Requirements needed in European household appliance performance standards to improve ease of use of appliances by older and disabled people

FINAL REPORT

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Colette Nicolle (c.a.nicolle@lboro.ac.uk)
Martin C. Maguire
Laurence Clift

Loughborough Design School
Loughborough University

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Contents

1. Background

This report is the result of a research and testing project undertaken for ANEC, the European Consumer Voice in Standardisation, in response to their call for a proposal for project ANEC-ML-2010-0044. The aim was to perform a study into ergonomic data needed for European household appliance performance standards to improve the requirements for the ease of use of appliances by older and disabled people. Our objective would be to gather numerical data rather than general guidelines.

The contracting organisation is the Loughborough Design School, formerly known as the Ergonomics and Safety Research Institute (ESRI) at Loughborough University, UK. The Loughborough Design School was formed on 1st August 2010. This brought together the Department of Design and Technology, the Ergonomics and Safety Research Institute, and the Department of Ergonomics into a single entity (www.lboro.ac.uk/lds).

2. Introduction

According to the Trace Centre as highlighted in “The Overlooked Consumer” (Tim Noonan Consulting Pty Ltd, 2007):

1. **You cannot make a product absolutely accessible.** You *can* make it *more* accessible, but there will always be people who cannot use it.
2. **Therefore... There are no magic numbers.** . . . [*for the perfect universal design*]

Ergonomics can, however, help to arrive at some values for design attributes to make products more accessible. As emphasised by the Applied Ergonomics Handbook (1987), the positioning of a control will depend very much on its function; however, “it should also depend on the sex and age of the operators who are going to use it, because of differences in sizes of men and women, and of differences in strength between younger and older people.” Also to be considered is whether a person may be using a wheelchair or already working to the limits of their ability, but nevertheless needing and wanting to carry out everyday activities to maintain their independence and quality of life.

The project has worked to provide values for performance data to improve the ease of use of household appliances by older and disabled people. Such values can be used as “signposts” to accessibility – following them will help produce a fair compromise to include as many users as possible.

2.1 Building on CEN/ISO TR 22411

CEN/ISO TR 22411, prepared by Technical Committee ISO/TC 159 Ergonomics, presents ergonomics data and guidelines for applying ISO/IEC Guide 71 in addressing the needs of older persons and persons with disabilities in standards development. It provides ergonomics data and knowledge about human abilities (sensory, physical, cognitive) and guidance on the accessible design of products, services and environments.

In discussions with TC159, it was clear that the data in CEN/ISO TR 22411 has been extracted and referenced from a range of international and cultural sources, and therefore the international dimension will be represented. However, our work still attempted to access further international data by contacting experts in the field.

There is still difficulty in providing universal data values which can be easily used in design or standards development. In searching through current standards and technical reports, similar figures keep recurring. For example, dimensions of manual controls (Table 9 of CEN/ISO TR 22411), which come from ISO 9355-3, and classification of force/torque for manual controls (Table 10 of CEN/ISO TR 22411) are also the figures used in DIN Technical Report 124, Products in Design for All. Despite this repetition of recommendations, such data, as is included in CEN/ISO TR 22411, have not been contextualised. If data is not contextualised, well structured and task-based, it could possibly still be used by designers and standards bodies, but they may be unsure if it is appropriate for their application.

This contextualisation process has been started by TC59/WG11 (Performance of household appliances – Usability and Accessibility). TC59/WG11 has produced a first example (with respect to toasters) for an accessibility standard for household appliances. Drawing mainly from CEN/ISO TR 22411, certain assumptions may have been made and tradeoffs may be needed when applying the data to other household appliances. For example, the toaster document says that the force required for activation shall be greater than 7 Newtons and less than 17 Newtons, and also that characters on appliances shall have a height of at least 5 mm. Our remit was to check what a range of data sources say and to what extent these figures are transferable to other appliances, which may be viewed or used at different distances and by a range of people with different abilities. From these sources we were then able to select and define recommendations suitable within the household appliance context.

According to expert advice with regard to CEN/ISO TR 22411, it was suggested that generic data should be prepared first and distributed into the design fields as widely as possible. The contractors take the view that if recommendations are product specific, we would be setting in stone the kinds of controls that must be used on products, rather than encouraging, or at least enabling, innovation. The approach of the project therefore aims for generic requirements for performance standards for all household products and appliances, rather than being too specific for individual appliances. Although considered out of the scope of the current project, some specific data was however found or deduced from the literature, e.g. distinction between floor standing or movable/handheld appliances, and have been included for completeness.

This current study has therefore attempted to contextualise the data in CEN/ ISO TR 22411 to household appliances by following the method outlined below.

2.2 Structure of this report

The structure of the remainder of this report is as follows:

3. Method – the process of compiling the guidelines and recommendations.
4. Household Appliance Tasks, Controls and Displays. This section provides a high level task analysis of the types of tasks performed for a range of household appliances, with examples for each, and suggests the types of controls and displays found on such appliances.
5. Control Types for Specific Variables. This section provides some high level guidance on the type of control recommended for a range of variables.
6. Summary of Recommendations. This table summarises the recommended values needed by older and disabled people for the use of household appliances (where a recommendation could be made from available data).
7. Control Recommendations. All recommendations made for controls (width/diameter, height, distance between and operating force) have been put into this separate table for ease of use.
8. Summary of Recommendations for Further Research.
9. References. These have been grouped into the following categories:
   References from CEN/ISO TR 22411,
   Reports from (the former) ICE Ergonomics, Loughborough University,
   References from Loughborough Design School further literature review.

Appendices
Appendix 1: Control Literature. This table summarises the literature on controls from Appendix 3, to make it easier to compare one with the other.
Appendix 2: Relevant Anthropometric Datasets. Recommended values were compared with selected anthropometric data to validate and ensure there was no disagreement between them.
Appendix 3: Existing values and gaps – the full picture.
Appendix 3 has two annexes to provide extracts from relevant literature.

The final table (Appendix 3) has extracted the headings from CEN/ISO TR 22411, and added additional headings where these did not exist but were felt relevant for household appliances. The order of headings follows that in CEN/ISO TR 22411, although we would recommend these headings be re-structured for ease of use, not just for this research but for CEN/ISO TR 22411 as well.

The 2nd column of Appendix 3 contains data/values found in CEN/ISO TR 22411.

The 3rd column contains data/values from other guidelines/sources, with references. More general guidelines are also given here for completeness, and in order to specify where research may be needed. These recommendations for further research are summarised in Section 8. This column also makes reference to anthropometric datasets which were used to validate the selected values.

In the 4th column, recommendations are made for specific values under each topic heading, where possible and appropriate. The recommendations here are shown in the Summary Table of Recommendations (Section 6).

3. Method

A mixed-method approach has been used, incorporating a review of possible tasks, controls and displays used in household appliances, a comprehensive literature review, and discussions with experts, by email and within our own team. In detail the following steps were taken:

1. Gather thoughts and comments from experts following discussions and suggestions from ANEC project advisors.

2. Develop a generic list of the tasks where relevant information is needed with respect to household appliances: visual tasks, reaching tasks, etc.

3a. Identify a list of the main controls (e.g. knobs and push buttons) that are used to carry out such tasks. The list would include controls for devices coming under CENELEC/IEC TC59, in particular washing machines, dishwashers, ovens, refrigerators, microwave ovens, irons and small kitchen appliances. The list might contain some variations of each control type such as a knob with an easy grip element but this would be limited.

3b. In a similar manner, identify the different types of displayed information that are found on household appliances.

4. Using the headings from CEN/ISO TR 22411, extract objective data/values in CEN/ISO TR 22411 that are relevant for household appliances.

5. Using the same headings, provide further data from other guidelines/sources, e.g. recommended control sizes. This will also include a review of the product evaluations from earlier days at ICE Ergonomics at Loughborough University, and a range of other documents (see References).

6. Compare and contrast data from the sources above, and discuss findings based on literature and expert knowledge.

7. Make recommendations for requirements needed in European household appliance performance standards to improve the ease of use of appliances by older and disabled people

8. Validate recommendations with selected anthropometric data and expert advice to see if these support or conflict with the recommendations. Anthropometric data from Steenbekkers and van Beijsterveldt (1998) have been chosen as a first step, as their data have been applied to design-relevant characteristics. Data have been extracted that can apply to household appliances, and then supplemented by additional anthropometric datasets where possible.

9. Where sufficient data are not available to make a recommendation on a particular variable, or where the data conflict, further research may be recommended.

These recommendations are therefore the considered view of the contractor following a critical appraisal of the literature, by:

- Comparing, contrasting and discussing the findings from relevant sources, and then
- Going back to selected anthropometric data and expert advice to see if these support or conflict with our recommended values.

A range of values is often given, rather than specifying one value, in order to provide the envelope in which the design should fit, without being overly restrictive. Acceptable ranges often are very wide – for example, the range of human hearing or vision capabilities. Whilst it might be appropriate in some cases to use one value or a narrower band, it is unnecessarily restrictive to require this where it is not necessary. A wide range merely states that the limits are clearly defined but there are many different acceptable values within that range, offering a wider choice of design possibilities.

Certain assumptions were made in conducting this study:

- Safety issues were not to be considered explicitly.

- No requirement for the use of assistive technologies.

- Although it is known that manual dexterity will deteriorate with cold, and vision with poor lighting, the requirements could only assume appropriate/comfortable levels of lighting and temperature.

4. Household appliance tasks, controls and displays

This section provides a high level task analysis of the types of tasks performed for a range of household appliances, with examples for each, and suggests the types of controls and displays found on such appliances.

Task type	**Example**	**Control or display types possible**
1 Turn product on/off (without starting or stopping a process)	Turn on power to an appliance	• Switch (on plug point)
2 Review list of possible control options	Choose washing machine programme	• Menu list (text or icons)
3 Choose a control option (action may also start a process)	Select washing machine programme Select oven operation (oven, oven + fan, grill, both together)	• Knob (selection points) – may be latched (see definitions below) • Slider (selection points) • Push button (one per option)
4 Set a value (discrete scale)	Timer on microwave Timer on cooker	• Knob (with notches at value points) • Push button (setting buttons with display)
5 Set a value – continuous scale (action may also start a process)	Heat level on oven Heat level on iron Thermostat level on boiler	• Knob (may be latched) • Slider
6 Start/stop a process	Set kettle to boil Set toaster going Stop toast burning Ignite a gas flame	• Knob • Switch • Push button (may have light or latch) • Slider (may have latch)
7 Control a flow	Control gas flame on hob	• Knob (continuous selection) • Slider (continuous selection)

8 Perform instantaneous action	Water spray on iron Ignite gas hob	• Push button
9 Check operation in progress	Kettle started boiling Oven still cooking	• Simple LED light indicator (in addition to any auditory feedback)
10 Check progress through an operation	Check if dishwasher or washing machine cycle near completion	• LED numeric display shows progress (time left) • Knob position (In addition to any auditory feedback)
11 Be alerted that process finished	Microwave cooking finished Washing machine cycle finished	• Auditory warning • Simple LED indicator goes off • Flashing light • LED numeric display value reaches zero
12 Closing/opening an appliance door	Door of washing machine Door of tumble drier	• Catch which requires handle to be lifted and pulled to open door.
13 Testing alarm	Testing smoke, CO2 or water overflow alarm	• Button on alarm device
14 Turning off alarm	Turning off CO2 or water overflow alarm	• Button on alarm device. (Note: Normally device only turns off when hazard stops being detected i.e. smoke clears.)

Figure 1: Tasks, Controls and Displays

Notes:

A **push button** returns to its ‘out’ position after being pressed.

A **latch button or latch knob** stays ‘in’ after pressing and is released when pressed again.

A **latch slider** has two positions ‘released’ and ‘latched’. When it is slid to the latched position it stays in this position until the process is finished when it automatically releases. Alternatively it may be released by an interrupt button or by pushing the slider out of the latched position. This control is often used with a toaster appliance as the process of moving the slider down to the latched position also lowers the base that the toast is resting on into the toaster.

An **LED numeric display** (light emitting diode) shows numeric values (e.g. time left or program number).

A **simple LED** indicator is a single light that is either on or off.
LED may be in one of a range of colours e.g. red, green, yellow, and appear bright against a black background. In future, appliances may have small black and white or colour LCD (liquid crystal display) equivalent to that on a portable games console or mobile phone.

5. Control types for specific variables

Figure 2 below provides some high level guidance on the type of control recommended for a range of variables, drawn together from previous studies at the Loughborough Design School. For large force application, there are no controls suitable, as hand levers etc. are unlikely to be required for household appliances. (Please note that the contractors make a distinction between a hand lever and a lever on a toaster, which would be considered a slider or latch slider.) Hand levers may nevertheless be an appropriate solution for some controls, for example, gross body actions are utilised to operate a salad spinner. This avenue could be explored by designers to apply to other operations.

To enable a better feel for the types of controls and common dimensions being used in today's household appliances, a quick survey was also undertaken of a range of appliances. This provided a 'reality check' and further contextualisation of values found in the literature in order to make a more informed choice where values conflicted. A selection of these photos is given below in Figure 3.

The list of control types is not meant to be comprehensive. For example, buttons or sliders (a linear control) could be latched, or may be used with an indicator light to give a visual cue of position. Controls with lights to indicate status are not suitable for those with visual impairment, but latched buttons would indicate status in both tactile and visual terms. For a control to be free from inadvertent action is context dependant and is likely to be a relative term, unless further protective solutions are also in use, such as latch covers or interlocks. It is unlikely that we can increase usability whilst eliminating inadvertent action completely.

The list, therefore, suggests the range of variables that should be considered and ways of accommodating them. This section does not suggest a particular type of control for an individual appliance, but only for a particular variable, such as the types of controls to consider when quick operation is required.

Other types of controls may indeed be used, e.g. remote controls or multi-mode controls (a single control that regulates all functions), all of which can be challenging for, or simply not wanted by, older and disabled people. It is suggested in Section 8 that further investigation be conducted on contact area and feedback for touchscreen and membrane buttons or objects, as well as the upcoming area of remote control of household appliances. There are likely to be other control mechanisms and future developments that require consideration, but these would be outside the scope of the current research project.

Key - (clear = poor, half-filled = acceptable, filled = good)

Variable	Push button	Toggle	Rocker	Slide switch	Thumb wheel	Finger knob	Finger lever
Large force application	○	○	○	○	○	○	○
Quick operation	●	●	●	◑	○	◑	◑
Small space requirement	●	●	●	●	●	◑	◑
Free from inadvertent action	○	○	◑	◑	○	●	○
Visual cue of position	○	●	◑	●	○	◑	●
Tactile cue of position	○	●	●	●	○	○	◑
Shape coding possibility	◑	○	○	○	○	●	●
Integral legends or symbols	●	○	●	●	○	○	○
Colour coding possible	●	●	●	●	●	●	●
Integral illumination	●	○	◑	○	○	○	○
Weather proofing	◑	○	○	○	○	●	●
Oil proofing	●	○	◑	○	○	●	●
Ease of operation with gloves	●	●	◑	○	○	◑	◑
Check reading array of like controls	○	●	◑	●	○	○	●
Simultaneous use of two like controls	●	●	●	●	◑	◑	●

Figure 2: Control types for specific variables

Latched Rotary knobs & push buttons on cooker

Bar knobs on cooker hob

Large bar knob for dialling wash program

Rotary knob and push buttons with LED indicators

Iron with rotary knob & steam control slider

Microwave with membrane buttons

Toaster with push buttons and bar knob

Latch slider with knob and push buttons

Figure 3: Selection of kitchen appliance controls used for comparison with guidelines

6. Summary of recommendations

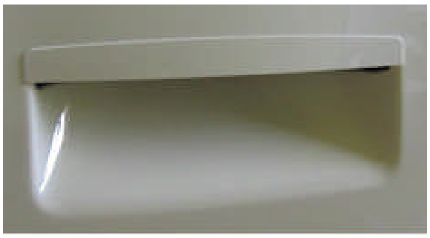
This table summarises the recommended values needed by older and disabled people for the use of household appliances (where a recommendation could be made from available data). All recommendations made for controls (width/diameter, height, distance between and operating force) have been put into a separate table for ease of use (Section 7).

Factor relevant to household appliances	
Tactile markings	NOTES: Braille is not being considered in this document. Using the upper end of the range of recommended dimensions will make it easier for people with reduced sensitivity to recognise dots, bars or symbols. Height of tactile structure: Between 0.8 mm-2.0 mm. Diameter of Tactile dot: 1.5-2.0 mm Tactile bar: 0.8-2.0 mm Length of tactile bar: 5-10 times the width. Different information can be conveyed by different elevations, which should vary by at least 0.8 mm and significantly more than that for important information. Dimensions of tactile symbol shall be adjusted to size of associated control, not to the size of the product. Distance between tactile letters, symbols or markings should be >5 mm.

Auditory signals	Sound levels should be adjustable to meet the needs of the user. Assuming a relatively quiet home environment, frequency of sound signals should be between 300 Hz-2000 Hz. Avoid frequencies above 3000 Hz. To accommodate background noise and diverse abilities and ages, use alternate frequencies for different signal information. Intensity should be between 55 dB-65 dB (assuming quiet surroundings in a household). Warnings at least 60-65 dB at ear of listener.
Visual information *and visibility of controls* *(visibility of controls not a heading in CEN/ ISO TR 22411)*	Field of vision: optimum ±15^{o} to the horizontal is recommended for primary controls in something like a workstation. However, for most controls for household appliances ±60^{o} would be an acceptable field of vision for viewing controls, especially since this represents ocular movement and hence is only significant if the person cannot move their head. Standing eye height: 1349-1729 mm Note: Recommendation of 1349 mm is based on UK females 65+ (which accommodates Steenbekker and van Beijsterveldt's females 80+) to 1729 mm, the 95th percentile UK male aged 18-64, who may be the tallest user in a mixed capability household. Avoid flash rates between 3-70 Hz, as this is where there is risk of epileptogenic effects (the highest risk is between 15 and 20 Hz). To avoid screen flicker, use a minimum of 80 Hz refresh rate.

Colour *and coding* *(coding not a heading in CEN/ISO TR 22411)*	Shape or surface coding permit easy and visual tactile identification. In size coding, control tasks should be given the same dimensions. There should be a maximum of three sizes with a minimum difference of 20% between sizes. On colour displays, red/green and blue/yellow combinations should not be used. White or yellow type on black or a dark colour is more legible.

Font size and Contrast	Font style is not covered in these recommendations, but it is recognised that this will affect overall size of the characters and therefore the values below are general guidelines. However, based on human factors knowledge, we can recommend that the font should be sans serif, and that upper and lower case labelling should be used. Glare, depending on the materials used, location of the appliance and position of the font on the appliance surface may all affect readability and therefore should also be considered for individual appliances. Contrast between background and text, symbols or markings, on both controls and displays, should be at least 70%. Letter size should be at least 12 pt, when viewing up to ½ metre away, at 70% contrast. Larger text size than 12 pt should be used if less than 70% contrast. However, to be more inclusive, use a distance of 1 metre, since a number of older people do not have their eyes tested or don't have their glasses in the kitchen. Therefore the following more precise values are recommended (where font style used followed British Standard BS 4274-1:2003): If 70% contrast is used and size of font is 4.7 mm x-height, research suggests that approximately 90% of people over the age of 65 would be able to read it at 1 metre (provided the lighting is at least 150 lux – Guidelines for artificial lighting in the kitchen are 250-500 lux). If a product is e.g. hand-held (at 40 cm), then the size of font could go down to 2.6 mm x-height and still include the same number of people, as long as the contrast is still at 70%. Although the larger font size will always be recommended, the characteristics of the product (e.g. its size) will determine the reasonable adjustments or modifications that can be made. Safety issue: Recommendations should assume arm's length distance (e.g. reading markings up close to a gas burner could pose safety hazards!) **Note**: Although some references (e.g. DIN TR 124) say 12 pt = 3 mm, by our measurement 12 pt = 2.2 mm x-height (that is, height of lower case x). 3 mm x-height is closer to 14 point.

Handles and catches *(not a heading in CEN/ ISO TR 22411)*	Handle should be obvious and not blend in with the appliance. Ideally a convenient height for handles and catches would be between 937-1156 mm (5^{th}-95^{th} percentile UK elbow height). To give the 95^{th} percentile ample space to use a hook grip or recessed handle (which you might find on a typical detergent tray for a dishwasher or washing machine) the dimensions should be: 51 mm deep, with a 51 mm lip, 89 mm wide This handle design does not require knuckle width (given below), but only adequate finger clearance for all four fingers, if needed. Therefore, even though most users will not need 89 mm, it will accommodate arthritic hands.  For a cylinder handle the dimensions should be:  Length: ≥100 mm Depth: ≥60 mm Handle circumference: ≥50 ≤110 mm UK 95^{th} percentile adult width at knuckles = 93 mm (Humanscale). According to Older Adultdata, 65-80 year old male 95^{th} percentile knuckle width = 90 mm. Therefore, these values will be accommodated by the dimensions above for the cylinder handle.

Doors *(Not a heading in CEN/ ISO TR 22411)*	This section applies to the height to the top of the appliance door, but the important figures are the reach ranges, which will determine access to the handle or control. See "Reach ranges and location and layout of controls." Height to the top of the appliance door should be at elbow height, 937-1156 mm from floor (which is the 5th-95th percentile UK elbow height). This assumes the user doesn't want to see through the glass of for example an oven door, in which case an adjustment in this value may need to be made. For front-loaded drum of washing machine: >300 mm diameter opening. For top-loaded drum opening size, length ≥250 mm, width ≥250 mm. Opening angle: >100^{o} but a wider aperture opening fully to 180^{o} is strongly recommended. Opening/closing the door (e.g. to a washing machine, tumble drier, microwave): Torque: 0.7 Nm – 1.2 Nm Force: <20 N Push button opening (eg to open door for washing machine): Diameter of push button: 13 – 26 mm Force: Mechanical buttons 2 – 10 N However, force for buttons operated by index finger should take more conservative value from Humanscale: 1.1-5.6 N, so the lower force is to be recommended.

Dimensions of manual controls	See summary table of recommendations for controls (Section 7), including Width or Diameter, Height, Distance between, and Operating Force for Push Button Rotary Knob Rotary Knob with bar, tail or pointer grip Slider switch Rocker switch
Force/torque for manual controls	See summary table of recommendations for controls (Section 7).

Reach ranges and Location and layout of controls	Comfortable reach (which would also include wheelchair users): 937-1550 mm from floor. However, using a more conservative value, we could suggest the following: Maximum upper reach for controls = 1200 mm above the floor. Lowest forward reach for any control 660 mm above the floor. (However, see recommendation for further research in Section 8.) General operating height = 850 mm above the floor. This height takes into account standing and sitting, including those in wheelchairs. Although not optimum, it is an acceptable compromise. Reach ranges above are still valid when requiring a lateral approach, as long as obstructions on the floor do not exceed a depth of 255 mm.

7. Control recommendations

Based on the summary of literature on controls in Appendix 1, this table summarises the recommended values needed by older and disabled people for the use of household appliances (where a recommendation could be made from available data).

Control type	Sub-category or qualifier	Width or diameter	Height	Distance between	Operating force
Push button		13 – 26 mm	2 – 5 mm of height or travel	For buttons on a vertical surface: ≥10 mm For buttons on a horizontal surface: ≥7 mm	Mechanical buttons 2 – 10 N Membrane buttons 2 – 5 N For keys (similar to a keypad): 0.5 – 1 N
Distance between: For vertical buttons, there is more chance of clipping the button above or below the one you are selecting, and so more clearance is recommended. Although we have not recommended top upper limits for distance between in order to allow for grouping, the following guidance is also available from Humanscale, but these are probably for industrial applications and hence larger than necessary (see General Notes at end of this table): For 1 finger operation, spacing = 51 mm. For 1 finger sequential = 25 mm. Several fingers 13 mm. For operating force, there is less chance of inadvertent action with mechanical buttons.					

Control type	Sub-category or qualifier	Width or diameter	Height	Distance between	Operating force
Rotary knob	Floor standing, e.g. cooker	34 – 50 mm	13 – 28 mm	25-51 mm	.02 – 0.10 Nm
	Smaller appliances (using a finger or pinch grip)	15 – 25 mm	Minimum: 13 mm	25-51 mm	.02 - .05 Nm (restricting to lower value, trading off size with force)

If the adjustment required of the knob is critical (e.g. radio tuning), a knob of (at least) 50 mm diameter should be used, because there is a limit to a person's sensitivity of movement, and a larger knob allows bigger movements at the end of the scale of the knob for fine adjustments.

For floor-standing appliances, use the higher spacing values above, and for smaller appliances the lower values are acceptable. Greater distances are allowed if knobs are not part of a group. Humanscale also recommends a minimum of 51 mm spacing between anything that needs to be gripped, although clearances are probably for industrial applications, hence larger than necessary (see General Notes at end of this table). However, these larger clearances may still be more appropriate for arthritic fingers.

Note that 4 year olds can generate 1 Nm so can operate low torque knobs (all sizes).

Control type	**Sub-category or qualifier**	**Width or diameter**	**Height**	**Distance between**	**Operating force**
Rotary knob: *Bar, tail or pointer grip dimensions*	Floor standing, e.g. cooker	Length: 25 – 60 mm Width 4 – 12 mm	10 - 28 mm		<2.5 Nm
Bar, tail or pointer grip dimensions	Smaller appliances (using a finger or pinch grip)	Length: ≥25 mm Width 4 – 12 mm	10 - 28 mm		<2.5 Nm

Rotary knobs with small dimensions are not appropriate design solutions for users with limited grip strength or dexterity and should be avoided wherever possible. In those instances where this type of control is essential or unavoidable, then the dimensions above should be adhered to.

In evaluation trials of cookers, it was recommended that a ridge should be placed at the twelve o'clock position as an aid to grip purchase and control setting indication. Large ridges which may precipitate interference must be avoided.

Control type	**Sub-category or qualifier**	**Width or diameter**	**Height**	**Distance between**	**Operating force**
Slider switch	(ideally should be concave)	>15 mm	5-19 mm		1 – 10 Nm
Rocker switch		≥ 9 mm	Half length: 10-15 mm		2 – 8 Nm

General Notes: These recommendations have been validated by guidance from Humanscale as optimum values, with the exception of the clearance between controls – See Appendix 2. Clearances in Humanscale are probably for industrial applications, and hence they would be larger. However, Humanscale was not solely intended for industrial applications and whilst the button recommendations may be suitable for industrial use, the good practice embodied only serves to raise the inclusivity of the design of domestic equipment using this data.

Some concern exists over the similar physical capabilities of young children and weaker older adults. Due to the similarity in torque and other forces that can be applied, then inclusive designs may be accessible to young children or the function may be operated unintentionally by stronger individuals. As an example, for torque values children up to 4 years can exert approximately 1 Nm on most sizes of rotary control. Weaker female users (77 years) can typically exert between 1.5 Nm (25 mm grip) to 4 Nm (115 mm grip). Best practice would suggest that rotary controls should be operable at these lower values, but that inadvertent use or access by children is prohibited by the use of cognitive or system means such as using more than one action to operate the control or having to operate a similarly low demand interlock.

8. Summary of recommendations for further research

Factor relevant to household appliances	
Position of information	Conduct user trials to relate viewing angle to users' height and reaches, without being design restrictive.
Location and layout of controls	There would be value in identifying primary, secondary and tertiary controls by criticality of function and frequency of use. The recommendation would then be to require that the most important (primary) controls are located within the comfortable reach of the majority of the population (5^{th} % woman to 95^{th} % man). It is pointless making primary controls ideal for very small users only, since large (tall, obese) people will struggle. Small people can reach up a bit, and tall people down a bit. The overlap would be the zone for placement (depending on population). Secondary and tertiary controls could then be located at less critical locations.
Font size	Since the Elton and Nicolle study included only 38 people over the age of 65 (mean age=74 years, SD=6.1), it would be useful to further validate the proposed values with a range of older and disabled users and household appliances.
Ease of handling	Research is needed to sort out recommendations for strength requirement, in particular with older users, considering differences between something like a vacuum cleaner we carry upstairs to lifting a full kettle, etc.
Handles and catches *(Not a heading in CEN/ ISO TR 22411)*	There is data in Humanscale for handle types – this data could be checked against the dimensions in the original drawings in the reference ELS 2003-3 to clarify some values.
Dimensions of manual controls	Further research is recommended on contact area and feedback for touchscreen and membrane buttons or objects. Also remote control of household appliances could be an upcoming area to investigate.
Knee and toe clearance	Knee and toe clearance needs some practical testing, since users tend to adopt coping strategies and postures (e.g. approaching from the side).
Reach ranges	Lower forward reach of 360 mm (given in CEN/ISO TR 22411) requires full mobility. 660 mm would be a good starting point, and lower values towards a minimum of 470 mm would need further research.
General recommendation	Confirm the proposed values by panel testing them with a range of older and disabled users and various floor-standing and hand-held household appliances. Loughborough Design School has suggested one or more of the recommendations as ergonomics student projects. ANEC and TC 122 will be kept informed.

General recommendation	A task analysis for a variety of individual household appliances would be a useful next step before undertaking further research to recommend more specific values for each type of product.

9. Dissemination and use of results

9.1 17th Plenary Meeting of CEN TC 122 Ergonomics

The preliminary study results were presented at the October CEN TC 122 “Ergonomics” meeting in Bruges (12-13 October 2010), where they were welcomed by the members. The participants felt the results would be of great interest to CEN/ISO TR 22411, giving more confidence to standards bodies and designers by providing data that is task-based and contextualised, in this case for household appliances.

It is important that ANEC’s research is disseminated to ISO/TC 159, as well as CEN/TC 122, and since contacts are already in place, this will be easily done. It was also suggested that ANEC combine this research with the collection of data on the inconveniences of older persons and persons with disabilities conducted by Ken Sagawa of ISO/TC 159, as this would give added value to both studies. In addition, the method used in this research would be very useful to feed into process standards as a guide to how to use Guide 71 and CEN/ISO TR 22411 for a range of application areas. However, it was pointed out that we may benefit from a closer link to ISO/TC 159, since CEN/TC 122 does not have a working group on Accessibility.

These points led to the following Resolutions by CEN/TC 122:

RESOLUTION 358: Thanks to ANEC.
CEN/TC 122 thanks Colette Nicolle for the presentation of the ANEC study and asks her to confirm with ANEC when they can provide the final report of the study for distribution.

RESOLUTION 359: Liaison between ANEC and ISO/TC 159.
CEN/TC 122 asks the ISO/TC 159, SC 4 and SC 5 to consider a liaison with ANEC due to the fact that accessibility work is done in these committees.

9.2 Next steps

9.2.1 Use of Results and the Standardisation process

It is suggested that the results from this research feed into the European/international standards process for the performance of household electrical appliances as covered by CENELEC/IEC TC59 and also IEC TC 59 Working Group 11. The report should also be circulated to Dr. Ken Sagawa, Chair of ISO TC 159, Working Group 2 Accessibility, so that the results can be considered for inclusion in future editions of CEN/ISO TR 22411.

The Contractors also suggest that, whilst guidance is useful to manufacturers, controls (and particularly controls for compromised users) will always require expert interpretation. Usability experts or professional designers should be used to filter design recommendations in order to optimise particular applications. In the absence of manufacturers using such services, basic guidelines will help, but adherence to such guidelines does not guarantee a high quality product in terms of usability.

9.2.2 Student Project Follow-up

One of the general recommendations emerging from this R&T project was to confirm the proposed values by panel testing them with a range of older and disabled users and various floor-standing and hand-held household appliances. A project is being conducted by an Ergonomics student in the Loughborough Design School at Loughborough University, under the supervision of Colette Nicolle, ANEC's Design for All representative in CEN TC 122 Ergonomics.

The project will be analysing different requirements needed of European household appliances predominantly within the kitchen environment. Following her own literature review, a requirement of the University, the student will be carrying out a focus group, individual interviews and observations with older people to highlight particular problems with their own household appliances. Based on the users' comments on good or poor design (qualitative data), measurements of those controls, etc. (quantitative data) and whether they are easy or difficult to use, the values will be compared with a selection of the recommended values proposed by the Loughborough Design School R&T project to assess their suitability across different users and appliances.

The project thesis will be submitted to Loughborough University in May 2011, and a summary will be made available to ANEC, CEN TC 122 and ISO TC 159 Ergonomics.

9.2.3 Publications

The Contractors are keen to disseminate this research more widely through a journal article, most likely to *Ergonomics* or *Applied Ergonomics*, as well as a contribution to a relevant conference. These papers could also draw from the results of the student's user-centred project and any further comment received from the previous dissemination process.

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Appendix 1: Control literature

This table summarises the literature on controls from Appendix 3, to make it easier to compare one with the other.

Control type	Sub-category or qualifier	Width or diameter	Height	Distance between	Operating force	Reference
Push button		≥7mm	≥7mm		≤7 N	TR22411 2008
				20 mm min 50 mm optimum		Salvendy 1986, from Grandjean
		13 - 26mm				ESRI AR218, 1980
	For no error	>=20mm 10-20mm (1 error)		>10mm (0 error) 7-10mm (1 error)	Mechanical ≤10N ≥2N Membrane ≤5N ≥2N	ELS2003-3
		> 15mm			1 - 8N	Salvendy 1986
		13-25 mm	1-6 mm	19 mm	1.1-5.6 N	Humanscale 1974
				Spacing for 1 finger operation = 51mm 1 finger sequential =25mm Several fingers = 13mm		Humanscale 1974
Keys		12 - 15mm	2 - 5mm of travel	18 - 20mm	0.24-1.5N	Vanderheid-en 1992
					0.5-1N	RNIB 2007
		13 mm	1-6 mm	19 mm	0.5-1.6 N	Humanscale 1974
Rotary knob	General	51 - 102mm	13 - 26mm			ESRI AR218, 1980
			13mm			Galer, Applied Ergonomics Handbook, 1987
		35 - 50mm	18 - 28mm	>25mm	0.02-0.1Nm	ELS2003-3
	Cooker	34 - 41mm				ESRI AR418 1985
	Arthritis sufferers	50mm				ESRI AR418 1985

Control type	**Sub-category or qualifier**	**Width or diameter**	**Height**	**Distance between**	**Operating force**	**Reference**
	Able-bodied	25 - 85mm				ESRI AR418 1985
					.02-.1 Nm (for cylinder knob)	ELS2003-3
	Fingertip	10-100mm	12.5-25mm		If <63.5mm <.2 Nm	Galer 1987
	Adjustment critical	>50mm				Galer 1987
	If <19mm knurled for increased grip					Galer 1987
	Finger grip *(or pinch grip)*	15 - 25mm		.	.02 - .05Nm	Salvendy 1986
		7 - 80mm	7-80mm			TR22411 2008
		13-51 mm	16-25 mm	51 mm	0.02 N	Humanscale 1974
	Hand grip	25 - 100mm			0.3 - 0.7Nm	Salvendy 1986
		15 - 60mm	60-100mm			TR22411 2008
	Bar, tail or pointer grip *Bar dimensions*	Length: 50 ± 10mm Width 8 ± 4mm	23 ± 5mm		.1-.2 NM	ELS2003-3
		Length >25 mm Width <25mm	12.5-75mm		2.5 Nm	Galer 1987
	Moving scale	25-100 mm	12.5-75mm			Galer 1987
Width of grip 6-13 mm	Pointer grip	25-51 mm	6-19 mm	51 mm	3.3 Nm	Humanscale 1974

Control type	**Sub-category or qualifier**	**Width or diameter**	**Height**	**Distance between**	**Operating force**	**Reference**
	Rotary selector *(pointer front, flat at rear)*	Length: 30 - 70mm Width: 10 - 25mm	>=20mm		0.1- 0.3Nm: 30mm long. 0.3- 0.6Nm: >30mm long	Salvendy 1986
	Both knob and rotary selector switch			25 mm min 50 mm optimum		Salvendy 1986 from Grandjean
Not recom-mended	Small finger	>5 mm	> 13 mm	--	--	Humanscale
Slider switch		>= 20mm	>= 20mm			TR22411 2008
		Length: >15mm Width >15mm			1 - 10Nm	Salvendy 1986
		5-25 mm	5-19 mm	--	--	Humanscale 1974
Thumbwheel		> 0.8mm			0.5 - 5Nm	Salvendy 1986
Rocker switch		> 10mm	Half length: 15mm		2 - 8Nm	Salvendy 1986
		5-33 mm	Length 13-64 mm	--	--	Humanscale 1974
Toggle switch				25 mm min 50 mm optimum		Salvendy 1986 from Grandjean
		3-5 mm	13-25 mm	51 mm	1.1-4.4 N	Humanscale 1974
General	Blind user	Increase at least 9.5mm	Increase at least .8mm			

Appendix 2: Relevant anthropometric datasets

Recommended values were compared with selected anthropometric data to validate and ensure there was no disagreement between them. Anthropometric data from Steenbekkers and van Beijsterveldt (1998) have been chosen as a first step, as their data have been applied to design-relevant characteristics. Their data and notes have been extracted if they apply to household appliances, and we have included our own notes *in italics* if appropriate. These data have then been supplemented by additional anthropometric datasets where possible.

Ideally, where robust data exist, 1st to 99th percentile population data should be used to establish design criteria, as this excludes the minimum of the population. However, there are inevitably costs associated with this and in many cases these can outweigh the benefits, with the most prominent exception being safety critical applications such as harnesses, protective equipment, etc. For this reason 5th to 95th percentile values are typically used as the basis for design conventions (as cited in Older Adultdata, Adultdata, etc.) and represent an industry accepted range of inclusion. However, there is a possibility that the portion of the population excluded in this way could contain a disproportionate number of disabled or elderly people, e.g. the weakest or those with the least reach.

The solution would be to use datasets that are specific to older and disabled people but most of these are much smaller and arguably less robust than those for the general population. Using extensive percentile ranges for these datasets is likely to be error prone and to significantly skew the resultant values. Designing to the upper and lower extremities of the data for elderly and disabled populations (1st to 99th), where they are available, may well start to exclude other members of the population who also need to use consumer products.

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(Even though a 1974 source, Humanscale is still relevant since bony, rather than fleshy dimensions, have not changed significantly in datasets over time.)

Open Ergonomics (2008) PeopleSize
(Adults aged 18-64 have relevance since recommendations are meant to be inclusive so extending ranges to include older people must not exclude the main populations. Accordingly some maximum dimensions must be drawn from the ‘normal’.)

Pheasant, S. (2006) Bodyspace: Anthropometry, ergonomics and design of work, (second edition), London; Taylor and Francis. Specifically from the following sections (because other tables with an international dimension do not explicitly cover the older population):
OPCS: The survey from the Office of Population Censuses and Surveys (OPCS) was conducted in 1981.
ICE Ergonomics survey of residents of care homes was conducted in 1983.

Smith, S., Norris, B. and Peebles, L. (2000). Older Adultdata, the handbook of measurements and capabilities of the older adult. London: Department of Trade and Industry. ISBN 0/9522571/57.
(Please note that Older Adultdata is a compilation and meta-analysis from various sources, and therefore original sources are consulted. Peoplesize is embedded in Older Adultdata and is a suitable alternative source – both are data compilations.)

Steenbekkers LPA and van Beijsterveldt CEM, eds. (1998). Design relevant characteristics of ageing users, Delft University of Technology.

5 Eye height sitting (cm)

Steenbekkers and van Beijsterveldt

Age - men/women	P_5	**Mean**	P_{95}
65-69	70.3	76.8	83.4
70-74	70.3	76	82.3
75-79	68.5	75.2	82.1
80+	65.2	73.7	79.9

PeopleSize

	P_5	**Mean**	P_{95}
UK adults, age 18-64	66.0	73.2	85.0

Pheasant (male)

Age - men	P_5	**Mean**	P_{95}
65-80 (OPCS)	70.5	76.0	81.5
'Elderly' (ICE)	67.5	74.0	80.5

Pheasant (female)

Age - women	P_5	**Mean**	P_{95}
65-80 (OPCS)	64.5	71.0	77.0
'Elderly' (ICE)	61.0	68.5	75.5

7 Frontal grip reach, seated (cm)
Smaller grip reach should be reference point, taller people can bend their arms.
Steenbekkers and van Beijsterveldt

Age - women	P_5	**Mean**	P_{95}
65-69	63.8		
70-74	62.3		
75-79	61.6		
80+	63.2		

PeopleSize

	P_5	**Mean**	P_{95}
UK adults, age 18-64	64.9	72.0	79.2

Pheasant (male) – distance from acromion to centre of object gripped in the hand with the elbow and wrist.

Age - men	P_5	**Mean**	P_{95}
65-80 (OPCS)	59.5	64.5	69.5
'Elderly' (ICE)	57.0	62.5	68.5

Pheasant (female)

Age - women	P_5	**Mean**	P_{95}
65-80 (OPCS)	54.0	59.0	63.5
'Elderly' (ICE)	51.0	56.5	62.0

20 Hand breadth (without thumb) (cm)
For grips or handles. The broadest (P_{95}) hand should be taken as reference

Steenbekkers and van Beijsterveldt

Age - men	P_5	**Mean**	P_{95}
65-69			9.6
70-74			9.7
75-79			9.8
80+			9.6

PeopleSize

	P_5	**Mean**	P_{95}
UK adults, age 18-64	7.2	8.2	9.3

Pheasant (standard population)

Age - men	**P_5**	**Mean**	**P_{95}**
male			9.5
female			8.3

21 Thumb breadth (cm)
When determining diameter of knobs or push buttons, according to Steenbekkers and van Beijsterveldt, this value is seldom critical and such a diameter depends more on available space. *Comment: Strategy for coping with impaired dexterity is independent of breadth of thumb. People will choose the strongest and least painful action to operate a control, but this will be related to their own digits. The breadth of that digit, in terms of the interaction with the control, remains seldom critical.*

Steenbekkers and van Beijsterveldt

Age - men/women	**P_5**	**Mean**	**P_{95}**
65-69	1.9	2.3	2.6
70-74	2	2.3	2.6
75-79	2	2.3	2.7
80+	1.9	2.3	2.7

PeopleSize

	P_5	**Mean**	**P_{95}**
UK adults, age 18-64	1.8	2.1	2.5

Pheasant (standard population)

Age - men	**P_5**	**Mean**	**P_{95}**
male	1.9	2.2	2.6
female	1.7	1.9	2.1

22 Forefinger tip breadth (cm)
Elderly users prefer good visibility of the knob (*and its label*) including when the fingertip is on it. Therefore, place icon or label above knob rather than on or underneath it. This gives an indication of the breadth of controls that have to be touched by the fingers.

Steenbekkers and van Beijsterveldt

Age - men/women	**P_5**	**Mean**	**P_{95}**
65-69	1.5	1.8	2.1
70-74	1.5	1.8	2.1
75-79	1.5	1.8	2.1
80+	1.5	1.8	2.0

Steenbekkers and van Beijsterveldt

Age - men	P_5	Mean	P_{95}
65-69			2.1
70-74			2.1
75-79			2.1
80+			2.1

PeopleSize

	P_5	Mean	P_{95}
UK adults, age 18-64	1.4	1.7	2.0

27 Eye height standing (mm)

Steenbekkers and van Beijsterveldt

Age - women	P_5	Mean	P_{95}
65-69	1425	1510	
70-74	1432	1517	
75-79	1385	1488	
80+	1376	1456	

PeopleSize

Age - women	P_5	Mean	P_{95}
65+	1349	1452	
65-74	1374	1472	
75+	1325	1425	
85+	1301	1395	
UK adults, age 18-64	1436	1573	1729

29 Elbow height, standing (cm)

For general use, the mean value is recommended in many cases as long as short users have a view of the surface (with their hands upon it).

Steenbekkers and van Beijsterveldt

Age - men/women	P_5	Mean	P_{95}
65-69	93.8	103.1	113.4
70-74	94	102.9	113.5
75-79	90.9	101.6	113.2
80+	89.2	99.9	111.6

PeopleSize

	P_5	Mean	P_{95}
UK adults, age 18-64	93.7	104.4	115.6

Pheasant (male)

Age - men	P_5	Mean	P_{95}
65-80 (OPCS)	97.5	105.5	113.5
'Elderly' (ICE)	93.5	102.5	112.0

Pheasant (female)

Age - women	P_5	Mean	P_{95}
65-80 (OPCS)	91.0	98.5	105.5
'Elderly' (ICE)	86.0	94.5	103.0

31 Maximum gripping force of one hand (N)
(Exerted for 3 seconds)
For brief exertions of force, use about 1/3 to ½ of value given.
Use lowest %ile value. On average strength of women is 2/3 that of men, and that of the very old is 2/3 of that of young adults.

Comment: Please note that population and methodology used may account for the differences between maximum gripping force of one hand (Humanscale's 235 N for a $P_{2.5}$ weak woman compared with Steenbekkers and van Beijsterveldt's 108 N for a P_5 woman aged 80+). Although these data are included here, a recommendation has not been made because of these differences. However, Section 8 does include a recommendation for further research on strength requirements, in particular with older users, considering differences between something like a vacuum cleaner we carry upstairs to lifting a full kettle, etc.

Steenbekkers and van Beijsterveldt

Age - women	P_5	Mean	P_{95}
65-69	177		
70-74	157		
75-79	118		
80+	108		

Older Adultdata (from Skelton 1994)

	P_5	Mean	P_{95}
65-69		255	
70-74		265	
75-79		216	
80-84		226	
85-89		186	

Humanscale

	$P_{2.5}$	Mean	$P_{97.5}$
Weak woman	235		
Strong woman		418	
Strong man			653

45 Pronation (degrees)
Maximum rotation of the wrist inward. (for turning controls)
Using Mean value implies 50% of people cannot achieve that angle and that many more than 50% cannot do it in comfort.
Recommend choosing a series of small (about 30^o) rotations for product handling, rather than one single extreme (about 90^o) rotation.

Steenbekkers and van Beijsterveldt

Age - men/women	Men P_5	Mean	Women P_5
65-69	79	80	84
70-74	80	82	82
75-79	77	84	89
80+	78	82	98

Note: A rather unusual finding in their study was the somewhat increased capacity for inward rotation with ageing (r = 0.13); in contrast the outward rotation of the wrist follows the general ageing pattern.

Humanscale

Minimum	29
Mean	77
Maximum	125

46 Supination (degrees)
Maximum rotation of the wrist outward.
(Also see note for 45 above)

Steenbekkers and van Beijsterveldt

Age - men/women	Men P_5	Mean	Women P_5
65-69	57	50	60
70-74	54	51	55
75-79	55	55	49
80+	49	37	49

Humanscale

Minimum	69
Mean	113
Maximum	157

47 Forefinger flexion (degrees)
Maximum downward bending of the stretched forefinger of preferred hand. When designing controls for hand-held tools, avoid triggers or push-buttons that have to be continually engaged by the forefinger. Use instead diminished resistance, or a control that can be activated by several fingers together *(or a lock-on button).*

Steenbekkers and van Beijsterveldt

Age - men/women	P_5	Mean	P_{95}
65-69		52	
70-74		54	
75-79		51	
80+		53	

No other data found.

48 Envelope of comfortable vertical reaching, standing (cm)
Urgent and frequent reaching tasks require a comfortable reach for the low percentile (e.g. P_5). Less vital objects may require more effort, but should remain within maximum reach of the low percentile.

Steenbekkers and van Beijsterveldt *(see next page)*

Table 19 — Envelope for vertical reach when standing, as a function of age

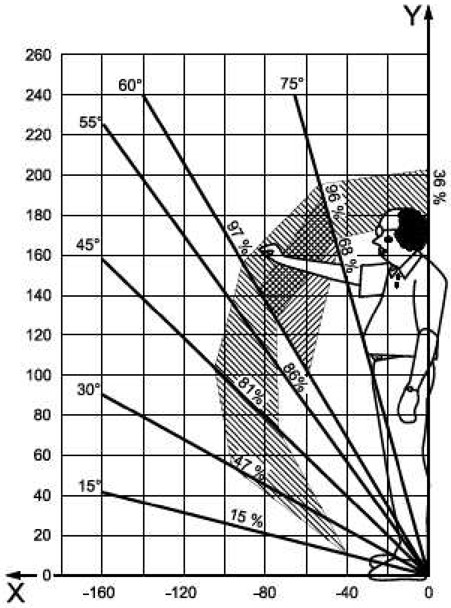
Age	Stature	Radius	Comfortable		Maximum	
				Mean radius		Mean radius
years	cm	degrees	*n*	cm	*n*	cm
20–30	< 175	90			49	204
		75	34	191	60	204
		60	49	147	60	184
		45			60	149
		60			53	110
		15			27	73
20–30	> 175	90			54	225
		75	29	209	62	225
		60	46	161	62	204
		45			62	165
		60			50	120
		15			24	77
50–74	< 170	90			182	199
		75	179	189	259	198
		60	231	149	258	176
		55	30	115		
		45			250	138
		30			172	99
		15			85	63
50–74	≥ 170	90			140	216
		75	135	205	207	214
		60	188	160	209	192
		55	20	125		
		45			202	152
		30			143	109
		15			43	72
75+	< 165	90			27	191
		75	50	183	71	189
		60	64	145	72	165
		45			60	123
		30			35	86
		15			11	59
75+	≥ 165	90			32	210
		75	41	197	63	205
		60	50	157	63	178
		45			55	138
		30			29	98
		15			13	66

From CEN/ISO TR 22411, Table 19, page 103

Also see diagrams and detail in the following from Steenbekkers and van Beijsterveld:

50-74 years of age, stature <170 cm (see page 369 Steenbekkers)
50-74 years of age, stature ≥170 cm (see page 370 Steenbekkers)
75+ years of age, stature <165 cm (see page 371 Steenbekkers)
75+ years of age, stature ≥170 cm (see page 372 Steenbekkers)

e.g.



a) Envelope for vertical reach when standing for age over 75 years and stature less than 165 cm

Key
X horizontal distance, cm
Y vertical distance, cm

A maximum
B comfortable

Humanscale

Small woman 65+ stature	146 cm
Average woman 65+ stature	158 cm (also small man)
Average adult 65+ stature	164 cm
Average man 65+ stature	170 cm (also large woman)
Large man 65+ stature	182 cm

71 Near reading visual acuity
For words on displays and controls of devices.
Use 12 point san serif, lower case.

Steenbekkers and van Beijsterveldt

Age - men/women	**P_5**	**Mean**	**P_{95}**
65-69		0.8	
70-74		0.8	
75-79		0.8	
80+		0.6	

72 Visual contrast sensitivity (pt)
This data is only for one contrast at one illumination level (grey on black at 100 lux – *other information is in chapter 5.2 of Steenbekkers)*

Steenbekkers and van Beijsterveldt

Age - men/women	**P_5**	**Mean**	**P_{95}**
65-69	6.3	8.1	10.0
70-74	6.3	8.2	10.0
75-79	6.3	8.7	12.6
80+	6.3	9.6	12.6

Steenbekkers and van Beijsterveldt

Age - men	**P_5**	**Mean**	**P_{95}**
65-69	6.3	8.1	10.0
70-74	6.3	8.3	12.6
75-79	6.3	8.8	12.6
80+	8.0	9.7	12.6

Steenbekkers and van Beijsterveldt

Age - women	**P_5**	**Mean**	**P_{95}**
65-69	6.3	8.2	10.0
70-74	6.3	8.0	10.0
75-79	6.3	8.6	10.0
80+	6.3	9.5	12.6

74 Tactile form recognition, equal shapes (s)
S = time to decide whether 2 reliefs are equal.
If tactile discrimination must be used, differences in the size of standard forms is to be preferred above differences in shape or line thickness (or depth of relief); the standard forms should be about the size of fingertips.

Steenbekkers and van Beijsterveldt

Age - men/women	**P_5**	**Mean**	**P_{95}**
65-69		12.9	
70-74		13.0	
75-79		13.9	
80+		14.9	

75 Tactile form recognition, different shapes (s)
S = time to decide whether 2 reliefs differ.
(See that different shapes lead to faster responses than above)

Steenbekkers and van Beijsterveldt

Age - men/women	**P_5**	**Mean**	**P_{95}**
65-69		10.9	
70-74		11.3	
75-79		12.1	
80+		13.8	

76 Tactile form recognition, different sizes (s)
If tactile discrimination must be used, differences in the size of standard forms is preferred above difference in shape or line thickness (or depth of relief); the standard forms should be about the size of the fingertips.

Steenbekkers and van Beijsterveldt

Age - men/women	**P_5**	**Mean**	**P_{95}**
65-69		8.2	
70-74		8.4	
75-79		9.3	
80+		11.3	

77 Tactile form recognition, different line thickness (s)

If tactile discrimination must be used, differences in the size of standard forms is preferred above difference in shape or line thickness (or depth of relief); the standard forms should be about the size of the fingertips.

Steenbekkers and van Beijsterveldt

Age - men/women	**P_5**	**Mean**	**P_{95}**
65-69		11.1	
70-74		11.8	
75-79		11.9	
80+		12.9	

Appendix 3: Existing values and gaps – the full picture

The order of factors follows that of CEN/ISO TR 22411. Extra headings in the first column have been added (*in italics*) where it seemed necessary and they did not exist in 22411.

Data/values from other sources should be specific figures or specifically related to household appliances. However, general guidelines have also been given where they will be helpful to standards bodies and designers. Recommendations emerging from this table are summarised in separate lists (in Sections 6, 7 and 8 of this report).

Factors relevant to household appliances	Data/values from CEN/ISO TR 22411	Data/values from other guidelines/sources	Recommendation
Alternative format	8.2.1 General considerations: Providing several alternative formats increases the probability of making a product or service accessible to the greatest number of people. **Comment**: Auditory feedback could be provided for push buttons. Knobs with notches can help with grasping and additional feedback, and Raised numbers or symbols on Controls or Labels.	Audible feedback: some people believed it would offer reassurance that buttons had been activated. Would need to be loud enough to be heard above background noise. Would need to be isolated if so desired. **[ESRI Reference AR499]** Controls should offer some feedback to inform operator that the control has reached correct position, e.g. a dial should have mechanical detents. **[ESRI Reference AR218]** Audible feedback guidelines available in EN 71 – 'noisy toys'.	

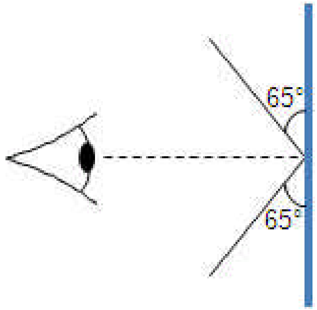
Tactile markings	8.2.2.1: some persons with touch impairments (e.g. older persons or persons with diabetes) have difficulty sensing tactile information. Dots with a convex shape (in contrast to cylindrical or peak form) and a sufficient amount of raised height above the surface increase accessibility. Table 1: Dimensions (in mm) of tactile markings used in applications (for fingers) National standard: Dots: 0,5 to 0,8 [48] 0,8 to 2,0 [46] Bars: 0,5 to 0,8 [48] International standard: Dots: 0,6 ±0.2[47] Bars: 0,5 ± 0,1[47] Size dimensions (dots diameter): National standard: 1.5-2.0 mm[48] International standard: 1.5±0.2mm (ISO 11683:1997)	In evaluation trials of cookers, it was emphasised that, as is common practice, clear indication of a control setting must be given by means of some graphic treatment of the control surface. The marker should be located at the 12 o'clock position to indicate that the control is set at OFF. **[ESRI Reference AR418]** If instructions are incorporated in the material of the product itself, e.g. engraved or embossed lettering, figures or symbols on metal, glass or plastic, the advantages of such methods in durability, reduction of numbers of separate parts, etc., should be weighed against a possible disadvantage in legibility, which is generally inferior to that of good printing. **[ISO/IEC Guide 37: 1995(E)]** When designing tactile information, a structure should be raised by between 0.8 mm and 2 mm. Information can also be conveyed via different elevations in the relief, which should vary by at least 0.8 mm. For important information, the height should be significantly more than 0.8 mm. (for example for push-button switches). Integrated Braille characters should also be raised by 0.7 to 1.3 mm and be given hemispherical tops. **[DIN Technical Report 124]** For haptic signals, use low frequencies for signalling events such as 25 Hz. **[Fisk et al 2009]**	NOTES: Braille is not being considered in this document. Taking greater dimensions will make it easier for people with reduced sensitivity to recognise dots, bars or symbols.. Height of tactile structure: Between 0.8mm-2mm. Diameter of Tactile dot: 1.5-2mm Tactile bar: 0.8-2.0mm Length of tactile bar: 5-10 times the width. Different information can be conveyed by different elevations, which should vary by at least 0.8mm and significantly more than that for important information. Dimensions of tactile symbol shall be adjusted to size of associated control, not to the size of the product. Distance between tactile letters, symbols or markings should be >5 mm.

	Comment: Use larger dimensions to detect tactile marking easily, especially for older persons or persons with eg diabetes, whose tactile sensitivity may be reduced**.** Section 9.2.3.2 of TR 22411 on Tactile spatial resolution: Threshold is generally measured by the closest distance 2 objects can be apart and still sensed separately. For fingers, the resolution is approx 1 mm-3 mm, with the forefinger having the highest sensitivity. Older persons have much less tactile spatial resolution capability. Their threshold, when defined by a 75% correct response rate, for the gap detection and the grating orientation recognition is about 1 mm and 2 mm, respectively. For letter recognition, the threshold, defined as 50% correct, is 5 mm.	**Tactile positions** 3-12 tactile positions. **[ELS 2003-3]**	

		Dimensions of tactile symbol shall be adjusted to size of associated control, not to the size of the product. Length of the tactile bar should be 5-10 x the width. Dimensions of tactile dot: Diameter: 0.8-2.0 m, Height: 0.4-0.8mm Dimensions of tactile bar: Width: 0.8-2.0mm Length: from 5w to 10w Height: from 0.4-0.8m **[Pr EN ISO 24503 – Ergonomics – Accessible design – Using tactile dots and bars on Consumer products (based on principles of accessible design from ISO/IEC Guide 71)]**	

Auditory signals	8.2.2.2: The signals for the same purpose in all products and services have the same temporal pattern across. different products and services. The signals for different purposes are clearly discriminable from each other. See ISO TR22411 for: Table 4: Examples of temporal patterns of operation confirmation signals. Table 5: Example of temporal patterns of end signals. **Comment:** These values may be relevant to for example microwave or oven controls, and also to indicate when eg the washing machine cycle ends.	Increased audio feedback in the form of tones to assist people who are blind to operate their washers and dryers. For example, according to the following report, the Kenmore and Whirlpool controls allow you to identify options by listening. If, for example, five spin speeds are available on the Regular cycle, five different tones will be heard as you repeatedly press the Spin Speed button. The highest tone indicates the fastest speed, and the lowest tone represents the slowest speed. When you cycle among the speeds, it is a simple matter to learn how many are available. "Accessibility Wash: New, Usable Washers and Dryers Are Released" in American Foundation for the Blind published in its AccessWorld at http://www.afb.org/afbpress/pub.asp?DocID=aw080303, cited in Tim Noonan's The Overlooked Consumers. Frequency range of sound signals (individual tones and mixtures of tones or sounds) should be restricted to 300 Hz to 2000 Hz. **[DIN Technical Report 124]** In quiet surroundings, the sound level at the ear of the user should be between 55 dB(A) and 65dB(A) at the normal distance between the user and the product. **[DIN Technical Report 124]**	Sound levels should be adjustable to meet the needs of the user. Assuming a relatively quiet home environment, frequency of sound signals should be between 300 Hz-2000 Hz. Avoid frequencies above 3000 Hz. To accommodate background noise and diverse abilities and ages, use alternate frequencies for different signal information. Intensity should be between 55 dB-65 dB (assuming quiet surroundings in a household). Warnings at least 60-65 dB at ear of listener. **(These values have been validated against Humanscale)**
		Avoid frequencies above 4000 Hz. For warning signals, keep within frequency range of 500-2000 Hz and intensities at least 60 dB at the ear of the listener. **[Fisk et al 2009]**	

Visual information	8.2.3.1: A flashing, blinking, and/or flickering light is effective in drawing attention and can be used for conveying task-relevant information to be discerned. However, light that is too bright and a certain range of repetition rates can be avoided to prevent photosensitive seizures. **Comment**: What is too bright?	Displays on fridge/freezers that are numbered more preferred to a more abstract type. **[ESRI Reference AR212]** Setting of oven temp: Incremental change should be 10 degree C and this should correspond with discrete steps of the data control knob. **[ESRI Reference AR564]** The flash rates most likely to induce convulsions have been found to be between 10 and 25 hertz, with a peak around 15-20 hertz. (See chart below for example of the relative sensitivity of individuals to different frequencies.) - Sensitivity to flicker increases with the intensity of the light and the portion of the person's visual field which is affected (e.g., a flickering or flashing screen is much worse than a small line cursor). Focusing attention on a flashing object would also increase its effect. - To avoid screen flicker use 80-100 Hz refresh rate with decay time approx. 10 ms to 10% luminance level. (p40) **[Vanderheiden and Vanderheiden, 1992]** **Comment:** 80-100 Hz refresh rate recommendation is probably out of date, so suggest a minimum of 80 Hz. Accommodation: viewing distance at least 400 mm. Field of vision for detection tasks: normal optical axis 15^o to 30^o below the horizontal. **[DIN Technical Report 124]** There is risk of epileptogenic effects from 3-70 Hz, with the highest risk between 15 and 20 Hz. Flash rates above 70 Hz are likely to be perceived as constantly 'on' (although the eye may still register flicker at rates of 160 Hz or greater). Accordingly, flash rates for use in domestic appliances where the flash needs to be detected should be less than 3 Hz. **[Wilkins, Veitch and Lehman, 2010]**	Field of vision: optimum $\pm 15^o$ to the horizontal is recommended for primary controls in something like a workstation. However, for most controls for household appliances $\pm 60^o$ would be an acceptable field of vision for viewing controls, especially since this represents ocular movement and hence is only significant if the person cannot move their head. To avoid screen flicker, use a minimum of 80 Hz refresh rate. Avoid flash rates between 3-70 Hz, as this is where there is risk of epileptogenic effects (the highest risk is between 15 and 20 Hz).

Position of information	8.3.1.1: visual information is placed near the central part of field of view; higher contrast, larger size and larger colour difference of the target can increase detectability; visual information for older persons can be presented in the lower portion of the environment. **Comment**: Useful field of view will be different for shorter or taller people, and for people in wheelchairs. Consider also whether appliances are floor standing or countertop. What size and contrast for information? How low should information be placed?	***Display*** **Viewing angle** Vertical: $\geq 120^{o}$, horizontal: $\geq 80^{o}$ **[ELS 2003-3]** **Comment:** In practice, viewing angle should relate to eye height and reach of typical users sitting and standing. However, there may be too many variables to consider. This viewing angle is much greater than the minimum required (± 15^{o}) to allow for standing/sitting. Angle also allows for distance of operator from the object and dictates size and presentation of information. This is a decent requirement but quite onerous for manufacturers. If centred around a mean height individual, then 120^{o} would be ideal, but due to distance from control, it's a bit irrelevant. Cone of vision is huge at 120^{o}!  We might wish to conduct user trials to relate viewing angle to users' height and reaches, without being design restrictive. However, this would not be necessary with an angle as wide range as 120^{o}, and values could be generated from data. Therefore, this research would be less important for household appliances than some other issues.	

Example of integrating the guidelines *(Not a heading in CEN/ISO TR 22411)*		Creating accessible input and control mechanisms that facilitate use by all people, particularly those with multiple disabilities requires careful balancing of the considerations. Below are some examples that demonstrate controls that integrate cross disability considerations in their design. Others will be added as the guidelines evolve. In some cases the design has more features than are necessary or has redundant features in order to demonstrate different possible combinations.	

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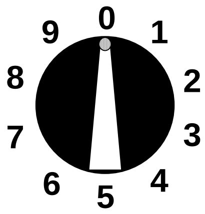

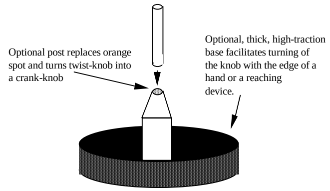

- Tactile pointer orientation (setting) can be easily determined by grasping knob (Low Vision & Blindness).
- High contrast pointer against black backing disk. (Low Vision)
- Red-Orange spot reinforces pointer tip (spot can be illuminated using plastic lightpipe) (Low Vision).
- Knob turns easily but is damped to allow turning by pressure on the side of either end of pointer or by rubbing on the edge of the back disk. (Physical Impairment)
- Thick back disk is made of high traction plastic to allow knob to be operated as an edge controlled knob. (Physical Impairment)
- Tactile detents on the major settings. If interscale settings are important (as on an oven temperature dial) then additional interscale detents would also be provided. (Low Vision, Blindness, Physical Impairment)
- Plastic pointer spot on knob can be removed and replaced with a small post to allow operation of the knob as a crank. (Physical Impairment)
- Lettering on panel is large, sans-serif, bold and raised. (Low Vision & Blindness)
- Space is available for optional braille back plate and very large print backplate. (Low Vision & Blindness)
</td>
<td></td>
</tr>
</table>

		- Knob setting can be illustrated (in directions) or remembered solely by visual orientation of knob, ignoring the actual printed numbers. (Cognitive) - Space and stationary dial plate allow special labels or pictures to be attached for non-readers. (Cognitive) - Numbers are stationary and all upright. (Low Vision, Blindness & Cognitive) - Uses clockwise movement convention for increasing values. (Cognitive) **[Vanderheiden and Vanderheiden, 1992]**	

Location and layout of controls *(related to reaching)*	8.3.1.2 Location: controls are easy to reach (see 8.12) 8.3.3 Layout: Position controls relative to their use or importance.	Design of controls and displays for a fridge not as critical as those for say a cooker. Not used frequently and any misuse is not potentially hazardous (except for possible deterioration of food). Position controls at front, at convenient height, usually near top of fridge. Controls should not be adjacent to eg light fitting which would interfere with the hand. **[ESRI Reference AR192]** Position of switches, if too low difficult for anyone who could not bend easily or who had restricted hand movement. Freezer controls, if place at very top of unit, rocker switches and temperature dial could be awkward for short and elderly people to read and use. Controls for fridge: a recessed design of temperature dial would be difficult for anyone with restricted hand function. **[ESRI Reference AR212]** **Comment:** Comfortable vertical reach for wheelchairs - 91-122 cm from floor. Ambulant and large % of wheelchair users = 137 cm from floor. Elbow height of 95th % adults = 1156 mm Elbow height of 5th % woman = 937 mm. **[Humanscale]** Humanscale gives 'top of shoulder to bottom of elbow,' so our recommendation is based on this. There would be value in identifying primary, secondary and tertiary controls by criticality of function and then requiring that the most important (primary) are located within reach of the majority of the population (5th % woman to 95th % percentile man). It's pointless making primary controls ideal for very small users only, since large (tall, obese) people will struggle. Small people can reach up a bit, tall people down a bit! The overlap would be zone for placement (depending on population). Secondary and tertiary controls could then be located at less critical locations.	Comfortable reach (which would also include wheelchair users): 937-1550 mm from floor.

		Waist level controls and displays location on a vertical surface is unacceptable. The exact preferred angle may depend on types of controls and displays used but angles between 10-20 degrees to the horizontal should be considered. For panels at eye level a vertical presentation may be acceptable, whilst location just below this, say shoulder level, may be best with angle of 5-10 degrees to the vertical. **[ESRI Reference AR483]** In the kitchen, the workspace for the hands, such as counters and sinks, should be at about elbow height or slightly below. This facilitates manipulation and visual control. Counter and sink may be put lower for wheelchair users. **[Kroemer, 2006]** **Comment:** Not so relevant to the appliance sitting on top of counter.	
		Control panel's location Requirements, no disabilities ≤ 1550; ≥ 1350 mm Requirements, wheelchair users ≤ 1000; ≥ 800 mm **[ELS 2003-3]** **Comment:** Lower value of 1350 mm is too high.	

		Controls are best located between waist and shoulder height. However, with free-standing dishwashers this is not possible. **[ESRI Reference AR218]** **Comment:** Not sure why only dishwashers are excluded. It's also not possible for many other under-counter appliances. Evaluation of the layout of a control panel on a grill and microwave oven, advised to place frequently used controls in the most convenient location and to group controls having a related function, i.e. START and STOP/CLEAR right at the top. 4 oven function pads (MICROWAVE, CONVECTION, DUAL COOK, GRILL) plus ROTISSERIE and TIMER/HOLD grouped together as they are used in combination. Weight pads (Kg..Lb, g.oz\) and Kg/Lb conversion pads together and adjacent to the automatic programmes with which they are used. LESS and MORE pads adjacent to the range of automatic programmes to which they chiefly relate. ONE TOUCH REHEAT and AUTO START/0 near the bottom as they are less frequently used and will be not confused with the START pad. **[ESRI Reference AR695]**	

In evaluation trials of controls for cookers, it was found that a vertical location is better than a horizontal one. Vertical positioning requires only pronation and supination of the forearm. Horizontal positioning requires considerable movement of the wrist, and people with arthritis tended to make many small wrist movements, releasing and grasping the control several times during each setting of the knob.
[ESRI Reference AR418]

Comment:
Please note that in this context, the terms “vertical positioning” and “horizontal positioning” do not refer to the distance between controls on a vertical or horizontal surface, but instead to the location of the entire control panel, as shown below.

Vertical location, e.g.:

Horizontal location, e.g.:

Visibility of controls *(ie seeing the controls)* *(not a heading in CEN/ISO TR 22411)*	8.3.1.2: the visibility of controls is considered so that they are placed in the visible range of the user (see 9.2.1.5).	Temperature control for fridge/freezer: if it is an increasing curved wedge, it would be more informative if it had a numbered display. **[ESRI Reference AR212]** **Control panel's location:** **Given:** C = Distance between floor and lower edge of control panel D = Distance between lower and upper edge of control panel Calculate the control panel's location in accordance with: $C + \frac{D}{2}$ **Given:** Distance A, 95th percentile (table 1 section 8.1.1):1670 mm) in Annex 3.2 • Distance A, 5th percentile (table 1 section 8.1.1):1460 mm) Distance B (figure 8.2 section 8.4): 500 mm Control panel's deviation from "Horizontal line of sight", α (figure 12.1): 15°, 30° and 60° (Pheasant, 1996) (C+D/2) = Control panel's location **[ELS 2003-3]** **Comment:** Not sure from this document what distance A is. There might also be a shoe allowance (25 mm) for the 5th % female and the 95th % male seems wrong. See the datasets below:	Field of vision: optimum ±15° to the horizontal for primary controls in something like a workstation. However, for most controls ±60° would be acceptable.

<table>
<tr>
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<td>
Standing eye height dataset
<table>
<tr><th>Dataset</th><th>5th percentile</th><th>Mean</th><th>95th Percentile</th></tr>
<tr><td>Peoplesize</td><td></td><td></td><td></td></tr>
<tr><td>Female 65+</td><td>1349</td><td>1452</td><td></td></tr>
<tr><td>Female 65 - 74</td><td>1374</td><td>1472</td><td></td></tr>
<tr><td>Female 75+</td><td>1325</td><td>1425</td><td></td></tr>
<tr><td>Female 85+</td><td>1301</td><td>1395</td><td></td></tr>
<tr><td>Adults 18 - 64</td><td>1436</td><td>1573</td><td>1729</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>Steenbekker</td><td></td><td></td><td></td></tr>
<tr><td>Female 65 – 69</td><td>1425</td><td>1510</td><td></td></tr>
<tr><td>Female 70 – 74</td><td>1432</td><td>1517</td><td></td></tr>
<tr><td>Female 75 – 79</td><td>1385</td><td>1488</td><td></td></tr>
<tr><td>Female 80+</td><td>1376</td><td>1456</td><td></td></tr>
</table>

Comment: The recommended range should be extended at the lower margin to include females of greater age and hence shorter stature. Recommendation is 1349 mm (based on UK females 65+ (which accommodates Steenbekker and van Beijsterveldt's females 80+) to 1729, the 95th percentile UK male aged 18-64 (Peoplesize), who may be the tallest user in a mixed capability household.
</td>
<td>Standing eye height:
1349-1729 mm</td>
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<td>Stationary Products: A visual distance the same as that used for manual operation of the controls should be assumed when labelling the controls. After positioning it should be possible to read, in particular handles, plug-in slots and controls within the grasping area, preferably at a height of 0.8 m to 1.0 m from the floor.
[DIN Technical Report 124]

Comment: 0.8 m to 1.0 m seem to reflect worksurface heights and therefore control heights. Doesn't seem to correspond to anthropometrics.</td>
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</tr>
</table>

Colour *and coding* *(coding not a heading in CEN/ISO TR 22411)*	8.5.1 Choice of colour. Colour appearance also changes with luminance levels. At lower luminance levels, namely a few cd/m^2 or 10 lux, bluish colour looks relatively brighter and reddish colour on the contrary darker. The colour combinations of green/red and yellow/blue are used with significant luminance contrast for persons with colour deficiencies to avoid confusion of the colours. 8.5.2: Colour combinations: black on yellow or light grey are general purpose combinations which provide strong definition without too much glare, pastel shades on pastel backgrounds or red lettering or symbols on light grey are difficult to see and should normally be avoided. Colour discrimination ability is reduced for people with low vision. Large luminance contrast can greatly help persons with colour deficiency, as well as those with low vision,to discriminate colours.	Control coding Types of coding include: colour, shape, surface, structure, dimension, position, text and symbols. Colour is not suitable in primary coding as it depends on lighting conditions and human colour perception impairment. Colours have inherent meaning that must be taken into account: red- danger, stop, yellow-caution, etc. Shape or surface coding permit easy and visual tactile identification. In size coding, control tasks should be given the same dimensions. There should be a maximum of three sizes with a minimum difference of 20% between sizes. Coding by text and symbols is based on functional identification of controls and is effective only under good lighting and visual checking conditions. Brief signs and common abbreviations, easily comprehensible without learning are suitable for this coding type. Alphanumeric characters have a high degree of unambiguity but require comparatively more space. Marking should appear above the control. See Chapanis and Kinkade (1972) for optimum size and thickness of alphanumeric characters relative to distance. The minimum symbol size is a function of surrounding brightness, distance of observation and geometric structure of symbols **[Salvendy, p597]** On colour displays, red/green and blue/yellow combinations should not be used. White or yellow type on black or a dark colour is more legible. **[RNIB, household appliances]**	Shape or surface coding permit easy and visual tactile identification. In size coding, control tasks should be given the same dimensions. There should be a maximum of three sizes with a minimum difference of 20% between sizes. On colour displays, red/green and blue/yellow combinations should not be used. White or yellow type on black or a dark colour is more legible.

		Emergency stop device **Shape and colour** The emergency stop device must be red. The immediate background around the device must be yellow. The push button must have a mushroom head or similar. **[ELS 2003-3]**	
Contrast	8.5.4: Luminance contrast: The higher the contrast, the better the visibility. The sensitivity to contrast for fine images decreases with age due to optical scattering in the eye. The contrast sensitivity is much lower for persons with low vision due to various types of visual impairments. **Comment**: Relevant to both controls and displays. Are actual values possible? See Table 7 (Colour combinations for signs and backgrounds) 8.6.1: Persons with low vision tend to prefer light text on a darker background rather than darker text on a light background. **Comment**: A guideline but no values.	The contrast should normally be at least 70%. Good quality black print on white paper provides a contrast of about 80%. **[ISO/IEC Guide 37: 1995(E)]** **Contrast** > 9:1; ≤ 15:1, C_R **[ELS 2003-3]** Try to achieve at least 50:1 contrast (black text on white background) – measured from solid black and solid white areas. **[Fisk et al 2009]** In a cooker evaluation, black pointers on black plastic background means settings not easy to see. **[ESRI Reference AR227]**	Contrast between background and text, symbols or markings, on both controls and displays, should be at least 70%. Text size and contrast will be dealt with together – see Font size.

Font size	8.6.2: A larger font size can improve accessibility under low luminance conditions. A larger font size can improve accessibility for older persons at near viewing distances. Annex C.3: Estimation of a minimum legible font size: A 16,6 point plain font is the minimum legible size for an individual aged 68 in the 10 cd/m^2 condition from a viewing distance of 0,5 m. As the *P* means the "minimum" legible size, the comfortable reading size could be set larger than this minimum, depending on the purpose. Font size in points, *P,* can be expressed by the Equation: $M = 0{,}3514 \times P$ **Comment**: Can we use this formula to calculate for someone e.g. age 80?	7.2.1: Type and size of on-product information should be as clear and as large as practicable to ensure legibility. The x-height (height of the lower case characters) of the type face should always be 1.5 mm or larger. In the so-called typographic point systems (Didot and Pica) the corresponding size would be approximately 4 points [1 point = 0.4 mm (Didot: 0.376 mm; Pica: 0.351 mm)] **[ISO/IEC Guide 37: 1995(E)]** The marking (in letter, graphic symbol, pictorial letter) is of a size easy to be recognised, and colouring and colour contrast should be arranged so that the symbols can be clearly discernible from the marking surface. **[JIS S 0012:2000]** When the contrast is lower, the letter size has to be at least 12 pt. For the elderly to be read at normal reading distance (35-55 cm). Study was conducted with 4 charts, each with a different contrast and diminishing letter sizes, to be read under one of 3 illumination levels (10, 100 and 1000 lux) **[Steenbekkers and van Beijsterveldt,1998]** Individual characters used on displays on the product should subtend an angle at the eye of between 18' and 22' of arc (see ISO 9355-2:1999, 4.2.1). **[ISO 20282-1, found in Bibliography of ISO/TR 22411]** Select 12 pt. X-height fonts when designing for older users. **[Fisk et al 2009]** **Comment:** Although some references (e.g. DIN TR 124) say 12 pt = 3 mm, by our measurement 12 pt = 2.2 mm x-height (that is, height of lower case x). 3 mm x-height is closer to 14 point.	Letter size at least 12 pt. x-height when viewing up to ½ metre away, at 70% contrast. Larger text size than 12 pt if less than 70% contrast. However, if we want to be more inclusive, use a distance of 1 metre, since a number of older people do not have their eyes tested or don't have their glasses in the kitchen. Therefore the following more precise values are recommended: If 70% contrast is used and size of font is 4.7 mm x-height, research suggests that approximately 90% of people over the age of 65 would be able to read it at 1 metre (provided the lighting is at least 150 lux). If a product is e.g. hand-held (at 40 cm), then the size of font could go down to 2.6 mm x-height and still include the same number of people, as long as the contrast is still at 70%. Although the larger font size will always be advisable, the characteristics of the product (e.g. its size) will determine the reasonable adjustments or modifications that can be made. Safety issue: Recommendations should assume arm's length distance (e.g. reading markings up close to a gas burner!)

The study suggests % of people over 65 years of age (wearing corrective lenses) at 1 M distance who would be included if text size of 4.7 mm is used with 70% contrast. This study used the font style from British Standard BS 4274-1:2003, a san-serif font with equal spacing and similar to Arial.

Log value	Letter size	90% contrast	70% Contrast	50%
0.7	7.4mm	100%	100%	100%
0.6	5.9mm	98%	98%	98%
0.5	4.7mm	95%	92%	92%
0.4	3.7mm	85%	77.5%	73%
0.3	2.9mm	65%	55%	45%
0.2	2.3mm	43%	31%	18.5%
0.1	1.8mm	23%	13%	4.5%
0.0	1.45mm	10%	4%	0
-0.1	1.2mm	3%	0%	0
-0.2	1mm	0%	0%	0
-0.3	0.8mm	0%	0%	0

Elton and Nicolle, 2009 and 2010]

The in-house lighting used in this study was 150 lux. However, guidelines for artificial lighting in the home are: (Grandjean, 1973)

Room	Lighting intensity (lux)
Living room	120 -250
Bedroom	50-120
Children's room	120-250
Kitchen	250-500
Bathroom	100-400
Stairs and passages	120-250

Comment: Since the study included only 38 people over the age of 65 (mean age=74 years, SD=6.1), it would be useful to validate the highlighted values with a range of older and disabled users and household appliances.

The study suggests that about 90% of people over 65 years of age (wearing corrective lenses) at hand-held distance would be included if text size of 2.6 mm is used with 70% contrast. This study used the font style from British Standard BS 4274-1:2003, a san-serif font with equal spacing and similar to Arial.

Log value	**Letter size**	**90% contrast**	**70% Contrast**	**50%**
0.7	4.2mm	100%	100%	100%
0.6	3.3mm	98%	98%	98%
0.5	2.6mm	95%	92%	92%
0.4	2.1mm	85%	77.5%	73%
0.3	1.7mm	65%	55%	45%
0.2	1.3mm	43%	31%	18.5%
0.1	0.75mm	23%	13%	4.5%
0.0	0.6mm	10%	4%	0
-0.1	0.5	3%	0%	0
-0.2	0.4mm	0%	0%	0
-0.3	0.3mm	0%	0%	0

[Elton and Nicolle, 2009 and 2010]

Comment: Since the study included only 38 people over the age of 65 (mean age=74 years, SD=6.1), it would be useful to validate the highlighted values with a range of older and disabled users and household appliances.

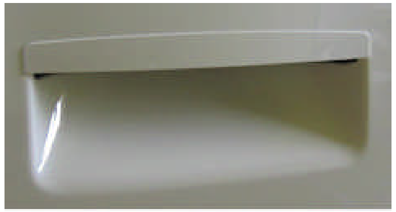
		[ELS 2003-3] **Letter height** ≥ 8 mm **Stroke width/height ratio** The requirements below are dependent on the display's polarity. Positive polarity = dark text on a light background; negative polarity = light text on a dark background. ≤ 8; ≥ 6 positive polarity (H/RB) **Width/height ratio** ≥ 0.7; ≤ 0.9 (BB/H) **Distance between letters** > 1 stroke width (RB) and ≤ 50% of BB	

		[ELS 2003-3] **Distance between words** > Letter width (BB) **Distance between lines** > 1 Stroke width (RB)	
		It should be possible to perceive the character height of body text at a viewing angle of 22' and the height of the characters should not be less than 3 mm (12 point). **[DIN Technical Report 124]**	

Font style	8.6.3: consistent stroke widths; open counterforms (the open space in letters like “e” and “a”); clearly visible ascenders and descenders (such as tails on the lower case letters “b” and “j”); wider horizontal proportions; extended horizontal strokes for certain letterforms (such as the arm of the lower case “r” or the crossbar of the lower case letter “t”). For older persons, there is some evidence that serif fonts assist reading speed, while sans-serif fonts are actually preferred subjectively. With high resolution displays or printed hardcopy, it is preferable to focus on overall font design, and ensure that serifs, if present, do not negatively affect legibility. However, as Figure 10 shows, when the output resolution (either on paper or screen) is low, a sans-serif font can increase accessibility because there will not be enough dots or pixels to render the serifs clearly.	Upper and lower case labelling should be used. **Font** Without serifs **Upper and lower case letters** Both upper and lower case letters in running text. Individual letters, words, prompts and headings may only have upper case letters. **[ELS 2003-3]**	

Loudness and pitch of non-spoken communication	8.9: Sensitivity to higher-frequency sounds decreases with age. This is a key factor when determining a range of sound pressures and frequencies for auditory signals that are to be heard in a quiet environment. See 9.2.2.1 and 9.2.2.2. **Comment:** What is appropriate range of frequency to accommodate older people and those with hearing impairment?	*Hearing auditory output* Use sounds which have strong mid-low frequency components (500 - 3000 Hz). (p21) For alerting devices the use of two or more spectral components in the 500 - 4500 Hz range is recommended based on ringer studies. Others suggest limiting the upper frequency to 3000 Hz to better accommodate people with mid-high frequency loss. (p22) Avoid high frequency flicker – over 2-3 Hz. (p26) **[Vanderheiden and Vanderheiden, 1992]**	See Auditory signals.

Ease of handling	See Annex 3.1 for extracts of Table 8 which are relevant to household appliances): Strength required , Posture Reach and grasping area Angle of rotation of the joints Frequency of Actions Precision required from movements One-hand use **Comment:** Strength required *e.g. for a hand-held blender. What is physical strength of 5th percentile woman?* Posture, relevant for wheelchair users or older people. Reach and grasping area: See DIN TR 124. How relevant to household appliances to grasp rather than push or turn? Also consider Assembly and Maintenance. This would be relevant for some small kitchen appliances.	Portable products: If carrying is an intended use, e.g. vacuum cleaner, the mass should not exceed 5 N. **[DIN Technical Report 124]** **Comment:** Under Strength and Endurance heading, DIN Technical Report 124 says: Strength requirement does not exceed 30% of physical strength of a 5th %ile woman. This requirement depends on the precise action that is being used: For a single handed lift for a 'weak woman', Humanscale gives 12 kg force reduced to 10 kg for a two-handed lift for the over 50's woman. Therefore maximum lift ought to be around 3 kg. Full body lift is more 'ergonomic' because it uses big muscle groups. Kettles, etc. are more like RSI type activities in the workplace, using poor lifting mechanics. The Health and Safety Executive issues guidance on lifting in zones closer to the body. For a woman, kg go from very low. 7 kg is normally used as a safe single-handed lift for women, but 30% of this would only be 2.1 kg. Research is needed to sort this out, in particular with older users, considering differences between something like a vacuum cleaner we carry upstairs to lifting a full kettle, etc.	

Handles and catches *(not a heading in CEN/ISO TR 22411)*		ICE reports give some general guidance on assembly and maintenance of small kitchen appliances: Vertical handles tend to be more ergonomically satisfactory than horizontal handles since a much greater range of users can find a position at which to exert max pulling force. **[ESRI Reference AR192]** However, an ergonomic checklist for dishwashers suggests on the bottom hinged, downward opening doors of a dishwasher the handle should be centrally positioned in horizontal position and at a convenient vertical height. **[ESRI Reference AR218]** **Comment:** A convenient height for e.g. a dishwasher handle is likely to be constrained by under-worktop design, which max would be about 900 mm. This is approximately elbow height of 5^{th} % UK adult (937 mm). Handles should offer a good, comfortable grasp for the hand. Designs which enable the fingertips only to grip may be aesthetically pleasing, but could present problems in use for people with long fingernails, restricted hand function or wet and greasy hands. Door handles: need ample space between the handle and the door for the user's hand. Smooth round finish provide a comfortable grasp. If small gap, would not be easy for someone with large hands or limited hand function to wrap their fingers around the handle. Handles with a square section not so well suited and comfortable as a rounded design. Handles with square sections could with use over a long period and under a range of conditions, be annoying to use. Vertical handles should be fairly large with adequate gap for the hand. The section in contact with the fingers should not be too thin and thus uncomfortable. **[ESRI Reference AR212]** UK 95^{th} % adult width at knuckles = 93 mm **[Humanscale]**	Handle should be obvious and not blend in with appliance. Ideally a convenient height for handles and catches would be between 937-1156 (5^{th} -95^{th} % UK elbow height). For ample space for 95^{th} % adult to use a hook grip handle (which you might find on a dishwasher or washing machine) the dimensions should be: 51 mm deep, 89 mm wide, with a 51 mm lip  This handle design does not require knuckle width, but only adequate finger clearance for all four fingers, if needed. Therefore, even though most users will not need 89 mm, it will accommodate arthritic hands.

<table>
<tr>
<td></td>
<td></td>
<td>In assessment of fridge/freezers: If handle is shallow, larger users may catch their knuckles on the fridge door.

Handle which is a length of curved section metal: users can choose a convenient height (but experts find that it would not provide good grip for someone with impaired hand function (but this was most liked by users!)
[ESRI Reference AR217]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>[ELS 2-003-1] :
Requirements dimensions
<table>
<tr><td>Grip size</td><td>Required dimensions mm</td></tr>
<tr><td>Width w</td><td>≥100</td></tr>
<tr><td>Depth d</td><td>≥60</td></tr>
<tr><td>Height h</td><td>≥35</td></tr>
<tr><td>Bow handle circumference c</td><td>≥50 ≤110</td></tr>
</table>
Comment: These values look like a ‘cylinder handle’ and seem suitable for this type.</td>
<td>For a cylinder handle the dimensions should be:

Length: ≥100 mm
Depth: ≥60 mm
Handle circumference:
≥50 ≤110 mm</td>
</tr>
</table>

		Knob/Handle – Grip (outer door) Requirements for measures in accordance with test procedure section 11.8.3.4 - figure 11.39: A.) Handle length: > 100 mm B.) Handle depth: > 30 mm C.) Handle height: > 60 mm D.) Knob diameter: 70-100 mm The knob/handle should satisfy the above measures.  **Comment:** The handle above looks like all 'knob' types but difficult to comment since the dimensions aren't clearly defined. **Grip surface, handle** Requirements for measures in accordance with test procedure section 11.9.2.7 - figure 11.48: a ≥ 25 mm b ≥ 100 mm c ≥ 35 mm d ≥ 35 mm e ≥ 60 mm All requirements for measures for the evaluated handle should be satisfied in accordance with above. **[ELS 2003-3]** **Comment:** This second example might be a recessed handle. There is data in Humanscale for handle types – we could check it against the original drawings in ELS 2003-3 if we have them, for dimensions, to clarify some values.	

Doors *(Not a heading in CEN/ISO TR 22411)*		**Door** ***The door – general*** **Location of the door** Requirements, no disabilities ≤ 1100; ≥ 1000 mm Requirements, wheelchair user ≤ 835; ≥ 595 mm **[ELS 2003-3]** **Comment:** When viewing the figure in the document, these values appear to show the washing machine on a plinth. The UK wouldn't normally put washing machines on plinths. Standard height is about 860 mm to go under a worksurface at 900. 1000-1100 mm could be a standard product on a plinth 10-20 cm high? Stove, oven, refrigerator and dishwasher openings should be at "no-bend" heights. **[Kroemer, 2006]** **Comment:** Not very practical. Although ideally, we would agree with 'no bend', in practice it won't happen without a bespoke kitchen due to appliance standardisation. Elbow height of 95^{th} % adults = 1156 mm Elbow height of 5^{th} % woman = 937 mm. **[Humanscale]**	Height to the top of the appliance door should be at elbow height (937-1156 mm) from floor.

		If freezer door has a strong door magnet some users may find it difficult to open. **[ESRI Reference AR217]** Minimum strength is needed to open and close the door, e.g. to a washing machine, tumble drier, microwave. **[RNIB, household appliances]** For ‘weak woman’: Pull at waist height, bent arm = 48 N Push = 88 N. **[Humanscale]** **Comment:** DIN TR 124 suggests 30% of 5^{th} % female. So take 30% =14 N Pull, 26 N Push. Consideration should be given to the air seal on chest freezers, which once opened a first time, creates a vacuum that needs to be overcome.	

		The door's design **Size, external door opening** > 300 mm D ≥ 300 mm conforms with **[ELS 2003-2]** for prescribed dimensions of front-loaded drum opening size. For top-loaded drum opening size, length ≥250 and width ≥250. **The outer door's opening angle** > 100^{o} **Comment:** Document in error says mm. **[ELS 2003-3]**	For front-loaded drum of washing machine: .>300 mm opening. For top-loaded drum opening size, length ≥250, width ≥250. Opening angle: >100^{o} but ideally a wide aperture opening fully to 180^{o}.

		Washing Machines: Loading a front loader demands bending considerably at the waist and usually people find it easier to kneel or squat. Low postures might be difficult to achieve for elderly and/or arthritic but they may find it even more difficult and physically demanding to stand up again. Those in wheelchairs will probably find it easier to use front loading particularly if the door can be pushing right back such that it does not interfere with wheelchair access. Front loader high aperture >53 cm Front loader medium aperture 47-52 cm Front loader low aperture <47 cm Extent to which door opens ,e.g top loader from side, or front loader from above. Less than 90^{o} $90\text{-}135^{o}$ $135\text{-}180^{o}$ **[ESRI Reference AR166]** Loading the washing machine was found easy for all users when there was a wide aperture opening fully to $180^{o.}$ **[ESRI Reference AR238]**	

		Opening/closing the door **Opening/closing torque (outer door)** ≥ 0.7; < 1.2 Nm **Opening/closing force (outer door)** < 20 N **[ELS 2003-3]** ***Comment:*** Torque is not very useful here, as machines are unlikely to be any significant values. Pushing is easier than pulling, but we haven't found any values approaching 20 N. Typically a standard force is nearer 80. So 20 N is a good low figure compared to other references. For 'weak woman': Pull at waist height, bent arm = 48 N Push = 88 N. **[Humanscale]** **Comment:** DIN TR 124 suggests 30% of 5th % female. So take 30% =14 N Pull, 26 N Push.	Opening/closing the door (e.g. to a washing machine, tumble drier, microwave): Torque: 0.7 Nm – 1.2 Nm Force: <20 N

		Push button opening (inner and outer door) 1.) Button size: Round: ∅ ≥ 12 mm, square: ≥ 10 mm. 2.) Activation surface: Concave activation surface. 3.) Activation force: ≤ 20 N; ≥ 2 N. 4.) The button differs from the rest of the drum's design: For example in terms of colour or shape. At least 3 of the above points are satisfied. **[ELS 2003-3]** **Comment:** This sort of push button for mechanical release of the door to the washing machine should still follow good design practice, ie, the same recommendations as given for control buttons. Force for buttons operated by index finger: 1.1-5.6 N If it is a bigger latch, it could be considered a handle and better data supplied:  A 2 finger lipped pull latch = 51 mm long, 19 mm deep, 13 mm lip. **[Humanscale]**	Push button opening (eg to open door for washing machine): 13 – 26 mm diameter of push button. Force: Mechanical buttons 2 – 10 N However, force for buttons operated by index finger should take more conservative value from Humanscale: 1.1-5.6 N, so lower force is to be recommended.

Type of controls *(not a heading in CEN/ISO TR 22411)*		Generally designs of arrowhead on buttons with a tail are preferred. Mixing of rotary knobs and push buttons on a waist-level panel could result in an unacceptable configuration. (This evaluation was for an electronic control panel) **[ESRI Reference AR483]** In evaluation trials of cookers, it was recommended that a ridge should be placed at the twelve o'clock position as an aid to grip purchase and control setting indication. Large ridges which may precipitate interference must be avoided. **[ESRI Reference AR418]** The design of a knob can greatly affect its usability by people with low vision or blindness. - No non-visual indication of setting. If vision blurred you cannot tell setting. - Difficult to put large print or braille labels on knob to be read even if user is blind. (Also harder to grasp and requires twisting motion) - Highly visible raised pointer. - Instant tactile indication of orientation allows setting to be read even if user is blind Easy to put larger print or braille labels on back panel. - Use of detents (large and small) can facilitate inter-numeral settings. - Black base disk provides high contrast and helps in control location/orientation on panel. - Design is also easy to grasp and can be turned by pushing the point around - no twisting if the knob turns freely enough (p54)	See Household appliance task and control types for more detail.

		Poor - round smooth knob no tactile orientation cue. Better - has tactile orientation cue but user has to feel around to find it. Better - orientation cue is less ambiguous. However the user must still feel the ends to be sure which is the pointer end. Best - has tactile orientation cue which is unambiguous and can be felt immediately upon grasping knob. (p54) **[Vanderheiden and Vanderheiden, 1992]** **Comments:** Where on a circular scale should numbers start at (e.g. 7 o;clock, 12 o'clock etc.)? All scales on one appliance should be configured in the same way. Touch sensitive buttons on glass or metal surfaces are hard to identify by touch and do not give sufficient feedback about being switched. **[ISO20282-1]** For washing machines, the crucial activities necessary to make it run as intended are: • Program setting • Temperature setting • Extra programming options • Opening/closing the drum and loading/unloading • Filling and cleaning of the detergent compartment **[ELS 2-003-2]** *Recommended spacing between controls:* Push button: 20mm (min), 50mm (optimum) Toggle switch: 25mm (min), 50mm (optimum) Knob and rotary selector switch: 25mm (min), 50mm (optimum) **[Salvendy, p592, from Grandjean, 1979]**	

		Use of different shaped knobs can produce better results. The bar knob with an extended wing and the knobbly knob with deep indentations and large protrusions afforded an easier grip for severely deformed hands. The round knobs necessitate a greater degree of extension of the fingers, which may be difficult for those with arthritis in the hands. **[ESRI Reference AR418 – photos from this report are available]** People lacking fine movement control may be unable to operate controls requiring accuracy (e.g. a mouse or joystick) or twisting or complex motions. (p58) **[Vanderheiden and Vanderheiden, 1992]** Individuals with arthritis, artificial hands, hooks, disabilities which restrict wrist rotation, or disabilities which cause weakness, have difficulty with knobs or controls that require twisting. Also difficult for people with loss of upper body strength, range of motion and flexibility as is common with elderly persons. . . . (Lever handles, now required in many building codes, facilitate access.) **[Vanderheiden and Vanderheiden, p62, 1992]** Concave and non-slip buttons facilitate the use of manipulation devices, artificial hands, hooks and mouthsticks. This is especially true where pressure is required. **[Vanderheiden and Vanderheiden, p62, 1992]**	

		Bar-grip shape, bar-grip knob The surfaces of the bar-grip sides should be parallel and the bar-grip should have the same profile along its entire length. **Distance between knobs and other adjacent components** ≥ 25 **Countersunk knob** The entire knob should be above the surface of the control panel. **[ELS 2003-3]**	See Summary Table of Recommendations for Controls.

Dimensions of manual controls	**Extracted from Table 9 – Dimensions of manual controls** [64] EN 894-3:2000, *Safety of machinery — Ergonomics requirements for the design of displays and control actuators — Part 3: Control actuators* **Figures also found in [DIN Technical Report 124]** **The following figures are for width or diameter of manual control (in mm)** **Contact grip:** Finger (e.g. pressing a button) ≥7 Thumb (e.g. sliding a latch) ≥20 **Pinch grip** Fingers, thumb (e.g. turn a small knob) ≥7 to ≤80 Hand, thumb (e.g. turn larger knob) ≥15 to ≤60 **The following figures are for length of manual control along the axis of movement or axis of rotation (in mm)** **Contact grip:** Finger ≥7 Thumb ≥20 **Pinch grip** Fingers, thumb ≥7 to ≤80 Hand, thumb ≥60 to ≤100	A dishwasher ergonomic evaluation recommended push buttons with an optimum diameter of ½-1" (13-26 mm). Adjacent push buttons should have space between them to prevent inadvertent operation , and locking mechanism to prevent 2 being pressed together. Visually obvious which buttons are in (i.e. ON/OFF) Rotary knobs should be between 2-4" (51-102 mm) in diameter and stand out ½-1" (13-26 mm). Should be easy to grasp (preferably with serrated edges) for those with impaired hand function, wet or greasy hands, or users wearing rubber gloves. **[ESRI Reference AR218]** Larger controls are, in general, easier to operate. Large round controls that have good traction surfaces and turn easily can often be operated with the side of one's hand. **[Vanderheiden and Vanderheiden, 1992]** *Rotary knobs* for the hand should have a diameter of 25 – 100mm, and for the finger 15 - 25mm. The force required to turn it should be 0.3 – 0.7Nm (hand) to 0.02 and 0.05Nm (finger). They are suitable for positioning for 2 or more positions, continuous, precise and quick adjustment. **[Salvendy, p581, Fig 5.3.3]** Cooker control panel: Cylindrical control knob: suggests a depth of 13 mm (Galer, ed., 1987). In their prototype evaluation the depth was 11.5 mm and users found it too shallow (even for 2 women with small hands). Curved blade: same recommendation as above for depth, but this was found to be easier to turn than cylindrical knob. Flat blade: Curved blade was marginally preferred to this flat blade because of the shorter length of flat blade. **[ESRI Reference AR564]** **Comment:** Compare and contrast with hand and finger sizes.	See Summary Table of Recommendations for Controls, including Width or Diameter, Height, Distance between, and Operating Force for Push Button Rotary Knob Rotary Knobs with bar, tail or pointer grip Slider switch Rocker switch

	Comment: Ref 64 is for safety of machinery. How relevant for household appliances? These are also the same figures as in **[DIN Technical Report 124]**	If you can attach a post to a twist knob it becomes a crank and can be operated more easily and without a twisting motion. If the knob is large, a post might be positionable within the circumference of the knob. For smaller knobs, an optional extension rod would provide additional leverage if there is enough room between knobs. **[Vanderheiden and Vanderheiden, 1992]** Optimum sizes can be specified for various types of control. In the case of knobs, the larger diameters are generally more suitable for sensitive controls. Small knobs should be reserved for non-critical adjustments. **[Applied Ergonomics Handbook]**	
		Push buttons **Button size** **[ELS 2003-3]** Requirements, square buttons ≥ 20 mm Requirements, round buttons ≥ 20 mm	

Distance between push buttons

> 10 mm

Shape of activation surface

Concave

Countersinking of the push button

The button’s activation surface NEVER passes the control panel’s surface.

[ELS 2003-3]

		Knob **Size, bar-grip knob** 1.) Bar-grip length: 50 (± 10) mm 2.) Bar-grip height: 23 (± 5) mm 3.) Bar-grip width: 8 (± 4) mm Points 1, 2 and 3 should be satisfied **Size, cylinder knob** Diameter: 35-50 mm Height of grip surface: 18-28 mm **[ELS 2003-3]**	

		If panel space is very limited, the use of minimum values for knob size will not degrade performance provided the resistance is very low. For diameters up to 63.5 mm (2 ½ inches) the torque should not exceed 0.2 nm (2 in lb). Size for fingertip grasp: Diameter – min 10 mm, max 100 nm Depth – min 12.5 mm, max 25 mm If the adjustment required of the knob is critical (e.g. radio tuning), a round knob of (at least?) 50 mm diameter should be used, because there is a limit to a person's sensitivity of movement, and a larger knob allows bigger movements at the end of the knob for fine adjustments. Size for a Moving scale with a fixed mark: Width: 25-100 mm Height: 12.5-75 mm Size for a moving pointer on a fixed scale: Pointer Length – minimum 25 mm, maximum, no limitation set b y the performance of the operator. Pointer Width – minimum, no limitation set by the performance of the operator, Maximum 25 mm Pointer depth – minimum 12.5 mm, maximum 75 mm **[Applied Ergonomics Handbook]**	

		The diameter for a cooker control should be within the range 34mm-41 mm. In making this recommendation it is noted that successful implementation must take into account inter-spindle distances. It is therefore also recommended that standards should be set for inter-spindle distances to ensure that the control diameters recommended can be used without resulting in interference between the user's hand and an adjacent control. **[ESRI Reference AR418]** In evaluation trials of cookers, it was recommended that a diameter of 50 mm is better than a diameter of 40 mm for people with arthritis. For able-bodied subjects the size of the control knob was relatively unimportant provided it was in the range of 1-3¼ inches (25-85 mm). Thus it is not always possible to use the results from one population to make recommendations regarding design for another population. **[ESRI Reference AR418]** *Rotary selector switches* (with a pointer at the front and flat at the rear) should have a length of 30 - 70mm, a height of > 20mm, and a width of 10-25mm. The force required should be: 0.1 – 0.3 Nm for 30mm long switch, and 0.3 – 0.6Nm for 30-70mm long switch. They are suitable for positioning for 2 or more positions, precise adjustment, precise adjustment, large force application, tactile feedback and for making the setting visible. **[Salvendy, p581, Fig 5.3.3]** *Thumbwheels* should have a width of > 8mm, and require a force of 0.5 – 5Nm. They are suitable for positioning for 2 or more positions, continuous, precise and quick adjustment. **[Salvendy, p581, Fig 5.3.3]** **Comment**: Some of these values depend on the size. For example, a 'finger sized' thumbwheel should be maximum 1 Nm, but a larger one could be greater, i.e. 5 Nm. In any case, thumbwheels need to project far enough for arthritic fingers to use and it can be difficult to see the markings.	

		A rocker switch should have a width of > 10mm, a half length > 15mm. and require a force of 2 - 8 Nm. They are suitable for positioning quick adjustment, tactile feedback and making settings visible. **[Salvendy, p582, Fig 5.3.3]** *A push button* (finger) should have a diameter of > 15mm, should require a force of 1 - 8 Nm. They are suitable for setting 2 positions and quick adjustment. A button may latch and hold a status (e.g. power on) or initiate an instantaneous action e.g. send a spark to light a gas flame. **[Salvendy, p583, Fig 5.3.3]** *Key design*: 25-150 grams of force, preferably adjustable with tactile and audible feedback, 2-5 mm of travel, 12-15 mm surface dimensions, 18-20 mm spacing. **[Vanderheiden and Vanderheiden, 1992]** *A flat slide* should have a length of > 15mm, a width of > 15mm, and require a force of 1 - 10Nm. They are suitable for positioning for 2 or more positions, continuous, precise and quick adjustment, and for making the setting visible. **[Salvendy, p583, Fig 5.3.3]** *A pinch slide* should have a height of > 15mm, a width of > 15mm, and require a force of 1 - 10Nm. They are suitable for positioning for 2 or more positions, continuous, precise and quick adjustment, and for making the setting visible. **[Salvendy, p583, Fig 5.3.3]** Diameter changes of at least 3/8" and thickness changes of at least 1/32" are more readily detectable by people who are blind. (p46) Use absolute reference controls (e.g., pointers) rather than relative controls (e.g., pushbuttons to increase/decrease, or round, unmarked knobs). (p53)	

		- Absolute reference controls (such as knobs with pointers) allow the user to determine their settings by directly sensing the control itself. Relative reference controls (like up/down volume control buttons, or the dial on a radio) require the user to view (or listen to) some other display while operating the control. Relative reference controls are more difficult cognitively and sensorially. - Moving pointers and stationary scales (e.g., rotating pointer with numbers on the panel) are better than moving scales and a stationary pointer (e.g., rotating knob with numbers on the knob). A user who is blind or has low vision can use knob (pointer) position to indicate setting. People with cognitive impairments can remember knob orientation or scale position rather than dealing with scale readings. It is also easier to attach large print, raised letter or braille labels to a stationary scale. Scales placed directly on a rotating knob are also mostly sideways or upside down. (p53) **[Vanderheiden and Vanderheiden, 1992]** Often controls are also displays. If the user has to make a particular setting, then he must be able to see when he has achieved it, and to make a quick visual check at any time. The ‘up-down’ toggle switch gives a clear indication of its setting; the push-pull switch and double-action push-button do not. For the latter controls, an additional indicator lamp is recommended, and certain components incorporate such indicators. Rotary switches are commonly used, but rarely with good pointer-shaped knobs to provide unambiguous indication of their setting. The size of the knob and the colour contrast between it and the panel, can also help the user, as does the adoption of a clock-face layout. The familiar positions are easily read, and the user can set the switch accurately even without looking. **[Applied Ergonomics Handbook]**	

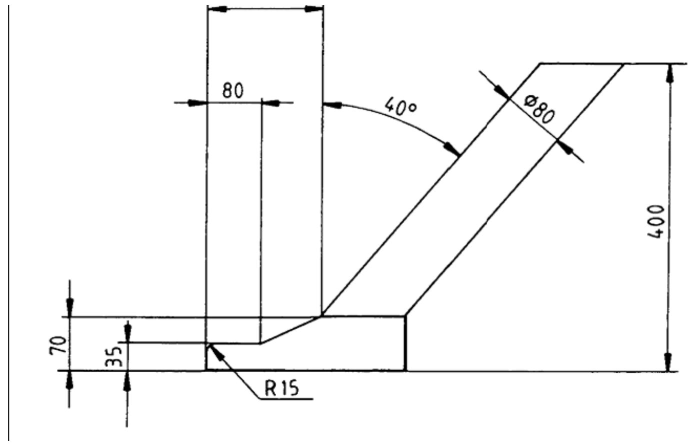
		The user is less likely to operate the wrong controls if he can distinguish them easily through differences of shape, colour and position. The use of shape to differentiate controls is particularly valuable, for the user can quickly and accurately recognize a hand-operated control by its 'feel' alone. **[Applied Ergonomics Handbook]** **Comment:** This may conflict with the aesthetics of the product.	
		Comments on some common types of controls: (controls towards top of list are generally more accessible) • Rocker switches (concave) + good example of push-push switch + good feedback for visually impaired users • Controls all operable from a single keyboard/keypad + good, especially if keyboard is repositionable • Pushbutton controls + good for head/mouthstick operation (preferably concave button requiring less than 100 grams of pressure) • Double-acting pushbutton controls + Push-push controls better than push-pull -difficult for blind users to tell status unless button locks in • Up/down (integrating) control buttons (e.g., volume control buttons) + requires little manipulation + best if light action and concave button - requires monitoring of some other output to determine setting - hard for visually impaired users if setting values are displayed visually - hard for deaf or hard of hearing users to judge volume (to others) - requires person be able to hold hand in place - requires timing/reaction time **Comment:** 100 g = 0.1 kg. 1 Kgf = 9.8 N (say 10 N), therefore 0.1 Kgf = 1 N. This corresponds to the very lowest reference in our control recommendations – too low really to avoid inadvertent operation. Given occasional mouthstick use, a greater force is ok (i.e. 2-5 N)	

		• Sliding or edge-operated controls + good for users with physical disabilities – problem for users who are blind – may be difficult for users who cannot stabilize their hands to make fine adjustments (especially sliding) • Light action + low effort, low fatigue – can cause multiple activation problems if too close together • Touch sensitive – very difficult for person who are blind to locate without activating. – must provide some other (auditory or tactile) feedback for blind users to be able to tell they have activated it. – heat or capacitive based touch switches may not react to mouth or headsticks NOTE: Some diseases such as diabetes and "white finger" can cause loss of sensation in the fingertips. Therefore, controls that are dependent on tactile feedback should not rely on fine tactile sensation. **[Vanderheiden and Vanderheiden, 1992]** **Comment:** Further research on recommended contact area and feedback for touchscreen buttons or objects? Also remote control of household appliances could be an upcoming area to investigate. (See section heading "Ergonomic data on human abilities and the consequences of impairment' for more detail.)	

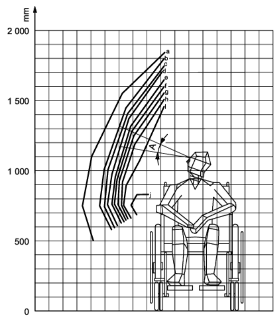
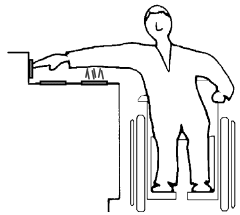
Force/torque for manual controls	**Extracted from Table 10 – Classification of force/torque for manual controls [64]** **Force/torque for female** <7 N) <0.33 N.m) negligible 7 N to , <17 N) 0.33 N.m to <1.0 N.m) low 17 N to < 33 N) 1.0 N.m to <2.0 N.m) low to average **Comment:** Ref 64 is for safety of machinery. How relevant for household appliances? These are also the same figures as in **[DIN Technical Report 124]**	Regarding electronic control panels, if there is a plastic membrane over a flush surface, it may require an excessive force to be exerted for switch operation. **[ESRI Reference AR483]** Controls should provide some resistance but not be too stiff. **[ESRI Reference AR218]** Advisable that machine can be switched on and left to operate without need for constant pressure on switch (so not tiring for those with severe weakness or painful joints). **[ESRI Reference AR306]** In holding, grasping and moving, it should be considered that strength is reduced to 30% of the physical strength of a 5th percentile woman according to DIN 33411-5. **[DIN Technical Report 124]**	These values have been considered in our own recommendations, e.g: Mechanical buttons 2 – 10 N Membrane buttons 2 – 5 N

		Hand Grip Strength (HGS) (kg), Mean = 29.7 = 297 N Pinch Grip Strength (PGS) (kg), Mean = 5.75 = 57.5 N [suggested values from a dexterity study with 14 users over 65 years of age in a thermo-neutral testing environment between 19°C-24°C.] Hand grip:Maximal grip strength (kg) a person can exert with their hand (measured by squeezing together the middle joints of all 4 fingers and the palm). Just the dominant hand was measured by following the standard protocol as provided with the dynamometer (Takei Scientific Instruments - T.K.K.5401 Grip D [Digital Grip Dynamometer]). The test was repeated three times and mean averaged. Pinch Grip: Maximal force that can be exerted between the index finger and thumb pulps. Just the dominant hand was measured in a standardised posture. The maximum force was measured in kg and was repeated three times then mean averaged. Equipment used was the Baseline Hydraulic Pinch Gauge. **[Elton, Dumolo and Nicolle, 2010]** **[Elton and Nicolle, under review]** **Comment: [from Humanscale]** Maximum static pinch grip (tip): Female (weak) 33N Pinch grip (lateral): Female (weak) 40 N Hand grip static squeeze: Female (weak) 235 N. (Compare these values with Elton et al above.) Gripping surfaces should be adequate to allow for the torque of the switch; a maximum torque of 2.5 nm (22 in lb) should not be exceeded. **[Applied Ergonomics Handbook]**	

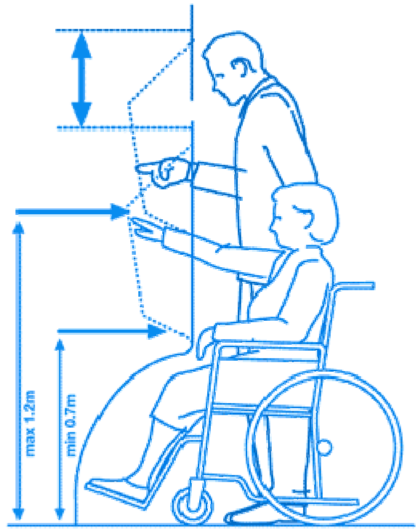
		Activation force in N Requirements, mechanical buttons (N) ≤ 10; ≥ 2 Requirements, membrane buttons (N) ≤ 5; ≥ 2 **Torque** Requirements, bar-grip knob (Ncm) ≥ 10; ≤ 20 Requirements, cylinder knob (Ncm) ≥ 2; ≤ 10 **[ELS 2003-3]**	
		The shape and size should show the user to operate the controlling part with a suitable force. **[JIS S 0012:2000]** **Comment**: Is the contact area big enough?	
		The pressure to activate a key should be between 0.5 and 1 Newton. **[RNIB, household appliances]**	

Knee and toe clearance	8.12.7.4: Where space below an object such as a basin is added to clear floor, ground space or turning space, a design providing enough space for knee and toe clearance is required. Additional space below an object cannot be considered as part of the clear floor or ground space or turning space. See Figure 21 **Comment**: Relevant to a floor standing appliance (e.g. washing machine) being used by a wheelchair user. Figure 21 on Leg Clearance is difficult to interpret out of context.	The ground clearance for the door(s) of floor standing cooking ranges when fully opened shall be at least 70mm. (As foot gauge dimension in EN 60335-2-77 clause 20.103.4 Fig104.) Clause 20.103.4 states Inadvertent access to the **cutting means** by the feet during operation shall be prevented, so far as reasonably practicable. **[EN 60335-2-77, Household and similar electrical appliances - Safety - Part 2-92: Particular requirements for pedestrian-controlled mains-operated lawn scarifiers and aerators]** 	

		Comments: Ground clearance of 70 mm (given above) is a minimum dimension to prevent access, rather than a maximum to prevent feet being squashed, so the logic doesn't really hold. The figures above give dimensions that could be used to recommend clearance. Heels would reduce lateral access (i.e. 40^o angle) so clearance would be similar. So, there are two types of clearance to consider: 1. Enough space to ensure you don't get your feet caught (i.e. at least 70 mm for fully opened door of floor standing cookers), 70 mm is very low (25 percentile UK adult) and doesn't allow for footwear or heel depth. Recessed step minimum height is 152 mm in Humanscale. 95^{th} % UK adult foot height = 88 plus heel of 25 mm, plus socks and uppers = 88 + 25 + 10 = 123 mm. So, with clearance to avoid contact 150 seems reasonable. 2. Enough space to ensure you can get close enough to the appliance. This needs some practical testing. Users might adopt coping strategies (e.g. approaching from the side) and postures. We would suggest further research.	

Reach ranges	8.12.7.8: Most people, whether standing or sitting and regardless of their ability to move the upper body and arms, can reach a height of 850 mm. The ability of wheelchair users to move their upper body varies widely, resulting in a large range for reach. Figure 22 shows comfortable sideways reach contours for wheelchair users depending on arm mobility, as an example. **Comment:** This figure also illustrate the highest comfortable viewing angle  **Key** A highest comfortable viewing angle a 10 % b 20 % c 30 % d 40 % e 50 % f 60 % g 70 % h 80 % i 90 % j 100 %	Normal placement of stove controls poses serious reach and safety problems for individuals who are very short or in a wheelchair. (Figure I-1-b, p45) **[Vanderheiden and Vanderheiden, 1992]**  Products should be designed so that when they are used, the functional grasping area is not exceeded. The following reference values have been established in practice: • Maximum reach upwards: 140 cm above the floor. • Maximum reach downwards: 40 cm above the floor. • General operating height: 85 cm above the floor. **[DIN Technical Report 124]** **Comment:** Fig. 22 in 22411 is relevant to viewing displays and viewing/reaching controls. Maximum reach upwards: 135 cm – small female. Maximum reach downwards: 47.5 cm – small female. Maximum reach downwards for Average adult = 38.9 cm Kitchen counter height for small female: 78.7 cm. **[Humanscale]** **Comment:** Humanscale goes to 2.5%ile, so recommended values from DIN TR 124 above seem ok. Table 10.6, p183 in 'Bodyspace' by Stephen Pheasant contains anthropometric estimates for older people including for example: eye height, elbow height, knee height, vertical and forward grip reach. Maximum height for small female = 1156 mm Lowest height of any operable part = 660 mm **[Humanscale]**	

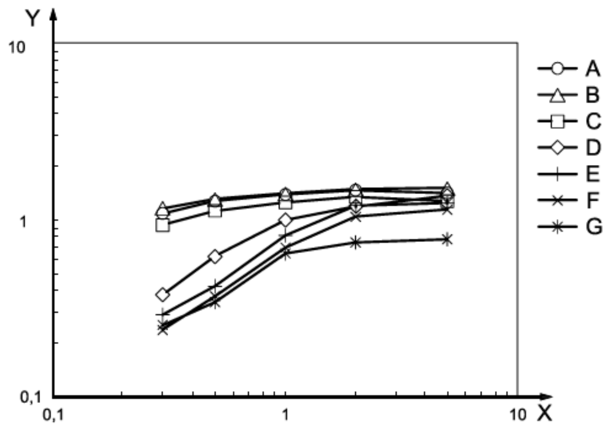
		See Annex 3.2 for Electrolux Laundry Systems 2003-3, Part 3: document-based evaluation for washer extractors **[**ELS 2-003-3] for Anthropomentric data for British adults, age 19-65. In many cases 500 mm (height of the wheelchair) can be added to the measures relating to seated people in this table.	

	The following examples can be given as dimensions of reach ranges for a person in a wheelchair whose individual ability to move the upper body and arms is unobstructed. Where a forward reach is unobstructed, the upper forward reach can be 1 200 mm maximum (optimum = 850 mm) and the lower forward reach can be 360 mm minimum above the floor or ground. See Figure 23, Unobstructed forward reach (full mobility of the upper body and arms). **Comments:** Relevant for position of controls (mainly for floor-standing appliances) or for one stored on the near edge of the countertop. 850 mm is a compromise, rather than optimum. Lower forward reach of 360 mm requires full mobility which seems a bit odd. In the absence of research, nearer 660 mm would be better. Therefore, further research is recommended.	If only a forward approach in a wheelchair is possible, then the maximum height of any interactive element on the terminal should not exceed 1.2 metres. Lowest height of any operable part not less than 0.7 m.  **[Gill, J., 2004, Access-Ability. Royal National Institute of Blind People.]**	Maximum upper reach for controls = 1200 mm Lowest forward reach for any control 660 mm above the floor. General operating height = 850 mm above the floor. This height takes into account standing and sitting, including those in wheelchairs. Although not optimum, it is an acceptable compromise.

		In designing the product, it should be considered that space for movement of upper body and arms is reduced to envelope curves corresponding to the functional grasping space of a 5th percentile woman. Thereby in addition to the optimum grasping space (e.g. in a sitting position, 28 cm from the edge of the table towards the front), the bending ability of the upper body* is also taken into account. *It is assumed that it is possible to bend the upper body in order to extend the grasping space to the functional grasping space (e.g. 38 cm forwards from the edge of the table). **[DIN Technical Report 124]** **Comment:** Bending ability and trunk mobility are taken into account with the recommendations above to some degree. A static reach would be just the arm length (668 mm) plus relevant dimension.	
	Where a clear floor or ground space allows a lateral approach to an object and the sideways reach is unobstructed, the upper sideways reach can be 1 220 mm maximum (optimum = 850 mm) and the lower sideways reach can be 360 mm minimum above the floor surface or ground. These reach values are still valid as long as obstructions on the floor do not exceed a depth of 255 mm. See Figure 24, Unobstructed sideways reaches.		Reach ranges above are still valid when requiring a lateral approach, as long as obstructions on the floor do not exceed a depth of 255 mm.

Feedback	8.17.2: Consideration should be given to the provision of appropriate feedback when each action in a sequence of actions is successfully completed. [ISO/IEC Guide 71:2001, 8.17.2] **Comment:** Can any specific values be proposed for household appliances? We can recommend feedback, e.g. volume of beeps in a bread-making machine when certain ingredients need to be added or when the bread is done, but are there specific values?	Tactile confirmation is given by means of a raising/lowering of the knob and relief on the control panel. The relief on the control panel must have a profile that is 0.5 mm high and 1 mm wide. **[ELS 2003-3]** **Comment:** Recommendation for Tactile Feedback can be found under Tactile Markings, using higher values than these in order to take into account arthritic fingers.	
Sharp points	8.18.2 Surfaces should be free from sharp points and edges which are a potential hazard to anyone but are particularly so for someone with a visual or touch impairment. [ISO/IEC Guide 71:2001, 8.17.2] The rounding of edges and corners e.g. radius ≥ 2 mm (ISO 9241-5)	Handles with a square section not so well suited and comfortable as a rounded design. **[ESRI Reference AR212]**	

The following headings from CEN/ISO TR 22411 relate to general aspects of human abilities and the consequences of impairment. Therefore, the values that may be suggested here have already been provided in earlier recommendations.			
Ergonomic data on human abilities and the consequences of impairment	9.1: For some human abilities, large-scale data sets are presented by descriptive statistics to illustrate the individual differences. The accumulated data are not always utilized directly in designing products and services. However, knowledge of human abilities is indispensable for standards developers and product designers whose work takes into account the needs of older persons and persons with disabilities. **Comment**: Difficult to make that leap from the data sets to requirements for performance standards. Where we have no values for household appliances, should introduce data from e.g. Humanscale and Older Adultdata where relevant, as a second stage to the research, which still needs more work?	The design of an everyday product should consider the global distribution of the intended user population's body dimensions, see ISO 7250 from Bibliography of ISO/TR 22411. Example: Buttons on a touch screen designed for average finger size are revealed to be unable for persons with large fingers. The size is changed to suit all but the 5% of the intended user population with the largest fingers. On another application, sufficient space is available so that there is no need to limit the size to accommodate only up to the 95th %, and 100% of the users are supported, however large their fingers. **[ISO 20282-1]** **Comment**: Is the contact area big enough? Button spacing on membrane switches should be 12.7 mm centre to centre, according to Humanscale. This probably refers to calculator type applications, and does not address the older and disabled population. Further research on recommended contact area and feedback for touchscreen buttons or objects?	

Visual acuity	9.2.1.2.1: Figure 30 shows visual acuity as a function of viewing distance for seven age groups from 10–19 years to 70–79 years of age [82] The data were obtained with a high contrast test chart (Landolt ring “C” printed black on a white background) at the luminance level of 100 cd/m^2 The participants wore optical lenses so as to obtain the best corrected acuity at the far point (5 m). The data were collected from a total of 111 participants stratified into different age groups. (See figure in next column)	In a cooker evaluation, control settings “high” “Lo” were misleading as “Lo” looked like 10. **[ESRI Reference AR227]** **Figure 30 — Visual acuity as function of viewing distance for seven age groups**  **Key** X viewing distance (m) Y visual acuity A 10–19 years of age B 20–29 years of age C 30–39 years of age D 40–49 years of age E 50–59 years of age F 60–69 years of age G 70–79 years of age NOTE 1 Data were taken at a luminance level of 100 cd/m^2, for corrected eyes at 5 m. NOTE 2 A visual acuity score of 1,0 is the nominal reference.	

<table>
<tr><td></td><td>Comment: This visual acuity data cannot easily be translated to performance data.</td><td>Up to a point, the eyes function better the more light they receive. Beyond that point glare can become a problem. At least 200 lux should be provided for adequate visual performance on general tasks and up to 2000 lux for finer or more difficult tasks.
[Applied Ergonomics Handbook]

Other guidelines for artificial lighting in the home are: (Grandjean, 1973)
Room Lighting intensity (lux)
Living room 120 -250
Bedroom 50-120
Children’s room 120-250
Kitchen 250-500
Bathroom 100-400
Stairs and passages 120-250</td><td></td></tr>
<tr><td>Colour combinations</td><td>9.2.1.2.2: Table 12 — Colour combination of fundamental colours and their distinctiveness (for older people at photopic level).

Comment: Guidance is available in table 12 on most appropriate colour combinations and hues. The Grey and White combinations might be most relevant as most kitchen (especially floor-standing) appliances are white or silver.</td><td></td><td></td></tr>
</table>

Useful field of view	Figure 34 shows examples of the UFOV area defined by the 50 % detectability of a disk target with variable contrast, or with variable colour, presented on a uniform grey background for 50 younger people (18–26 years old), and for 50 older people (50–78 years old) [84] Contrast is defined here as ratio between background and test target. It is clear that the UFOV is smaller for older people than for younger persons under all conditions. The range of the Useful Field of View (UFOV) declines with age, and is affected also by characteristics of the target such as size, contrast, illumination and so on. The larger the target size and the higher the contrast, the larger the UFOV span becomes. Colour difference between the target and the background is also an important factor affecting the UFOV span. The larger the colour difference, the larger the UFOV span. **Comment:** Useful field of view probably not so relevant for small household appliances.		

Contrast sensitivity	9.2.1.7: . . . for a visual stimulus at 100 % contrast (the ideal contrast of black and white characters such as those used in a Landolt ring or Snellen chart), the range of visible spatial frequencies are 0,01 cpd to 30 cpd, 0,01 cpd to 20 cpd, and 0,01 cpd to 3 cpd for younger people, older people and people with low vision, respectively. A visual pattern that contains frequency components beyond the range, i.e. higher or lower than the limit, is difficult to see clearly. At a lower contrast, 10 %, for example, the range of visible spatial frequency is very restricted. For a person having low vision, the range is limited to about 0,15 cpd to 0,8 cpd, while it is more extended from approx. 0,09 cpd to 9 cpd and 0,08 cpd to 20 cpd for older and younger people, respectively. **Comment:** Not very helpful for determining text size/contrast for appliances.		
	Table 13 from ISO/TR 22411 – Contrast multiplier for different ages. **Comment**: Relevant for electronic displays, but is there an easier method to decide values?		

Hearing sensitivity	9.2.2.1¨ To ensure that 90 % of 70 year old adults can hear a 2 000 Hz signal as well as does an 18 year old, the signal would have to be made at least 30 dB louder. **Comment**: To what extent can this be converted to appropriate sound level for auditory feedback/warnings? 9.2.2.2.1: In quiet surroundings, acoustic signals of 55 dB – 65 dB (A) are usually preferable [46] for listeners including older people without serious hearing loss [88]		Sound levels should be adjustable to meet the needs of the user.

	Section 9.2.2.2.2: Auditory signals in noisy environments. The minimum level difference between an audible signal and a background noise has been determined experimentally, as shown in Table 14 [89]. The listeners were young adults aged 18 to 24 and older adults aged 55 to 79, all having otologically normal hearing for their ages. The signal was a short pure tone and the background noises were domestic noises typical in Japan [90] When the signal level was higher than the noise level by the amount given in Table 14, ninety percent of each listener group responded that the signal was barely audible. In the same experiment, both listener groups responded that the signal was audible enough when the signal level reached 75 dB. **Comment**: Consider minimum and optimum sound levels See Table 14 from ISO/TR 22411: Minimum level difference between signal and background noise in order for the signal to be audible against the noise.		

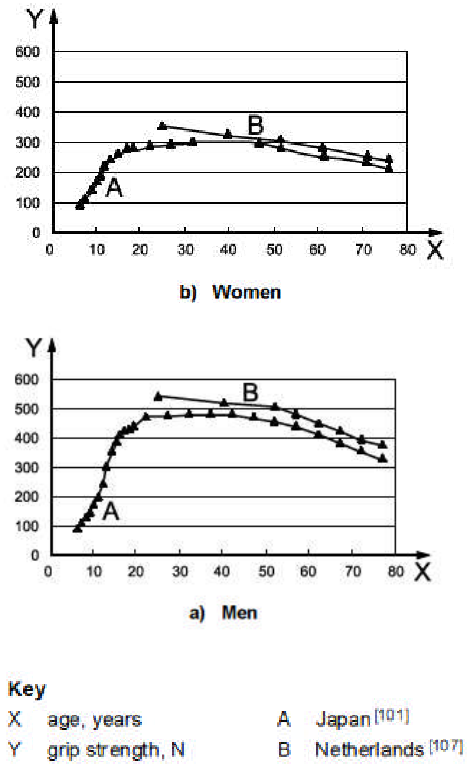
Tactile spatial resolution	9.2.3.2 Spatial resolution is the most important tactile characteristic to be considered when creating alternatives to visual information on spatial content. Spatial resolution is the ability to determine the distance between two objects presented simultaneously on the skin. The threshold is generally measured by the closest distance two objects can be apart and still sensed separately. For fingers, the resolution is approximately 1 mm–3 mm, with the forefinger having the highest sensitivity. . . . The ageing effect on tactile spatial resolution has been reported [93] The data show that for all body regions, the thresholds are much higher for older participants than younger. Older persons thus have much less tactile spatial resolution capability. In general, sensitivity decreases for older persons by about 50% for a whole body region. **Comment**: See Figure 45, Ageing effect on tactile spatial resolution. How to interpret the data in Figure 45 for assessing sensitivity in palm, finger base and fingertip when using controls for household appliances, e.g with tactile dots or symbols on appliances? Also see Figure 46, Tactile spatial resolution. The threshold, when defined by a 75 % correct response rate, for the gap detection and the grating orientation recognition is about 1 mm and 2 mm, respectively. For letter recognition, the threshold, defined as 50 % correct, is 5 mm.		

Physical abilities	Table 17 provides a list of physical variables, some of which may affect controlling household appliances. The only variables that are particularly affected by age are the following: Gripping force Pulling force Torque Shoulder strength Elbow strength Wrist strength Wrist – pronation Wrist – supination Wrist – flexion Wrist – extension Wrist – deviation (radial and ulnar) *(minimal effect)* Reaching envelopes Comfortable reaching vertical – standing Maximum reaching vertical – standing Comfortable reaching horizontal – sitting Maximum reaching horizontal – sitting **Comment**: To what extent will these affect controlling household appliances?	Advisable that machine can be switched on and left to operate without need for constant pressure on switch (so not tiring for those with severe weakness or painful joints). **[ESRI Reference AR306]**	
Dexterity	9.3.1.2: Figure 50 shows the hand steadiness measured for different age groups from 20 yrs to over 80 years of age [107]. The hand and arm were not allowed to be supported. The hand steadiness score is equivalent to the minimum hole diameter. The diameter increases with age, meaning that fine motor control deteriorates with increasing age. **Comment**: Relevant to pressing small buttons on household appliances.	Avoid designs which require complex assembly procedures, eg involving nuts, bolts, clips, etc. They might involve fine manipulative skill and careful location of various parts so difficult for people with dexterity or coordination difficulties. i.e. the best food processors have fewer parts and are easily assembled. **[ESRI Reference AR306]** Small and stiff knobs on ovens difficult to use when wearing oven gloves. **[ESRI Reference AR227]** **Comment**: Difficulty of using controls when wearing oven gloves is relevant to everyone.	

Reach envelopes – when standing	9.3.2.2: The reach envelopes in upper limbs have a great effect on manipulation. The reach envelope depends on the range of motion (RoM) in upper limbs and, generally, the RoM decreases with age. Age-related differences for reach envelopes when standing and sitting were measured in the Netherlands in 1998 with healthy people [107] See Table 19 for the envelope of comfortable and maximum vertical reach when standing for six groups of different age and stature. Figure 53 shows graphical representations of the data for a group of people over 75 years of age and less than 165 cm in height, and for a group of people aged between 20 and 30 and more than 175 cm in height. **Comment**: Relevant for reaching to high controls, eg. on a fridge/freezer. The data from tables referred to above all come from Steenbekkers and don't change anything we've already recommended.		

Reach envelopes – when sitting	See Table 20 (Envelope for horizontal reach when sitting, as a function of age) provides the envelope of comfortable and maximum horizontal reach at sitting for three groups of different age and stature. Figure 54 shows the data for a group of over 50 years of age and less than 170 cm in stature. The data were taken by asking people to mark with the right arm the area within reach on the horizontal plane at elbow height. *Comfortable reach* is a reach without bending the body forwards; *maximum reach* is a reach with bending the trunk. The data in the comfortable range in both Tables 19 and 20 can be used for situations in which individuals have to reach frequently for products. The data of the maximum range can be used for situations in which individuals have to reach for light-weight products or in which products have to be reached for only occasionally [107] **Comment**: How relevant for wheelchair users when accessing using controls on household appliances? The data from tables referred to above all come from Steenbekkers and don't change anything we've already recommended.	In designing the product, it should be considered that space for movement of upper body and arms is reduced to envelope curves corresponding to the functional grasping space of a 5th percentile woman. Thereby in addition to the optimum grasping space (e.g. in a sitting position, 28 cm from the edge of the table towards the front), the bending ability of the upper body* is also taken into account. *It is assumed that it is possible to bend the upper body in order to extend the grasping space to the functional grasping space (e.g. 38 cm forwards from the edge of the table). **[DIN Technical Report 124]** **Comment: Comfortable range:** If we ranked controls (e.g. primary controls = on/off and safety, secondary = functionality, tertiary **=** preference),then we could offer grouping advice. Comfortable reach should be for primary controls, and most dimensions allow for that. Maximal reaches quoted are just that – maximum including torso movement/shoulder 'punching' etc. – normal movements but not always employed. Our recommendation would be less strict – if we could strip out lower order controls and allow their placement in more demanding areas. There would be value in identifying primary, secondary and tertiary controls by criticality of function and frequency of use. The recommendation would then be to require that the most important (primary) controls are located within the comfortable reach of the majority of the population (5^{th} % woman to 95^{th} % man).	

Rotation: Pronation	9.3.2.3.1 – see anthropometric data summary.		
Rotation: Supination	9.3.2.3.2 – see anthropometric data summary.		
Strength and endurance	9.3.4.1: Elderly females are only two-thirds as strong as males of the same age on average. In a healthy population, there is an eight-fold difference in gripping force between the strongest and weakest groups of persons. Older persons are also less strong than younger persons when pushing with two hands or pulling with one hand. For the strength of constructions, it is recommended that the strongest individual be used as the criterion. For handling products, the weakest individual should be used. The ability to exert force decreases with age.	In holding, grasping and moving, it should be considered that strength is reduced to 30% of the physical strength of a 5th percentile woman according to DIN 33411-5. **[DIN Technical Report 124]**	

Grip strength	9.3.4.2: *Contact grip* is one where a unidirectional force is applied by a finger, the thumb or hand to the control. *Pinch grip* is one where the control is held by fingers and/or thumb without clenching the fist. *Clench grip* uses all fingers wrapped around the control (see ISO 9355-3). The size suitable for a control depends on the type of grip used. See earlier 8.12.3.1. Figures 63 provides the maximal grip strength for Japanese males and females as a function of age [101] Grip strength data were obtained for both right and left hands as maximal-effort contraction. Measurements were made on the right and left side, with two trials on each side in a standing position. The results of Steenbekkers and van Beijsterveldt [107] are also shown for comparison. (See figure in next column) **Comment**: Contact actuation and Pinch actuation relevant to operating controls. Clench actuation may be relevant only for the handle?	 **Comment:** Clench actuation may be used by people with stiff fingers instead of pinch grip.	

Pushing/pulling strength	Figure 72 indicates the relationship between the height of the grip and the pushing and pulling strength values. The pushing and pulling strength values were taken from about 200 Japanese males. Measurements were performed when standing. Figure 73 provides the relationships between height of the grip and pushing and pulling strength. **Comment**: These graphs could possibly feed into recommendations for maximum pushing strength and maximum pulling strength required e.g. when closing or opening appliance doors? However, these forces seem to apply to moving items rather than closing doors. How relevant for household appliances, when comfortable forces in any case should be recommended?		

Annex 3.1: Extracts from Table 8 Aspects of handling for ease of use (CEN/ISO TR 22411) with comments

Aspect	**Influence of the aspect in a product or service**	**Example**	**Loughborough's Comments or Values needed**
Strength required	For a product to be handled easily with one or both hands, avoid excessive load of the skeletal muscle of upper limbs (i.e. muscles that contribute to forward elevation of upper limbs or holding of products, and so on). The muscular strength of the skeletal muscle is greatest in youth and middle age.	The strength does not exceed 30 % of the physical strength of a 5th percentile woman [46] [46] DIN Fachbericht 124:2002, *DIN Technical Report 124 — Products in Design for All*	*e.g. for a hand-held blender. What is physical strength of 5th percentile woman? This depends on the exact action under scrutiny.*
Posture	Some users have difficulty kneeling or squatting. Some users are limited to a seated position or are unable to bend joints.	Ensure products/services can be used while seated.	*Relevant for wheelchair users or older people.*
Reach and grasping area	Users have a limited region to comfortably reach and grasp objects.	An example of the grasping area is shown in Figure 14 in TR22411.	*See DIN TR 124.* *How relevant to household appliances to grasp rather than push or turn? Generally people will move to most comfortable position to operate household appliances.*
Angle of rotation of the joints	Some users have difficulty rotating their wrist or arms through large angles.		
Frequency of actions	Strain on a joint can result from repeated actions, particularly where force is excessive.		
Precision required from movements	Some users have coordination difficulties or tremor, making simple actions like inserting a key more difficult.		
One-hand use	Some users have only one functioning hand. Products can be designed for one-handed use of either the left or right hand.		

Annex 3.2: Extract from Electrolux Laundry Systems 2003-3, Part 3: document-based evaluation for washer extractors [ELS 2003-3]

This data has been checked against *Peoplesize (data on the right).* The ELS document contains the usual dataset, and although there are differences, they are within acceptable limits.

				Peoplesize			
Dimension	**Men, 95th percentile (mm)**	**Women, 5th percentile (mm)**		**UK adults 18-64 95th % male**	**5th % female**	**UK** 95th % male	**UK 5th % female**
Shoulder breadth	510	355		441	345	449	339 (acromium)
Standing eye height	1745	1405		1729	1436	1754	1415
Standing shoulder height	1535	1215		1533	1252	1556	1231(acromium)
Standing elbow height	1180	930		1173	963	1192	984
Standing hip height	1000	740		983	767	1002	752
Standing knuckle height	825	660		831	667	845	657
Standing knee height	595	455		542	435	552	426 (knee cap)
Sitting eye height	845	685		850	660	863	649
Sitting shoulder height	645	505		673	504	684	494
Sitting elbow height	295	185		272	161	276	157

Note: In many cases, 500 mm (height of the wheelchair) can be added to the measures relating to seated people above.