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Ergonomics — Accessible design — Ease of operation

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Foreword

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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).

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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*, Subcommittee SC 3, *Anthropometry and biomechanics*.

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

Operation of products and equipment used in everyday life requires a range of human physical characteristics and capabilities. The range is broad, including very limited capabilities among parts of the population. To improve operating accessibility, products and equipment must be designed using ergonomic principles related to physical characteristics, capabilities and limitations among populations.

This document provides ergonomic considerations for design to increase the operating accessibility of products and equipment specific to human physical characteristics, capabilities and limitations (e.g. body size, reach range, strength, dexterity).

This document adopts the guidance on accessibility given in ISO/IEC Guide 71 and ergonomics data given in ISO/TR 22411.

Ergonomics — Accessible design — Ease of operation

1 Scope

This document provides ergonomic requirements and recommendations for increasing accessibility in terms of ease of operation through the design of products and controls of daily use. It is intended to aid the design of products and equipment that can be handled and manipulated easily and comfortably by people with the widest range of physical characteristics, capabilities and limitations across the widest age range.

The requirements and recommendations specified in this document are based on general accessibility considerations as well as specific design considerations based on human physical characteristics, capabilities and limitations related to the operation of products and equipment, such as body size, strength, reach range and dexterity. Some considerations of cognitive factors are also presented.

Products and equipment for professional use only, as well as those used only by technical experts, are not covered in this document. Design aspects related only to information and marking are not included.

This document includes no general ergonomic requirements or recommendations for manual handling, working postures or safety of machinery but the contents are based on general knowledge of those issues.

NOTE ISO 11226, ISO 11228-1, ISO 11228-2, ISO 11228-3, EN 894-3+A1, EN 1005-2, EN 1005-3, EN 1005-4 and EN 1005-5 provide ergonomic requirements and recommendations for manual handling, working postures and safety of machinery.

2 Normative references

ISO 20282-1:2006, *Ease of operation of everyday products — Part 1: Design requirements for context of use and user characteristics*

IEC 63008:2020, *Household and similar electrical appliances — Accessibility of control elements, doors, lids, drawers and handles*

EN 301 549, V3.1.1:2019, *Accessibility requirements for ICT products and services*

3 Terms and definitions

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

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
control
element of a product with which a user operates the product

EXAMPLE Buttons, levers, knobs.

3.2
control panel
board that integrates controls, including information and marking

3.3
information and marking
visual or tactile characters and symbols, written or spoken instructions, and other indicators provided with the product to assist the user with its operation and use

EXAMPLE Labels, meters, indicators.

3.4
operation
action that a user performs to achieve an intended goal supported by the predefined behaviour of the product

EXAMPLE Lifting, lowering, carrying, gripping, rotating, pushing, sliding, touching.

Note 1 to entry: See Annex A.

3.5
ease of operation
extent to which a product, control or control panel is used with ease and comfort

4 General requirements

4.1 General

Subclauses 4.2 to 4.10 provide general accessibility requirements and recommendations for ease of operation. The design of products, controls and control panels shall take into account these requirements and recommendations.

Considerations on user characteristics related to everyday products shall be in accordance with ISO 20282-1:2006, Clause 7.

Safety issues in general shall take precedence over any accessibility requirements and recommendations.

4.2 Layout of controls and control panels

Placing a control and a control panel for users to access without bending or stretching increases accessibility, accommodating the widest range of seated and standing anthropometry (including use of a wheelchair) to the product. A control or control panel that is prominent and identifiable also increases accessibility. See also 5.4.

The following specific design requirements and recommendations are intended to increase accessibility related to location and layout of a control or control panel:

— The position of a product's control or control panel should be recognizable from the user's field of view when he or she is looking at the whole product. See 5.4.3.

— The top–bottom and left–right orientation of a control panel shall be identifiable.

EXAMPLE A tactile marking at the top of a control panel to show upwards for people with limited visual abilities.

— A product control or control panel shall be located within reach of a user's position. See 5.4.1 and 5.4.2.

— A product control or control panel should be identifiable by its particular shape.

EXAMPLE An input control with a large push-button.

— A control should be located in a position that is not hidden by the user's hands during operation.

NOTE Operation includes actions of various types, such as with a single hand, both hands and hands with low dexterity, and some actions interfere with seeing or touching a control.

— A control or control panel should have sufficient spacing around it so that the user's fingers or hands do not interfere with the operation or with nearby controls or control panels.

— The layout of a control or control panel should be logical and consistent with regard to frequency and process of use.

EXAMPLE Controls aligned in a sequential order or placed in a group, along with frequency of use.

— Controls should be grouped by a common shape, size and colour when coordinated in operation.

— Each control should have a single function.

— When more than one function is assigned to a single control, information and marking shall be provided to show the functions.

— Specific controls such as keyboard keys or buttons in a control panel of a product which serve as "home" keys or buttons should be identifiable with surface features facilitating tactile identification.

EXAMPLE A raised dot on the "5" key in a numeric keypad.

4.3 Strength required for operation

Considerations of population strength characteristics, such as age, sex and physical capabilities and limitations, for operation of a product and controls that require user strength output (e.g. holding, gripping, pushing, sliding) increase accessibility.

The following specific design requirements and recommendations are intended to increase accessibility related to human strength. For the strength of each particular action, see Clause 5.

— Strength for operating a product should be set at the minimum suitable force required for comfort control.

— A product that needs excessive strength for operation should have an additional device to assist, thereby decreasing the required strength.

NOTE Some people with physical limitations of the upper or lower limbs, in particular people with rheumatism or spinal cord injuries, are unable to operate some products.

— When operation of a product requires opening and closing, the actions should require minimal strength to be accessible by the widest range of population (e.g. age, sex, strength limitations), except where a fail-safe mechanism and safety considerations are needed (see 4.9).

— Products, controls and control panels shall have a non-slippery surface finish with purchase for hands or fingers to make operation easier for people with muscle strength limitations.

— When a product uses a touch screen, care should be taken with the appropriate pressing strength.

4.4 Dexterity

Considerations of user's finger or hand dexterity increases accessibility to ease operation for the widest range of users, including people with dexterity limitations.

The following specific design requirements and recommendations are intended to increase accessibility related to dexterity:

— A control should be designed to be operated by people with the widest range of dexterity capabilities and limitations, including those in a higher age range or with compromised dexterity abilities.

— A control that needs fine dexterity for operation should have an assistive tool or an indicator, such as a visual scale, to guide the operation.

— Use of different time durations for different operations on the same control, such as a long and a short pressing time, should be avoided except for particular cases, such as avoiding incorrect operation or using long and short pressing times to denote different control functions (such as in touch screens).

NOTE The dexterity is sometimes negatively affected by wearing gloves.

4.5 Avoidance of simultaneous multiple operations

Multiple operations should not be imposed at one time on one operating part of a product.

The following specific design requirements and recommendations are intended to increase accessibility related to avoidance of simultaneous multiple operations:

— Simultaneous multiple operations, such as pressing and rotating, should not be used except to ensure safety and to prevent misuse, for example in the case of child-resistant products.

— An alternative method of operation should be provided when simultaneous multiple operations are provided (see 4.6).

4.6 Provision of multiple means of operation

Provision of multiple means for operating a product or control increases accessibility, enabling the widest range of users to use the product.

The following specific design requirements and recommendations are intended to increase accessibility related to multiple means of operation:

— A product should have multiple means of operation for its main parts.

EXAMPLE 1 An input control using either a keyboard, a touch screen or a voice input.

EXAMPLE 2 Operation which requires touching with two fingers can be carried out by touching with just one finger.

— Compatibility with assistive devices for people with physical limitations should be made possible.

4.7 Provision of feedback

Provision of feedback for operating a control increases accessibility.

The following specific design requirements and recommendations relate to the provision of feedback:

— Operation of a control should prompt acceptance or response feedback to the user through multiple means of information (e.g. visual, auditory, tactile or haptic).

EXAMPLE A response to show “accepted” or “error” by means of a visual display or an auditory signal.

— For a series of operations, feedback should be given to the user after each operation, together with information related to the status or stage of the operation.

— For a cyclic series of operations, information related to a starting and an ending stage should be provided.

EXAMPLE A rotating dial control that stops at an ending stage.

— Reaction time for feedback shall be constant for a group of related operations.

— Tactile or haptic feedback should be used for people with limited visual or hearing abilities.

EXAMPLE A short vibration used for a touch screen input device when operated with a finger.

— When tactile vibration is used as feedback, care should be taken to avoid excessive vibration that causes discomfort and other problems for human touch.

— The direction and amount of movement of a control should correlate with the resulting change(s) in a product or an indicator.

EXAMPLE Clockwise rotation of a control denoted by a clockwise turning scale.

4.8 Logical process

Provision of logical and straightforward processes for operating a product increases accessibility when a sequence of operations is required.

The following specific design requirements or recommendations are intended to increase accessibility related to the logical process of operating a product:

— Complicated multiple steps in hierarchical processes for operating a product should be avoided.

— Unnecessary repeated actions shall be avoided. If repeated actions are necessary, the times repetition is necessary should be reduced.

EXAMPLE Use of a single combined operation when the operation is always followed by two or three of the same sequential operations except for ensuring safety.

— An "undo" function shall be possible for a sequence of operations to stop at any stage and to restart the sequence from the first operation.

EXAMPLE A press button provided to return to the initial stage of a series of operations at any time.

— A set duration of a timed response for an operation shall be sufficiently long to allow an unfamiliar or untrained user to operate it comfortably. Notification of a limited time or a residual time for the operation as well as manual setting for a preferred time by a user should be provided.

— Programmable settings for frequent sequential operations should be provided. The programme should be able to be easily started and edited by a user.

NOTE A set of sequential operations fixed in a programme is effective for people with limited cognitive abilities.

— The shape and placement of a control or control panel should be designed so the user intuitively understands the action which is necessary for its operation.

EXAMPLE A small tab attached to a package that is meant to be pulled.

— A paired operation of a product should be used for easy and intuitive understanding of the mutual relation of the operations.

EXAMPLE A control using a toggle switch for "ON" and "OFF", "UP" and "DOWN" or "LEFT and RIGHT".

4.9 Safety and a fail-safe mechanism

Considerations to ensure safety and a fail-safe mechanism increase accessibility.

The following specific design requirements and recommendations are intended to increase accessibility related to safety and a fail-safe mechanism:

— A control should be designed to be operated with the minimum suitable force that avoids inadvertent and unintentional activation.

NOTE People with limited visual abilities can press control buttons unintentionally.

— Reach range, body size and the user position shall be designed to avoid unintentional activation of a control.

— A control shall be placed apart from other controls or have a lock mechanism or a cover to avoid unintentional operation.

EXAMPLE 1 A nurse call button in a hospital that is isolated from other controls.

EXAMPLE 2 A lighter with a child-resistant mechanism that is difficult for a child to ignite.

EXAMPLE 3 An emergency push-button with a cover to avoid inadvertent operation.

— A product shall be designed to stop its operation in a safe and non-harmful state after incorrect operation.

— Warning or caution shall be provided to inform users of the state of a product through multiple means of sensory information.

— A fail-safe mechanism shall apply to a control, control panel or product.

EXAMPLE A microwave oven that stops warming when the door is opened.

— When incorrect operation occurs in a series of operations, undoing from any point should be made possible.

— Sharp points or sharp edges shall be avoided when designing a product, a control or a control panel.

— Readily visible warning labels explaining the product mass and operation requirements shall be provided when necessary.

EXAMPLE A package that has a label showing mass and a warning.

4.10 Other (assembling, installation, storage and maintenance)

The following specific design requirements and recommendations are intended to increase accessibility related to assembling, installation, storage and maintenance of a product.

— The size, shape and mass of a product shall be designed for easy holding, lifting and carrying (see 5.2).

— A handle or catch for easy holding, lifting and carrying, if attached to a product, should be designed for easy grasping by hands or fingers and for keeping a mass in balance. A heavy product should be provided with additional mechanisms for easy manual handling, for example casters (see 5.2).

— When assembling a product, control, control panel or any other part of a product should be distinguishable in shape and colour for easy understanding of the assembly process.

— A product should be designed for easy installation, mounting and decomposition. Connection of wiring or attachments should also be easy.

— The layout and process of storing a product shall be easy and understandable.

EXAMPLE The packaging of a product which has instructions for storage.

5 Ergonomic requirements and recommendations for ease of operation

5.1 General

Subclauses 5.2 to 5.4 provide ergonomic requirements and recommendations with regard to physical actions for ease of operation when designing products, controls and control panels. Annex A provides a list of design items and human abilities to be considered for accessibility. Annex B provides relevant

data of human abilities with figural representations and Annex C textural descriptions of the figures for people with difficulties in visually retrieving the figural information.

For household and similar appliances, in particular their controls such as handles, doors, drawers and lids, the accessibility requirements given in IEC 63008:2020, Clauses 5 to 7 shall apply.

For ICT products, in particular operating parts, the accessibility requirements given in EN 301 549, V3.1.1:2019, 5.5 to 5.9 shall apply.

5.2 Holding, lifting, carrying, pushing or pulling with hands or feet

5.2.1 Shape and size of products

A product that is operated by holding, lifting, carrying, pushing or pulling with hands or feet should have a shape and size suitable for these actions to be easily performed by the widest range of users, taking account of the direction of force, range of movement and posture required to perform the action.

5.2.2 Mass to hold, to lift and to carry with hands

A product that is operated by holding, lifting and carrying with hands should have a mass suitable for these actions to be easily performed by the widest range of users, taking account of position of the action (e.g. height), direction of force and posture required to perform the action. The acceptable mass should be based on population strength data, including age differences, sex differences and the effects of physical limitations.

A product that has a mass that is difficult or impossible to hold, lift or carry should have a mechanical assisting device, such as a handle or a grip, for ease of action, or should be provided with other means of transportation.

NOTE 1 Data related to the acceptable mass for lifting with two hands and for carrying with one or two hands for male or female persons of different ages have been reported by HQL.[15][16] The data are useful for designing the mass of a whole product or a package that is lifted or carried by hand. See B.3.1 and B.3.2.

NOTE 2 Data related to the maximum strength for lifting a crate in a standing posture for male or female persons of different heights (tall, medium and short) and for different gripping types (side-gripping and bottom-gripping) has been provided by DIN 33411-5. Male persons exert higher strength than female persons do. The middle height condition is optimum for yielding lifting strength for both male and female persons. No significant difference is found between side-gripping and bottom-gripping. The data are useful for setting a limit for the mass of a product for lifting. See B.3.3.

NOTE 3 ISO 11228-1 defines 5 kg as a reference mass for the evaluation of lifting and lowering strength in non-occupational use for children and older people. It also describes 3 kg as a lower limit for applying the standard.

5.2.3 Strength (pushing or pulling with hands or feet)

A product that is operated by pushing or pulling with the hands or feet should be sufficiently strong to make these actions suitable and easy for the widest range of users, taking account of the direction of force, range of movement and posture required to perform these actions. The acceptable strength should be based on population data that include age differences, sex differences and the effects of physical limitations.

NOTE 1 Data related to the maximum strength for pushing or pulling with one or two hands for male and female persons of different ages have been reported by DTI[20] and TU Delft.[21] The strength for pushing and pulling is in the range of 100 N to 400 N for one hand and 100 N to 500 N for two hands, both depending on age. Pushing strength is greater than pulling strength in both cases. The data are useful for designing a door or a cart pushed or pulled by hand, for example. See B.3.4 and B.3.5.

NOTE 2 Data related to the maximum strength for pressing or lifting a bar and a pedal with the feet for male and female persons of different ages have been reported by DTI.[20] The strength is in the range of 50 N to 700 N for male persons and 50 N to 500 N for female persons, depending on age. The highest strength is found in the age range of 20 years to 40 years. Pressing strength on a bar is much higher than the lifting strength on a bar and a pedal. Male persons show higher strength than female persons do. Data are useful for designing brake pedals of pushchairs or trolleys, for example. See B.3.6.

5.3 Gripping, grasping, rotating, twisting, pushing or pulling (with fingers), pinching, sliding and touching

5.3.1 Shape and size of products, controls and control panels

A product, control or control panel that is operated by gripping, grasping, rotating, twisting, pushing or pulling (with fingers), pinching, sliding or touching should have a shape and a size suitable for these actions to be performed easily by the widest range of users, taking account of the direction of force, range of movement, posture required to perform the actions and dexterity.

Shapes or sizes that require high dexterity for operation should be avoided for people with dexterity limitations (e.g. caused by Parkinson's disease or rheumatism).

NOTE 1 Data for the maximum grip diameter measured anthropometrically for the circle made with the thumb and the forefinger for male and female persons of different ages have been reported by TU Delft.[21] The grip diameter measured are in ranges of 39 mm to 43 mm (male) and 36 mm to 39 mm (female), both showing a gradual decrease with age. These data can be used for the design of grip size for products such as rails, handles and umbrellas. See B.3.7.

NOTE 2 Grips of different diameters are in practical use in different design fields depending on the context of use. Table 1 presents data for some examples.

Table 1 — Grip diameters for handrails

Context of use	Diameter mm	Sources
Handrails in built environment (circular shape)	45 to 60	ISO 21542
Handrails in built environment (elliptical shape)	50 to 70 (width) 25 to 50 (depth)	ISO 21542
Handrails used for assistive products	25 to 45	ISO 17966
Rounded poles (in ergonomic experiments)	30 to 40	HQL[16]

NOTE 3 Data for steadiness of hand–eye coordination as related to dexterity for male and female persons of different ages have been reported by TU Delft.[21] The steadiness was measured using a task in which a thin needle was inserted into a hole without touching the hole edge. This hand–eye coordination gradually deteriorates with age, which means that dexterity decreases with age. The data are useful for designing pointing devices for computers and ticket inserting machines, for example. See B.3.8.

NOTE 4 The maximum angle of inward rotation (pronation) and outward rotation (supination) of the wrist for male and female persons of different ages have been reported by TU Delft.[21] Reduction of the movable range with age is found for outward rotation, with no significant change for inward rotation. The wrists of female persons are more flexible than male persons. Data are useful for designing, for example, a rotational knob, a key or a screwdriver. See B.3.9.

NOTE 5 Data for the diameter of a circular dial for ease of rotation with fingers for male and female persons of different ages have been reported by HQL.[18] Data show that a diameter of 20 mm to 25 mm is easily achievable for rotation with the fingers. The data are useful for designing circular dials of household appliances, for example. See B.3.10.

NOTE 6 Data for the preferred stroke length for ease of pushing a small button with the forefinger were reported by Kikuchi et al. for people of different ages.[22] Strokes in the range of 0,5 mm to 1,0 mm were most preferred by people of all ages, with a slight tendency that older people preferred a longer stroke than younger people. The data are useful for designing small push-buttons used for household appliances, for example. See B.3.11.

5.3.2 Strength (hands and fingers)

A product, a control or a control panel that is operated by gripping, grasping, rotating, twisting, pushing or pulling (with fingers), pinching, sliding and touching with hands or fingers should be sufficiently strong for these actions to be performed easily by the widest range of users, taking account of the position of the action (e.g. height), direction of force and posture required to perform the action. The acceptable strength should be based on population strength data that include age differences, sex differences and the effects of physical limitations. Consideration should be devoted to height for wheelchair users, in particular.

A product, a control or a control panel that is operated by the hands and fingers should be designed so that people with limitations of strength or of dexterity of hands or fingers (e.g. because of Parkinson's disease or rheumatism) are able to operate it.

NOTE 1 Data for maximum grip strength for male and female persons of different ages are available from scientific papers[23][24][25] and research project reports (TU Delft,[21] MEXT[26]). Male grip strength is in the range of 100 N to 550 N and female grip strength is in the range of 100 N to 350 N, depending on age. They respectively show the highest values at 20 years to 30 years of age, gradually decreasing with age thereafter. The data are useful for designing products that require squeezing with the hands, such as refuelling hoses and pliers. See B.3.12.

NOTE 2 Data for the maximum twisting strength of the wrist have been reported by NITE[27] and DTI[18] using circular knobs of 50 mm diameter (NITE) and of 40 mm diameter (DTI) for male and female persons of different ages. The necessary twisting strength is in the range of 3 Nm to 5 Nm for male adults and 2 Nm to 4 Nm for female adults, depending on the grip type and knob type. The strength increases with age from 2 years to 20 years until it reaches a plateau, which remains until 60 years of age. It then decreases. No significant difference was found between inward and outward rotation. The data are useful for designing doorknobs, keys and dials for household appliances, for example. See B.3.13.

NOTE 3 Data for the maximum twisting strength of the upper limbs have been reported by NITE.[27] The data were sampled from 38 male persons and 42 female persons who were 60 years to 73 years old. The maximum torque strength is about 5 Nm to 8 Nm for male persons and 3 Nm to 5 Nm for female persons. The necessary torque for inward rotation (pronation) is greater than that for outwards rotation (supination). The data are useful for designing large and heavy handles for household appliances, for example. See B.3.14.

NOTE 4 Data for the maximum torque with two hands for jar opening have been reported by DTI[19] and TU Delft[21] for male and female persons of different ages. The opening torque ranges from 3 Nm to 10 Nm for male adults and from 2 Nm to 6 Nm for female adults, depending on the jar diameter and the lid type. The typical ageing effect is a rather steep increase up to about 20 years, a plateau in adulthood and a gradual decrease with age thereafter. A significant effect is found for the jar diameter and the lid type, i.e. smooth or knurled. The data are directly useful for designing packages. See B.3.15.

NOTE 5 Data for the maximum pushing strength with a finger have been reported by DTI[19] and NITE[27] for male and female persons of difference age groups. The DTI data show strength to be in the range of 120 N to 180 N for male adults and 80 N to 130 N for female adults, whereas NITE data show the range as 40 N to 60 N for male adults and 30 N to 60 N for female adults. This difference depends on the measurement method employed: a force plate for DTI and a real push-button for NITE. No large difference is found between forward and downward pushing, but a significant difference exists between the forefinger and the thumb. The data are useful for designing push-buttons of various types used in home appliances. See B.3.16.

NOTE 6 Data for the maximum pulling strength with a finger have been reported by DTI for a practical case of pulling on a can ring pull.[20] The data were collected from male and female persons of different ages for two ring pull positions: horizontal and vertical to the top of the can (see Figure B.17). The pulling strength is 50 N to 150 N for male adults and 30 N to 100 N for female adults, reflecting the general ageing effect. The data are directly useful for designing the ring pull of a can. See B.3.17.