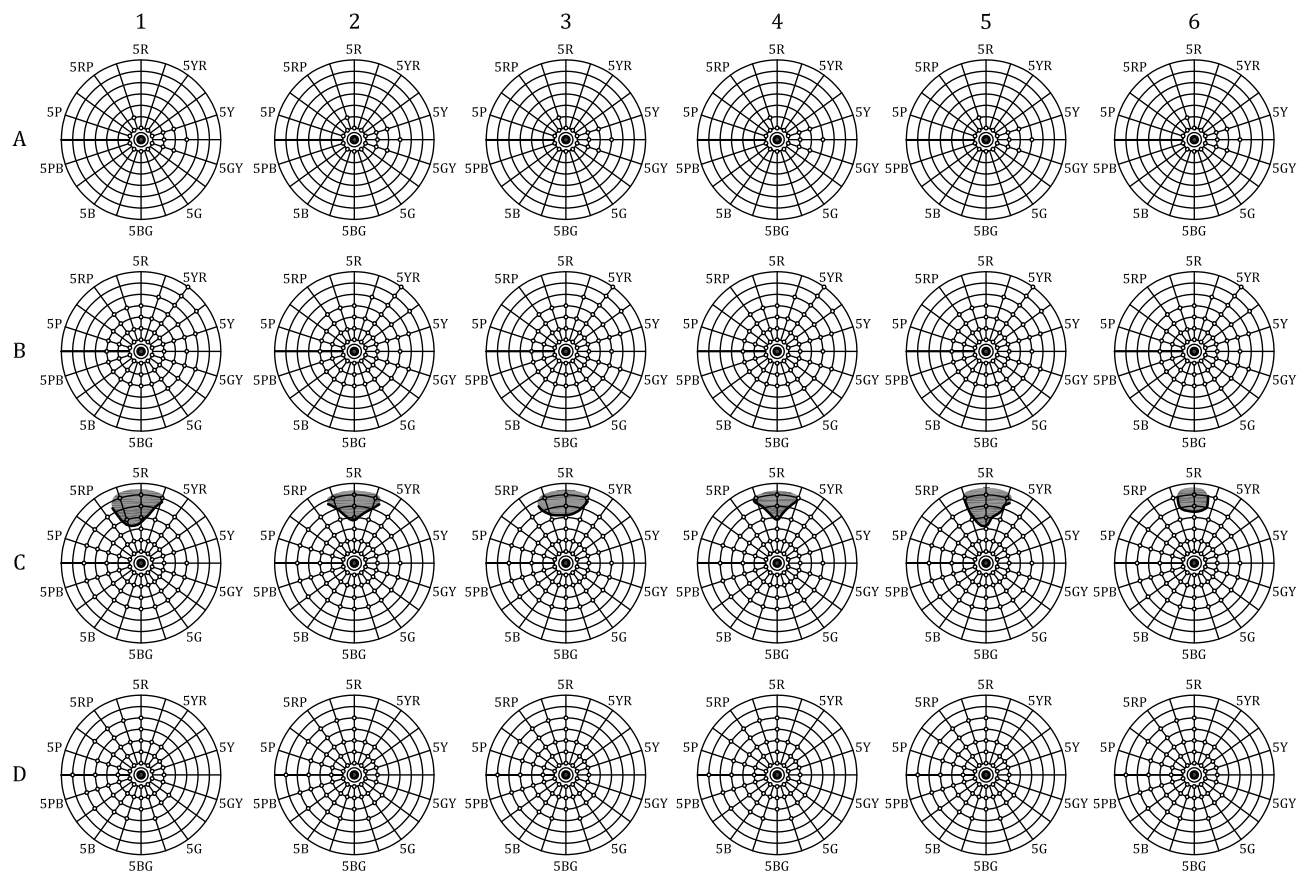
6.2.3.3 Methods and conditions of data collection

The procedure in the experiment was exactly the same as that described in 6.2.2. Colours used 200 test samples evenly distributed in the Munsell colour space and thirteen fundamental colours (red 5R5/12, yellow-red 5YR7/14, yellow 5Y8/12, green-yellow 5GY5/8, green 5G5/8, blue-green 5BG5/8, blue 5B5/8, purple-blue 5PB5/8, purple 5P5/10, red-purple 5RP5/10, white N9.5, grey N5, and black N1). These colour samples were made in Japan and sent to the 6 countries for their experiments.

Illuminance was set at around 500 lx of daylight fluorescent lamp. There was a slight variation in the illuminance setting among countries due to coarse control of the illuminance level, but the settings were all within the photopic range. The effect of the difference was small and negligible.

6.2.3.4 Data

Figure 10 shows an example of a span of colour category for “red (5R5/12)” measured for young people in the 6 countries listed above. The data of each country was plotted together side by side to see national differences at four different value levels of 3, 5, 7, and 9 in the Munsell colour space. It is clear that there are no large differences in size and shape of the span of colour-category of red although slight differences among countries are observable.



Key

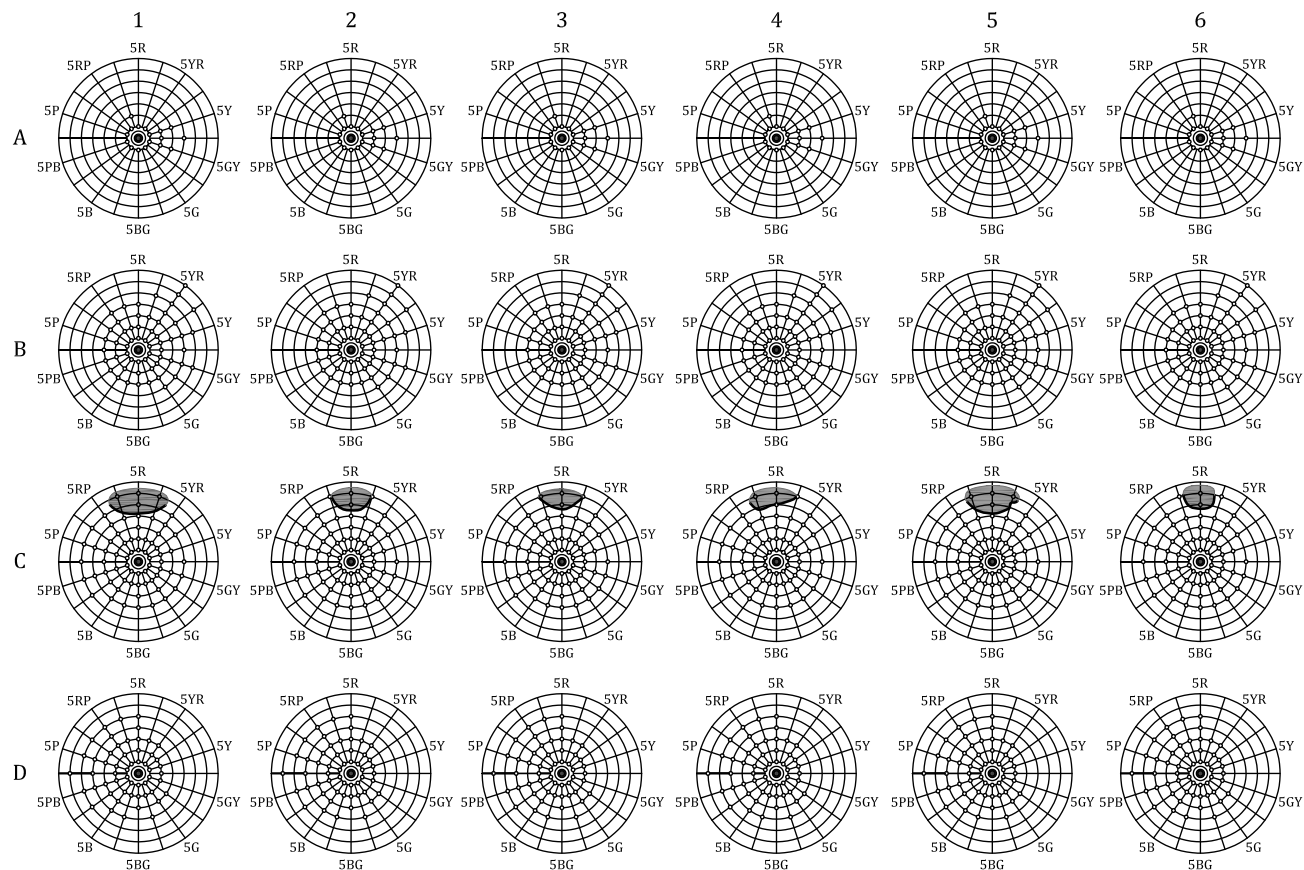
- A Munsell value 9
- B Munsell value 7
- C Munsell value 5
- D Munsell value 3

- 1 Japan
- 2 USA
- 3 Germany
- 4 Republic of Korea
- 5 Thailand
- 6 China

Figure 10 — Span of fundamental colour “red (reference 5R5/12)” for young people at photopic vision (moderately bright level) measured in 6 countries (50 % similarity level)

Figure 11 shows similar data but for older people, drawn in the same way as in Figure 10. Again, the span of fundamental colour of “red” is essentially the same for all the 6 countries. Furthermore, the span for older people is smaller than that for young people in all 6 countries.

These data indicate that one standard set of data, if established in one country or area, can be applicable to other countries or areas in the world.



Key

- | | | | |
|---|-----------------|---|-------------------|
| A | Munsell value 9 | 1 | Japan |
| B | Munsell value 7 | 2 | USA |
| C | Munsell value 5 | 3 | Germany |
| D | Munsell value 3 | 4 | Republic of Korea |
| | | 5 | Thailand |
| | | 6 | China |

Figure 11 — Span of fundamental colour “red (reference 5R5/12)” for older people at photopic vision (moderately bright level) measured in 6 countries (50 % similarity level)

6.2.3.5 Limitations

The data presented here have been collected from people with normal colour vision at photopic level only.

6.2.3.6 Application examples

Summarizing all the data of 6 countries, a common database for the span of categorical colours and colour combination tables were created (see ISO 24505).

6.2.3.7 References

- Data source: Reference [33];
- Cross-references in this document: 6.2.2;
- Other references: Reference [77].

6.2.4 Contrast sensitivity (young people, older people and people with low vision)

6.2.4.1 General

Contrast of luminance is one of the most important variables affecting visibility of visual signs and displays as well as that of small objects like a needle and thread. Sharpness of those visual images depends largely on the contrast, and designers should pay attention to the contrast effect on visibility to make their designed objects clearly visible.

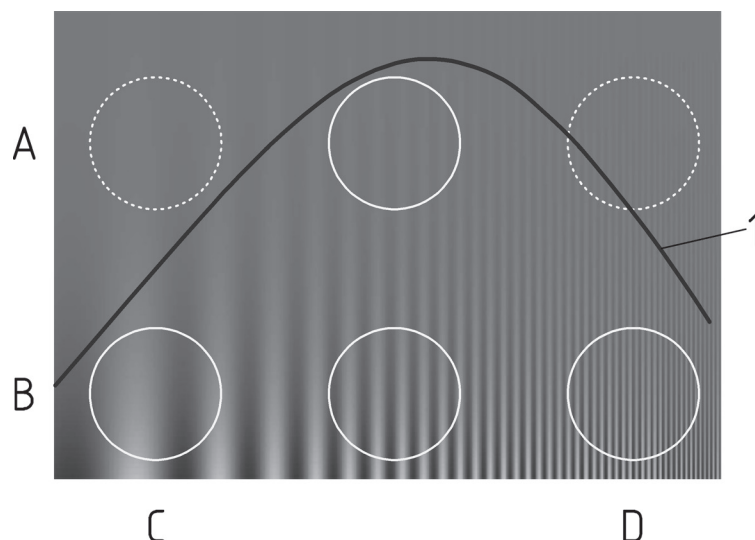
Contrast is defined as a luminance difference between any adjacent areas of a brighter and a darker part. Visual sensitivity to contrast is concerned with how clearly the eye sees the contour. The sensitivity is often measured by having people identify if they can see a black and white stripe pattern (usually of a sine wave grating pattern) when the depth or luminance difference of the brightest and darkest parts is gradually increased or decreased. The observation is done to find a borderline to barely see the stripe pattern.

Scientifically, contrast sensitivity is expressed as so-called contrast sensitivity function (CSF) that shows a borderline expressed on a contrast vs. spatial frequency plane (see [Figure 12](#)), where spatial frequency and contrast are shown together with a line that indicates the CSF, i.e. a grating detection borderline. In this example, solid circles mean visible parts and dashed circles invisible parts in the domain of spatial frequency vs. contrast.

The human visual system has a peak of contrast sensitivity at 3 or 4 cycles per degree (cpd). The sensitivity gradually decreases towards the both ends of the spatial frequency spectrum, both for higher frequency regions (i.e. finer gratings) and lower frequency regions (i.e. coarser gratings). This effect can be taken into consideration for designing visual signs and displays.

NOTE Spatial frequency is defined as the number of pairs of dark and light lines per degree of visual angle. Spatial frequency units are expressed in cycles per degree (cpd). A grating with 3 cpd, for example, would have three pairs of dark and light lines per degree of visual angle. One degree of visual angle corresponds to 8,7 mm at the distance of 50 cm from the eye.

The shape of CSF changes with age as well as with visual impairments. This subclause provides CSFs of young people, older people and people with low vision.

**Key**

- A low contrast
- B high contrast
- C low spatial frequency (coarse pattern)
- D high spatial frequency (fine pattern)
- 1 grating detection border line (CSF)

Figure 12 — Contrast sensitivity function plotted on the spatial frequency vs. contrast plane

6.2.4.2 Sampled population

The CSF data were taken from the following three different groups:

- young people: 24 young people without visual impairment, ranging in age from 20 years to 28 years;
- older people: 20 older people without visual impairment, ranging in age from 70 years to 77 years;
- people with low vision: 72 people with low vision (medically diagnosed), ranging in age from 18 years to 70 years.

6.2.4.3 Methods and conditions of data collection

Contrast sensitivity functions for young people, older people and people with low vision were measured at a photopic (moderately bright) level. A sine-wave grating pattern was presented on a flat CRT screen which was set at the distance of 2 m for young and older people and 50 cm for people with low vision. The grating was presented at one of the four orientations of 0°, 45°, 90°, and 135° from the horizontal axis at a random order. Participants reported the orientation by a four-alternative forced-choice method. Average luminance of the grating patterns was 50 cd/m².

Younger and older people wore correction lenses to adjust their accommodation power to be best at a far point (5 m). No correction was made for people with low vision.

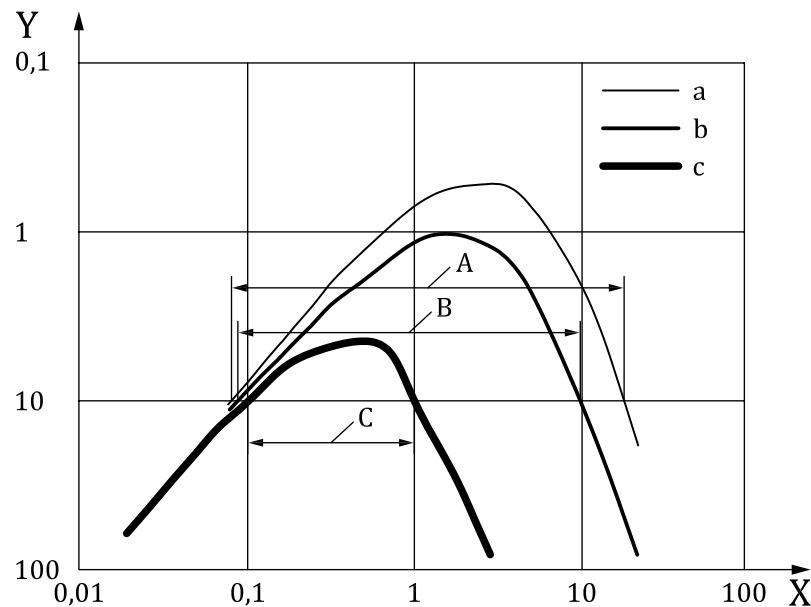
6.2.4.4 Data

Figure 13 shows average contrast sensitivity of the three groups, young people, older people and people with low vision, as a function of spatial frequency, called CSF. The contrast is defined by Michelson contrast here (see NOTE).

The older people were less sensitive at higher frequencies above a few cycles per degree than young people were. This means it is more difficult for older people to discriminate or recognize the fine grating in the higher frequency region.

For persons with low vision, the sensitivity was much lower in middle-to-high frequency regions compared to younger or older people. Care should be taken when designing visual signs for people with low vision because they are often unable to discriminate patterns that are easily discriminable for young or older people.

NOTE Michelson contrast (modulation 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, respectively, per cycle of the dark and light grating pattern.



Key

- X spatial frequency (cycles per degree)
- Y contrast at threshold (%)
- a young (average, 20–29 years)
- b older (average, 70–79 years)
- c low vision (median, 18–70 years)
- A visible range at 10 % contrast for younger people
- B visible range at 10 % contrast for older people
- C visible range at 10 % contrast for people with low vision

Figure 13 — Contrast sensitivity function of human visual system for young people, older people and people with low vision

6.2.4.5 Limitation

The data presented here are only for a photopic (moderately bright) level which is above about 10 lx of luminance or a few candela per square meter of luminance. The shape of CSF changes at a lower or an extremely higher illuminance level and different CSFs for those conditions are expected. A band-pass shape with a reduction of sensitivity at the lower spatial frequency region and a low-pass shape with a reduction at the higher frequency region is expected for a higher luminance level and for a lower luminance level respectively.

The CSF shows the sensitivity to a grating pattern of a single spatial frequency. In a complex pattern or a natural scene having multiple components of the frequency, the overall sensitivity to that complex pattern cannot be estimated easily from the CSF.

6.2.4.6 Application examples

The CSF data can be used to estimate a visible range of spatial frequency where an individual can detect a grating whose contrast is known. For example, for a visual image with a 100 % contrast (the ideal contrast of black and white images as used in the Landolt ring or Snellen chart), the range of visible spatial frequencies are 0,01 cpd to 30 cpd for young people, 0,01 cpd to 20 cpd for older people, and 0,01 cpd to 3 cpd for people with low vision ([Figure 13](#)). A pattern containing frequency components beyond those ranges is difficult to see with extremely low or no contrast.

At a lower contrast of 10 %, for example, the range of visible spatial frequency can be very narrow. For a person with low vision, the range is only about 0,1 cpd to 1 cpd (C in [Figure 13](#)), while it is 0,1 cpd to 10 cpd (B in [Figure 13](#)) for older people and 0,1 cpd to 20 cpd (A in [Figure 13](#)) apply to younger people.

When designing visual signs that contain fine details such as small letters or low contrast such as pictures of pale colours, special care should be taken to accommodate the visible range in the plane of spatial frequency vs. contrast for older persons and persons with low vision. When the image contains fine details, the image should be enlarged or contrast should be increased to make it more visible.

Contrast reduction usually occurs for visual electronic displays seen in a lit condition. Reflected light from the display surface can reduce the contrast of images. In this case, the lighting direction or the display angle should be arranged so that it reduces the reflected light.

6.2.4.7 References

- Data source: Reference [\[67\]](#);
- Cross-references in this document: [6.2.1](#), [6.2.5](#);
- Other references: References [\[80\]](#) and [\[62\]](#);

6.2.5 Contrast for legibility (ageing effect)

6.2.5.1 General

Contrast between a character and a background is one of the critical factors that affect the legibility of a character. [Figure 14](#) illustrates different contrast of a character on a fixed grey background as an example. As shown in the figure, increasing the brightness of the character from dark to bright changes the contrast from high positive to high negative contrast in between low positive and negative contrast is seen. Similar contrast change occurs for a fixed brightness of a character on a variable brightness of background. Characters printed on a highly reflective paper or an electronic display with highly reflective surface usually have low contrast when illuminated by a strong light source due to an increase of background brightness that consequently reduces the contrast and legibility. Coloured characters or coloured backgrounds also have a large variety of contrast depending on the colour used. For example, a yellow character on a white background usually has a low contrast and is difficult to read. To provide good legibility contrast is an important factor that designers should pay attention to.

This subclause provides data on the effect of contrast (i.e. luminance contrast) on the legibility of characters for young and older people.

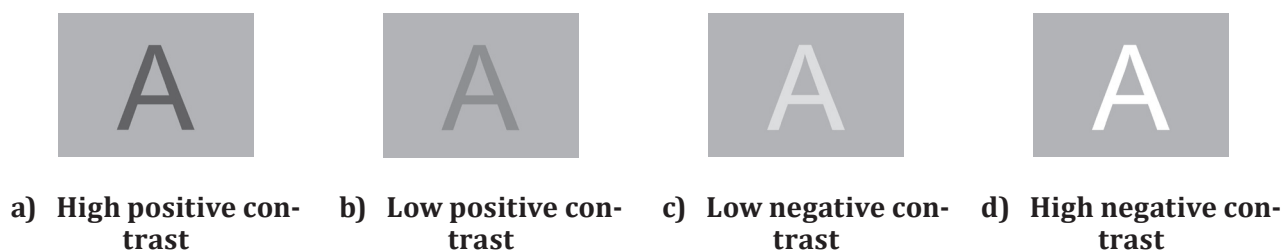


Figure 14 — Character on a grey background with variable contrast

NOTE 1 Positive contrast means a character or symbol that is darker than the background. Negative contrast means a character or symbol brighter than the background.

NOTE 2 Contrast is usually defined for luminance and colour separately, even for a coloured sample using its luminance or chromaticity value. The luminance contrast has much more effect than the colour contrast on the sharpness of an image. Therefore, contrast means the luminance contrast, unless stated otherwise.

6.2.5.2 Sampled population

The data on legibility with variable contrast were obtained from the following two groups of different ages:

- 56 young people without visual impairment, ranged in age from 18 years to 28 years (mean = 21,9 years, sd = 2,16 years);
- 55 older people without visual impairments, ranged in age from 60 years to 77 years (mean = 67,1 years, sd = 3,93 years).

6.2.5.3 Methods and conditions of data collection

The legibility data were taken by presenting a character on a CRT monitor at various contrasts against a background of a mean luminance of 40 cd/m². The contrast was either positive or negative. Participants evaluated legibility, after seeing a character presented for one second, using a 5-point scale of legibility with an additional response of “not visible” as shown below:

- 5: very legible;
- 4: slightly legible;
- 3: moderate (neither legible nor illegible);
- 2: slightly illegible;
- 1: very illegible;
- 0: not visible (at or under the visibility threshold).

Viewing distance was fixed at 70 cm. All the young and older participants wore correction lenses to adjust their accommodative power best at the far-point (5 m). For older participants, further correction lenses were attached to bring their best accommodation point to a viewing distance of 70 cm.

Three kinds of characters were used. Each set contained a total of 86 different characters picked up at random for the experiment.

- Simple characters in sans-serif font of positive polarity (alphabets, numerals, and alphabets, numerals Japanese phonetic signs).
- Complex characters in serif font of positive polarity (Japanese Kanji, i.e. Chinese characters).

- Simple characters in sans-serif font of negative polarity (alphabets, numerals, and alphabets, numerals Japanese phonetic signs).

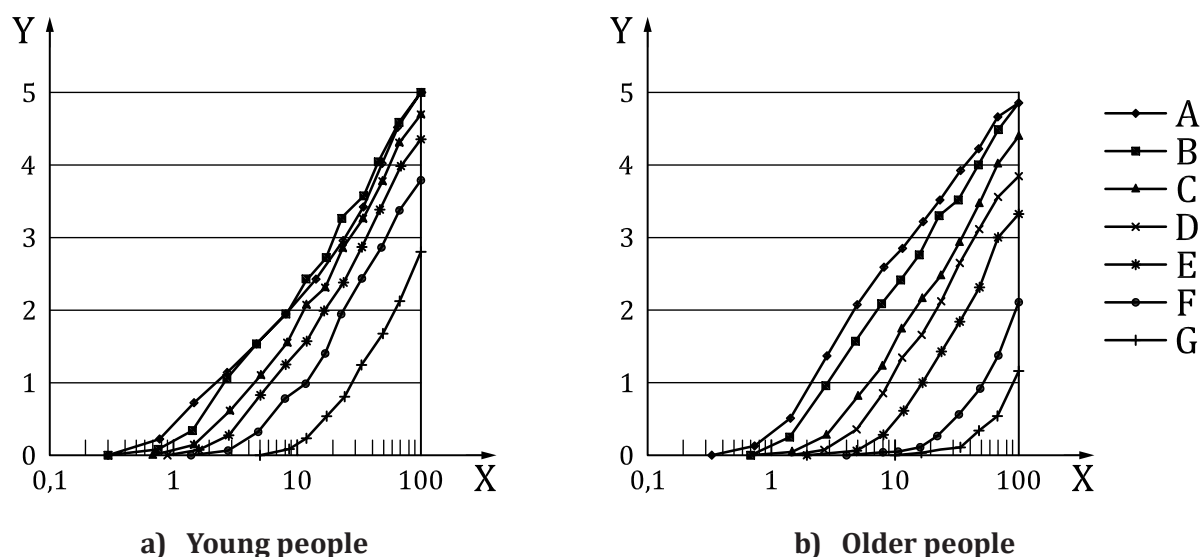
The data on negative polarity are not shown here but can be found in [6.2.5.7](#). The data were taken for seven sizes of a character from 8 pt to 160 pt to examine the effect of font size on the contrast.

6.2.5.4 Data

[Figure 15](#) a) and b) shows the legibility evaluation data for simple characters of positive polarity as a function of contrast, for young and older people, respectively.

The evaluation score for legibility became higher for all font sizes and for both age groups as contrast increased. The legibility was also determined by the font size (i.e. the larger the font size, the higher the legibility). To keep a certain level of legibility, a higher contrast was needed for a smaller character. Age-related difference was observed for all the font sizes. The difference was relatively large for a smaller font size below 18 pt, for which older people show much lower legibility than young people do.

There was an effect of font type, serif or sans-serif, though it is not shown here. Sans-serif fonts gave better legibility than serif fonts even when the contrast was the same. The effect was more pronounced for a smaller font size than for a larger one.



Key

X	contrast (%)
Y	legibility evaluation score
A	160 pt
B	80 pt
C	40 pt
D	28 pt
E	18 pt
F	12 pt
G	8 pt

Figure 15 — Legibility of simple characters of seven different font sizes with positive polarity as a function of contrast

6.2.5.5 Limitations

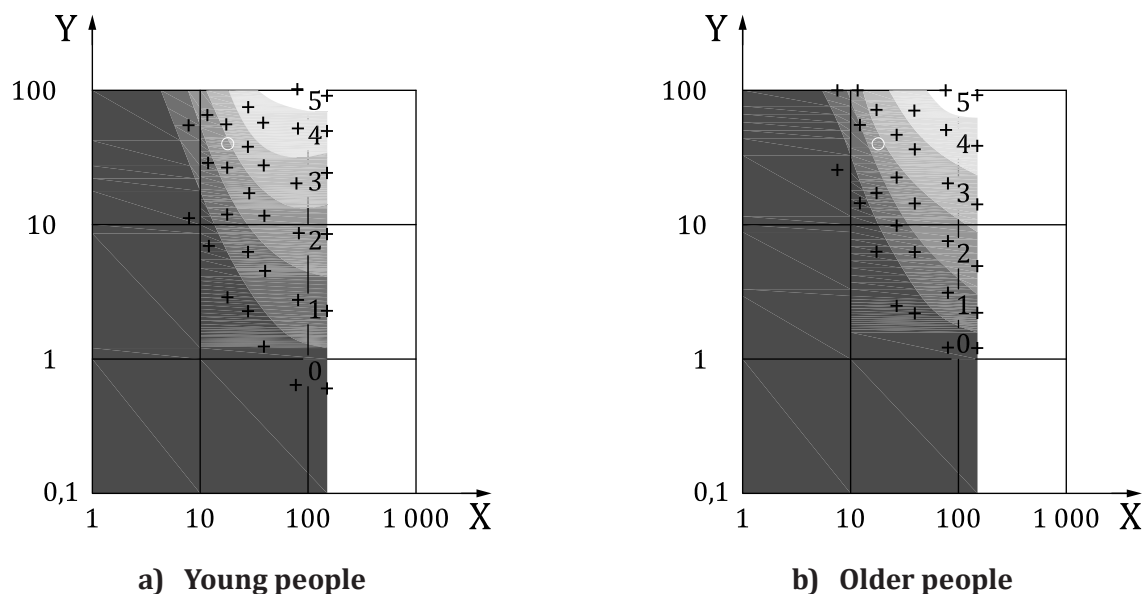
The data are directly applicable for a moderately bright level supporting photopic vision, which is beyond about 10 lx of illuminance or a few cd/m² of luminance. It is also applicable to a positive contrast where a black or darker character is presented on white or brighter background.

The font size in this data is defined only for a viewing distance of 70 cm. For other viewing distances, the size should be changed proportionally to the reference distance of 70 cm. For older people, the visual acuity change with viewing distance should be taken into account (see 6.2.6).

6.2.5.6 Application examples

The present data can be replotted as equal legibility contours on a two-dimensional plane of font size (in pt) and contrast. Figure 16 shows this two-dimensional representation. The different grey-coloured zones indicate each of the 5 legibility levels and the below threshold (not visible) level. For a given combination of contrast and font size, the legibility level score can be estimated directly from Figure 16.

For example, a character (alphabet or numeral) of 18 pt with 40 % contrast seen at the distance of 70 cm (an open circle in Figure 16) is at the legibility level of 3 (moderate) for young people, and level of 2 (slightly illegible) for older people.



Key

X font size (pt)

Y contrast (%)

NOTE A small white dot shows an example of legibility estimation described in the text.

Figure 16 — Map of legibility level as a function of font size (in pt) and contrast for simple characters for young and older people

6.2.5.7 References

- Data source: Reference [79];
- Cross-references in this document: 6.2.4, 6.2.7;
- Other references: none.

6.2.6 Visual acuity (effects of age, viewing distance and luminance)

6.2.6.1 General

Visual acuity is an ability to discriminate fine details of images or objects that relates to sharpness or distinctness of a visual image. This is a matter of concern when people read letters or see pictures. When visual acuity is low, sharpness and distinctness of visual images become worse or blurred, and a larger size of a letter or a picture is required to see them more clearly.

It is well known that visual acuity changes with viewing conditions such as luminance level, contrast, viewing distance and other factors like position in a visual field. Among these factors, viewing distance is one of the factors with the greatest effect where the age of viewer is concerned. It is therefore important to consider the viewing distance when designing visual images seen by older people.

Luminance, which means the background luminance on which the test image is displayed, is another important factor affecting visual acuity, but this effect occurs consistently for both young and older people.

In this subclause, the visual acuity data are presented as a function of viewing distance and luminance with age of a viewer as a parameter.

6.2.6.2 Sampled population

Visual acuity data in this subclause were taken from 111 participants and divided into 7 age groups as follows:

- 1) 10–19 years old (average 14,9 years), 11 participants;
- 2) 20–29 years old (average 22,8 years), 28 participants;
- 3) 30–39 years old (average 33,0 years), 11 participants;
- 4) 40–49 years old (average 46,5 years), 10 participants;
- 5) 50–59 years old (average 52,4 years), 10 participants;
- 6) 60–69 years old (average 65,3 years), 22 participants;
- 7) 70–79 years old (average 72,8 years), 19 participants.

Male and female were nearly balanced for each age group, except for the group of 40–49 years in which most of the participants were female. All the participants had no eye disease and no history of eye surgery.

6.2.6.3 Methods and conditions of data collection

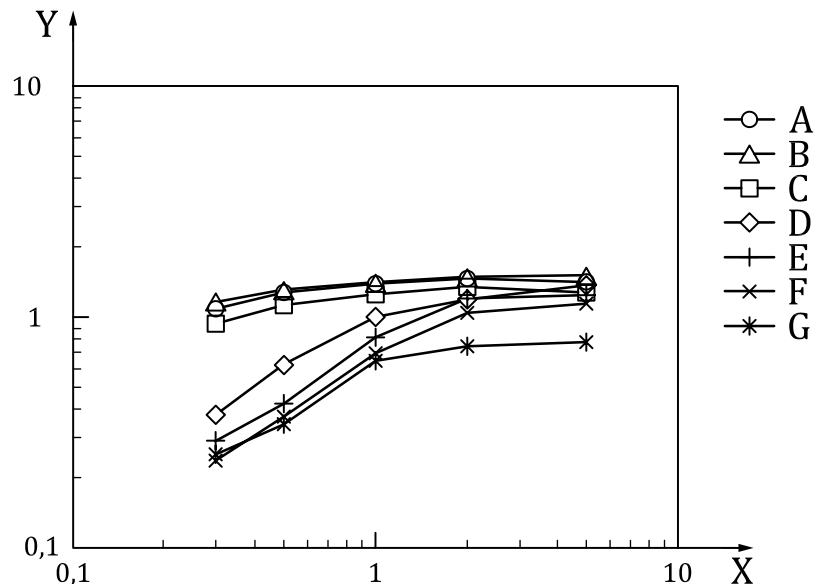
The data were obtained with a test chart based on the Landolt ring, which was printed on a white sheet with a gap in the ring in one of 8 directions. In investigating the effect of viewing distance, the luminance level of the white background sheet was set at 100 cd/m² and the viewing distance was changed from 0,3 m to 5 m. In investigating the effect of luminance, the distance was fixed at 5 m and the luminance was changed from 0,05 cd/m² to 11 000 cd/m².

The participants were asked to report the direction of the gap in the ring by choosing one from 8 directions. With reducing the size of the ring, the minimum size at which 50 % of correct responses was obtained. The visual angle of the gap at this minimum size gives the critical resolution of the eye, and the reciprocal of the visual angle (expressed in minutes of arc) finally gives the visual acuity.

All the participants wore correction lenses prepared for the measurement so that their best acuity was obtained at a far viewing point of 5 m.

6.2.6.4 Data

[Figure 17](#) shows the visual acuity as a function of viewing distance for seven age groups. The luminance level was fixed at 100 cd/m². For participants of 10–19 years old, the visual acuity remained almost constant at around 1,0 although it reduced slightly at shorter viewing distance of 0,3 m. On the other hand, for participants of 40–49 years old or older than this, the acuity clearly decreased at shorter distances of 1 m and below. Visual acuity at shorter distance is quite low for older people, and enlarged letters or signs are necessary for them to see clearly.

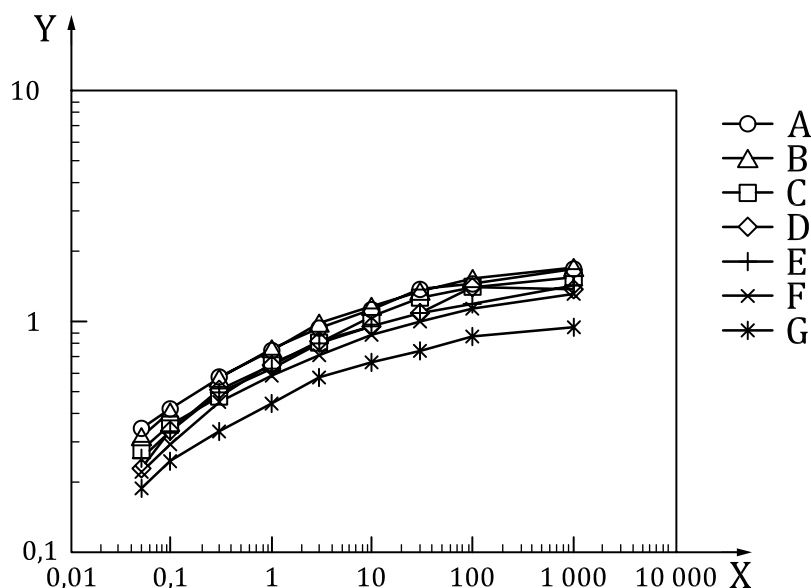


Key

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

Figure 17 — Visual acuity as a function of viewing distance for seven age groups

[Figure 18](#) shows visual acuity as a function of luminance for seven age groups. The viewing distance was 5 m. Visual acuity for all age groups decreased in a similar rate as the luminance level decreased. This result suggests that the effect of luminance on visual acuity has no age dependence and can be expressed as a single formula for all ages. It also shows that a visual task that needs fine resolution of images is not appropriate to do in dark conditions for both young and older people generally.



Key

X	luminance (cd/m ²)
Y	visual acuity
A	10–19 years old
B	20–29 years old
C	30–39 years old
D	40–49 years old
E	50–59 years old
F	60–69 years old
G	70–79 years old

Figure 18 — Visual acuity as a function of luminance for seven age groups

6.2.6.5 Limitations

Data were taken with corrected lenses to measure every participant under the same visual condition (best corrected vision to a far viewing point). People wearing glasses of their own choice do not necessarily show the same change of visual acuity as shown in [Figure 17](#). However, the relative change of visual acuity with luminance level generally applies to most of the viewing conditions.

6.2.6.6 Application examples

Visual acuity is expressed as the reciprocal of minimum discriminable visual angle. Therefore, when visual acuity is reduced by half, for example from 1,0 to 0,5, the size of a letter or a picture needs to be doubled to maintain the same level of visual resolution. This inverse relationship is basically applicable to most of the viewing conditions.

However, it is noted that visual acuity does not directly relate to the legible font size. For the relationship between visual acuity and font size, see [6.2.7](#).

6.2.6.7 References

- Data source: Reference [\[42\]](#);
- Cross-references in this document: [6.2.7](#), [6.2.8](#);
- Other references: Reference [\[88\]](#).

6.2.7 Minimum font size for legibility (effects of age, viewing distance and luminance)

6.2.7.1 General

Characters are used frequently and widely in our daily life. Font size for better legibility is always a matter of concern for designers of displays, pamphlets, and booklets like instruction manuals. However, ergonomics data and a method to estimate a legible font size have not been available because the legible font size is affected by so many factors such as font types, viewing conditions or human cognitive factors.

This subclause provides a set of data for legibility on Japanese and Chinese characters that were taken for young and older people in some typical reading conditions to provide the basic data showing the effects of age, viewing distance, and luminance.

6.2.7.2 Sampled population

Forty-seven young people ranging in age from 20 years to 27 years (average 22,7 years), and 46 older people ranged in age from 60 years to 78 years (average 68,3 years) participated in the experiment.

Males and females were nearly balanced for both the young and older group. All have or have had no eye disease and no history of eye surgery.

6.2.7.3 Methods and conditions of data collection

The legibility was measured as the minimum size of a character that gave the 80 % correct character identification by presenting a single character at a time. The test character was printed in black on a transparent sheet giving high contrast when illuminated from the rear. Three different types of characters were used as follows:

- simple characters: a mixture of Japanese phonetic signs called Hiragana, Katakana, and numerals;
- complex characters 1: Kanji characters (or Chinese characters) with 5–10 strokes;
- complex characters 2: Kanji characters (or Chinese characters) with 11–15 strokes.

For each group, two font-types, serif and sans-serif, were used.

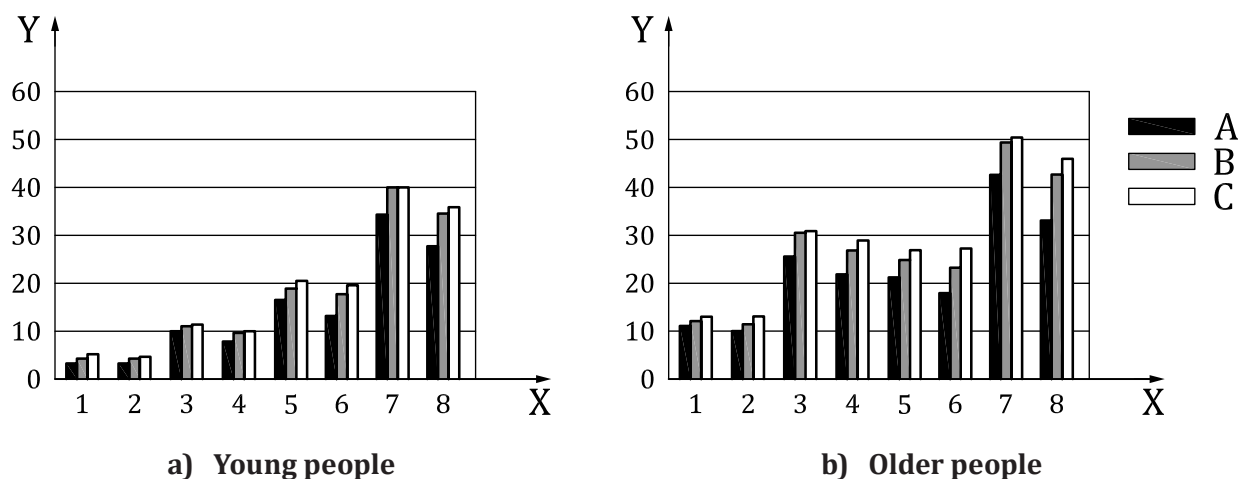
Four viewing conditions were used which consisted of combinations of two viewing distances, 0,5 m and 2,0 m, and two luminance conditions, 0,5 cd/m² (dark) and 100 cd/m² (bright).

Results were calculated as a probability of correct identification of characters for a font size in given viewing conditions. For this, a total of 12 consecutive trials were carried out by a participant with the same font size but different characters. The probability of 80 % of correct response was used to define minimum font size for legibility.

All the participants wore corrected lenses prepared individually for the experiment to keep a common accommodative power among participants which gave a best corrected vision to a far viewing point of 5 m.

6.2.7.4 Data

[Figure 19](#) a) and b) shows the minimum font size for legibility as a function of viewing conditions for young and older people respectively. The X-axis represents the 8 viewing conditions including the different font-types (serif and sans-serif). For each condition, minimum font size for legibility for 3 groups of characters (simple characters, complex characters 1, and complex characters 2) was given. Minimum font size for legibility is smaller for the shorter viewing distance and for the brighter condition in general. Marked differences between younger and older people are found at the short distance (0,5 m) in which about 3 times as large a font size is required for older people compared to that for young people. This is consistent with the visual acuity data shown in [Figure 17](#).

**Key**

- X viewing conditions
Y font size (pt)
A simple characters (Japanese Kana, numerals)
B complex characters 1 (Chinese with 5–10 strokes)
C complex characters 2 (Chinese with 11–15 strokes)
1 0,5 m, 100 cd/m², serif font
2 0,5 m, 100 cd/m², sans-serif font
3 0,5 m, 0,5 cd/m², serif font
4 0,5 m, 0,5 cd/m², sans-serif font
5 2 m, 100 cd/m², serif font
6 2 m, 100 cd/m², sans-serif font
7 2 m, 0,5 cd/m², serif font
8 2 m, 0,5 cd/m², sans-serif font

Figure 19 — Minimum font size for legibility of single characters for young and older people

Regarding the effect of font type, i.e. serif and sans-serif, the serif font needs slightly but consistently larger size than the sans-serif font for all the viewing conditions, which indicates that sans-serif is slightly more legible than serif font.

6.2.7.5 Limitations

It is noted that the data were taken with correction lenses to keep a common accommodative condition (best corrected vision to the far viewing distance of 5 m) among the subjects. People wearing their own preferred glasses do not follow the data trend expressed in [Figure 19](#). However, relative changes of the font size with different viewing conditions such as darker or lighter condition can generally apply.

The data were collected for some fixed conditions i.e. luminance, distance, font type, etc. To apply the present data in different condition an estimation method that takes into account the effects of those conditions is required (see JIS S 0032).

As already mentioned in [6.2.7.3](#), the minimum font size for legibility here was defined by 80 % correct identification of characters. This means that the font size is still at threshold level and not at the level of ease of reading. If font designers are concerned with the comfortable level of legibility, the size should be enlarged. The factor of enlargement can be defined relative to the minimum font size for legibility consistently for all the viewing conditions (see Reference [\[84\]](#)).

6.2.7.6 Application examples

Minimum font size for legibility in specific conditions can be estimated directly from the data shown in [Figure 19](#). The effects of viewing conditions and font types are also shown by the data and can apply to other conditions. One example of the estimation method is given in JIS S 0032.

6.2.7.7 References

- Data source: Reference [\[42\]](#);
- Cross-references in this document: [6.2.6](#), [6.2.8](#), [6.2.9](#);
- Other references: References [\[88\]](#), [\[84\]](#) and [\[35\]](#).

6.2.8 Minimum font size for legibility (international comparison)

6.2.8.1 General

Different fonts are used in different countries and legibility can differ among fonts. Therefore, it is worth testing the legibility of different fonts in different countries to recommend a standard font size across the countries.

This subclause provides data on the legibility of a single character for 6 different countries using the same experiment and the same viewing condition for groups of younger and older people.

6.2.8.2 Sampled population

The legibility experiment was carried out in each of six countries: China, Germany, Japan, Republic of Korea, Thailand and the USA. Each country recruited 15 to 20 people in their 20s and also 15 to 20 people in their 60s and 70s as participants in the experiment. They all had no impairment and no experience of surgery of the eye.

6.2.8.3 Methods and conditions of data collection

Legibility was investigated with a number of single characters in different sizes, printed in black on white paper. Ten font sizes from 2 pt to 114 pt were used. For each size, twelve different characters were tested. The participant was asked to read characters in their natural viewing manner, i.e. with glasses if they are used in their daily life, at fixed viewing distances of 0,5 m and 2,0 m. The illuminance at the viewing position was set at 500 lx approximately.

Under the same experimental conditions, the participants' visual acuity (spatial resolution ability) was measured using a Landolt-ring test chart.

Three types of characters, 4 languages, and 2 font types were used in the experiment as shown in [Table 8](#). Japan used alphabets to investigate an effect of non-native language. The legibility data for Japanese characters is presented in [6.2.7](#).

Table 8 — Experimental conditions used for the international comparison for legibility

Type of characters	Language	Country	Font type
Numerals	Arabian numerals	China	Serif Sans-serif
		Germany	
		Japan	
		Rep. of Korea	
		Thailand	
		USA	

Table 8 (continued)

Type of characters	Language	Country	Font type
Simple characters	Alphabet uppercase	Germany	Serif
		Japan	
	Chinese simple	USA	Sans-serif
		China	
Complex characters	Hangeul simple	Rep. of Korea	Serif
	Thai simple	Thailand	
	Alphabet lowercase	Germany	
		Japan	
Complex characters	Chinese complex	USA	Sans-serif
		China	
	Hangeul complex	Rep. of Korea	Serif
	Thai complex	Thailand	

6.2.8.4 Data

[Figure 20](#) and [Figure 21](#) show the minimum font size for legibility, for a serif font and for a sans-serif font respectively, measured in six countries, for young people (the left panel in [Figure 20](#) and [Figure 21](#)) and for older people (the right panel in [Figure 20](#) and [Figure 21](#)). The minimum font size for legibility was defined as the 80 % level of correct identification. Data in [Figure 20](#) and [Figure 21](#) are for a viewing distance of 0,5 m.

Visual acuity data of the participants were also measured in the same experimental condition, which are provided in [Table 9](#) for reference.

The minimum font size for legibility of young people ranged from 3 pt to 7 pt (at the 0,5 m distance), which is similar to that in shown in [6.2.7.4](#). For older people the legible font size became larger in a range from 6 pt to 17 pt. This result was reasonably expected based on the decrease in visual acuity with age at a short viewing distance generally, and also from the visual acuity data actually measured for younger and older people in each country (see [Table 8](#)).

The effect of different languages on the minimum font size for legibility is not clearly seen in [Figure 20](#) and [Figure 21](#). This can be due to some un-controlled factors such as the individual acuity of participants. Correction of data by visual acuity may be necessary for comparing the differences among the fonts in different countries more precisely.

Rough estimation using the simple inverse relationship of visual acuity in [Table 8](#) and font size data in [Figure 20](#) and [Figure 21](#) revealed that there was no remarkable effect of the different fonts of different languages used.

The sans-serif character shows smaller font size than the serif font for most of the conditions meaning that sans-serif is more legible. For older people in Thai language, minimum legible font size for sans-serif is much larger than that for serif-font.

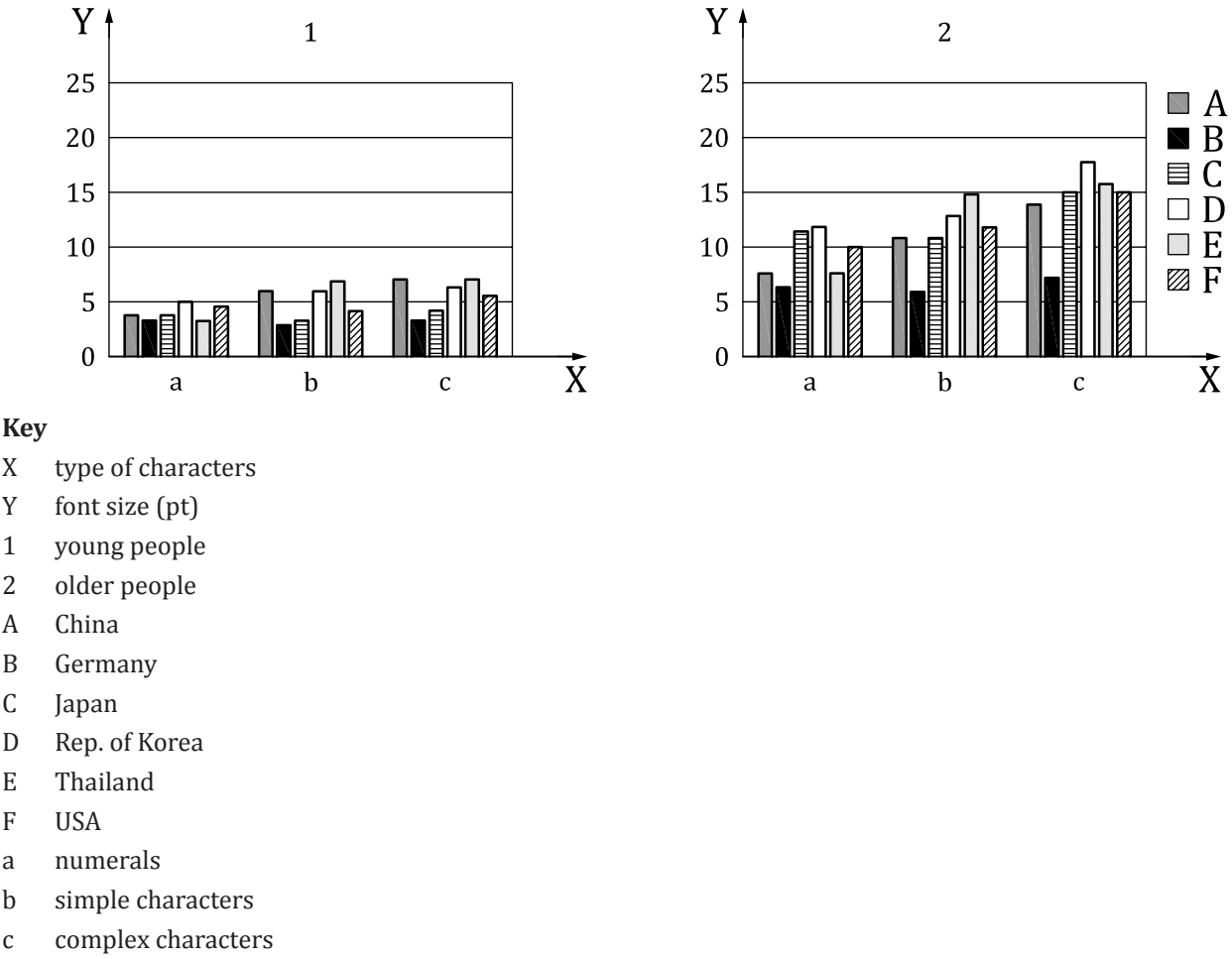


Figure 20 — Minimum font size for legibility for single characters for six different countries and serif font

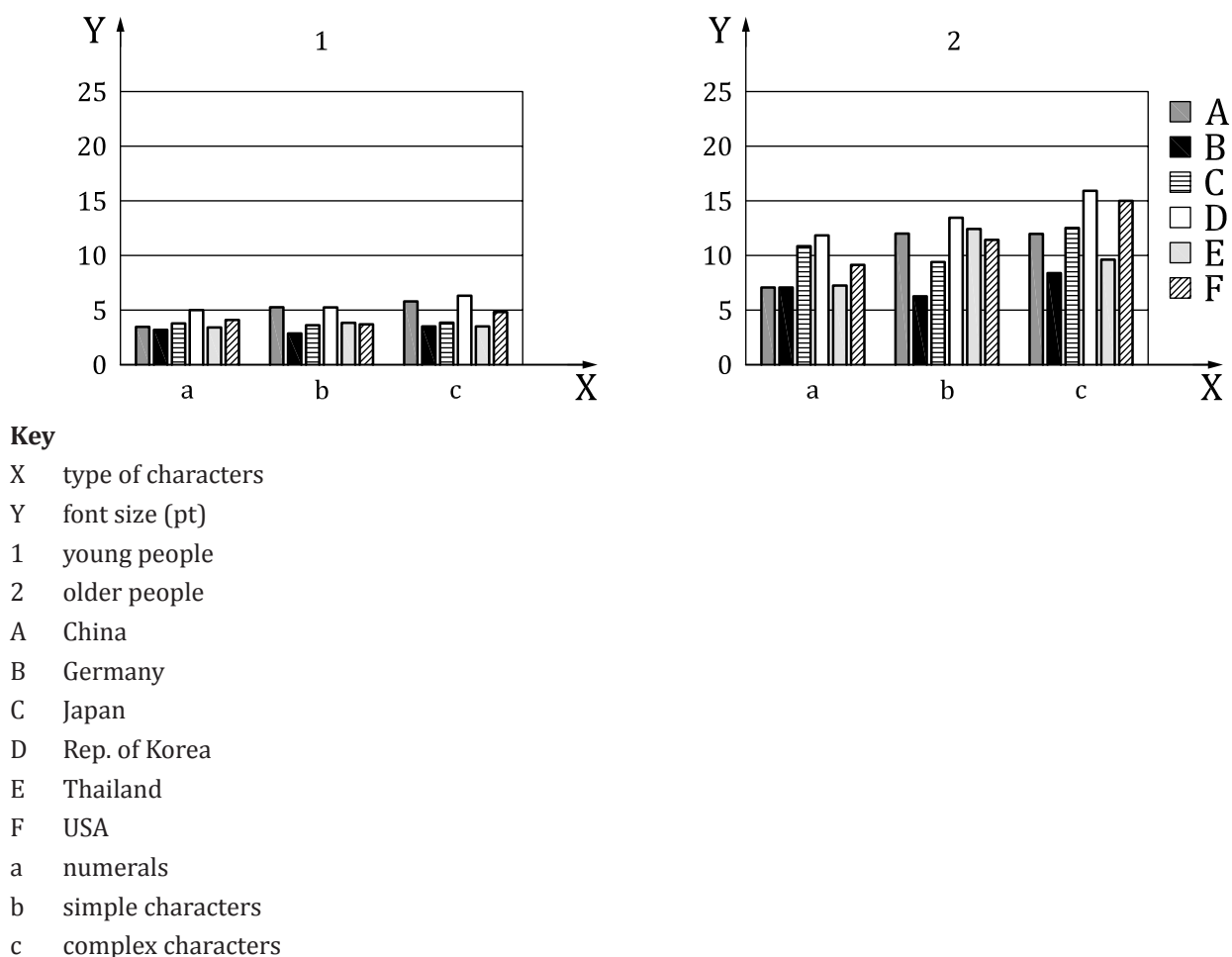


Figure 21 — Minimum font size for legibility for single characters for six different countries and sans-serif font

Table 9 — Averaged visual acuity of people who participated in the legibility experiment in each country

Country	Young people	Older people
Rep. of Korea	1,47	0,37
China	1,92	0,74
Germany	2,14	0,91
Japan	1,27	0,63
Thailand	2,18	0,55
USA	1,69	0,68

6.2.8.5 Limitations

Figure 20 and Figure 21 present font sizes at the minimum legible level defined as 80 % correct identification in the different conditions. The font size should not be smaller than this. The font size for comfortable seeing and reading may be much larger than the minimum legible size.

6.2.8.6 Application examples

The minimum font size for legibility at short viewing distance of 0,5 m can be estimated directly from the data shown in [Figure 20](#) and [Figure 21](#). For other conditions, the inverse relationship between visual acuity and font size can be roughly applied to estimate the minimum font size for legibility (see [6.2.6](#)).

6.2.8.7 References

- Data source: Reference [\[77\]](#);
- Cross-references in this document: [6.2.6](#), [6.2.7](#), [6.2.9](#);
- Other references: Reference [\[35\]](#).

6.2.9 Minimum font size for legibility (low vision)

6.2.9.1 General

Persons with low vision have extremely low visual acuity due to retinal and/or neural disorders in visual pathways, and the visual acuity cannot be corrected even with correction lenses. They need fairly large font size when they read characters and pictures. The extent to which persons with low vision can read characters is different depending on the impairment of retina or visual pathways.

Luminance level and luminance contrast of characters are also significant factors affecting legibility for people with low vision. Higher luminance level and high contrast are usually preferable for them, but these conditions sometimes cause glare and consequently degrade the legibility.

This subclause provides data about how big the font size needs to be to read characters in a typical viewing condition for people with low vision.

6.2.9.2 Sampled population

The data were obtained from 59 persons who were medically diagnosed as having low vision. Details of their diseases and distribution are shown in [Figure 22](#). This reflects a typical distribution in Japan, but can differ in other countries.