
**Ergonomics of human-system
interaction —**

Part 430:

**Recommendations for the design
of non-touch gestural input for the
reduction of biomechanical stress**

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Published in Switzerland

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

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

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

This document was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 4, *Ergonomics of human-system interaction*.

A list of all parts in the ISO 9241 series can be found on the ISO website.

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

Introduction

Non-contacting hand and arm gestures (e.g. mid-air gestures) for interacting with computing devices are emerging as a useful form of input for both consumer and commercial applications.

Non-contacting gestures can be particularly well-suited for certain tasks, equipment and environments, such as with wearable technology (e.g. head-mounted displays, instrumented gloves), in dirty or sterile settings (e.g. kitchens or operating rooms) or for tasks where both hands are also used for other activities (e.g. sorting packages).

This document provides guidance on the design and selection of non-contacting hand and arm gestures and recommends methods for the usability and ergonomic evaluation of gestures in order to prevent fatigue and discomfort during prolonged gesturing.

ISO 9241-910 provides a common set of terms, definitions and descriptions of the various concepts central to designing and using tactile or haptic interactions. It also provides an overview of the range of tactile or haptic applications, objects, attributes and interactions.

ISO 9241-920 provides basic guidance (including references to related standards) in the design of tactile or haptic interactions.

ISO 9241-940 provides ways of evaluating tactile or haptic interaction for various aspects of interaction quality, such as haptic device attributes, logical space design and usability.

ISO 9241-960 provides guidance on gestures for tactile or haptic interaction. It explains how to describe their features and what factors to consider when defining gestures.

There are many factors to consider in the selection of non-contacting hand and arm gesture sets for human-computer interaction, including task, workstation, environment, natural language, recall, common existing contacting hand gesture sets, technology limitations on gesture recognition, usability, preference, arm and shoulder fatigue and other ergonomic factors. This document provides guidance primarily on usability, preference, arm and shoulder fatigue and biomechanical or kinesiology factors. This document recommends methods to assess these factors based on the reliability and validity of the methods.

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Ergonomics of human-system interaction —

Part 430:

Recommendations for the design of non-touch gestural input for the reduction of biomechanical stress

1 Scope

This document provides guidance on the design, selection and optimization of non-contacting hand and arm gestures for human-computer interaction. It addresses the assessment of usability and fatigue associated with different gesture set designs and provides recommendations for approaches to evaluating the design and selection of gestures. This document also provides guidance on the documentation of the process for selecting gesture sets.

This document applies to gestures expressed by humans. It does not consider the technology for detecting gestures or the system response when interpreting a gesture. Non-contacting hand gestures can be used for input in a variety of settings, including the workplace or in public settings and when using fixed screens, mobile, virtual reality, augmented reality or mixed-mode reality devices.

Some limitations of this document are:

- The scope is limited to non-contacting gestures and does not include other forms of inputs. For example, combining gesture with speech, gaze or head position can reduce input error, but these combinations are not considered here.
- The scope is limited to non-contacting arm, hand and finger gestures, either unilateral (one-handed) or bilateral (two-handed).
- The scope assumes that all technological constraints are surmountable. Therefore, there is no consideration of technological limitations with interpreting ultra-rapid gestures, gestures performed by people of different skin tones or wearing different colours or patterns of clothing.
- The scope is limited to UI-based command-and-control human computer interaction (HCI) tasks and does not include gaming scenarios, although the traversal of in-game menus and navigation of UI elements is within scope.
- The scope does not include HCI tasks for which an obviously more optimal input method exists. For example, speech input is superior for inputting text than gesture input.
- The scope includes virtual reality (VR), augmented reality (AR) and mixed reality (MR) and the use of head-mounted displays (HMDs).
- The scope does not include the discoverability of gestures but does include the learnability and memorability of gestures. It is assumed that product documentation and tutorials will adequately educate end users about which gestures are possible. Therefore, assessing gesture discoverability is not a primary goal of the recommendations in this document.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

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

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

3.1 localized fatigue

reduced ability of muscles to generate force that occurs with prolonged repeated or sustained activities of the hands and arms

Note 1 to entry: This can be measured as reduced strength or perceived as weakness, discomfort, pain, tremors or altered motor control of the hand or arm. The symptoms can occur at the time the activity is performed or hours later.

Note 2 to entry: The fatigue considered here is also known as peripheral fatigue. Central fatigue (e.g. central nervous system) is not considered.

3.2 anatomical structures and landmarks of the hand

commonly agreed terminology for structures, regions or surfaces of the hands, which facilitate description of the location of the hand in space

Note 1 to entry: Use medical anatomical terms to describe anatomical structures and landmarks, for example palmar, dorsal, radial, ulnar surfaces; digits (1 to 4 = index, middle, ring, small); thumb; finger and thumb joints [carpometacarpal joint (CMC), interphalangeal joint (IP), proximal interphalangeal joint (PIP) and distal interphalangeal joint (DIP)].

3.3 joint posture

position of the joints of the upper extremities

Note 1 to entry: Some joint postures of interest are fingers and thumb in flexion/extension and abduction/adduction; wrist in extension/flexion and ulnar/radial deviation; forearm in pronation/supination; elbow in flexion/extension; and shoulder in flexion/extension, abduction/adduction, internal/external rotation and elevation.

Note 2 to entry: The terms used to describe joint postures can be applied to both static joint postures and joint movements. A static posture is described in degrees relative to a reference frame (see ISO 9241-400 and Reference [11]). Joint movement directions are described using the same terms.

3.4 optimal joint posture

joint posture where muscles are in the least activated state

Note 1 to entry: Typically, optimal joint postures are postures where the muscles that control joint movement are in their least activated state. This may also be referred to as neutral posture, i.e. a position that parts of the body assume when relaxed. Optimal joint postures are influenced by the posture of adjacent joints, the mass of adjacent body segments, the direction of gravity relative to the joint postures and other factors.

EXAMPLE Wrist (for power grip): 20° of extension, 0° to 15° of ulnar deviation and a grip diameter of 3 cm to 5 cm; forearm: 0° to 60° of pronation; elbow: 0° to 90° of flexion; shoulder: 0° to 20° of flexion, 0° to 20° of abduction and 0° to 60° of internal rotation.

3.5

hand microgesture

movement or posture of the fingers and hand that does not involve movement of the shoulder or movement of the elbow in flexion or extension

Note 1 to entry: Hand microgestures may also be called finger gestures. Hand microgestures can include forearm pronation and supination.

4 Selection of non-contacting gestures

4.1 Overall approach to the selection of non-contacting gestures

Many factors should be considered in the design and selection of non-contacting hand and arm gestures and their assignment to commands. These factors include natural language, memory, ease of forming gestures, prior gesturing experience and ergonomics. In this clause, recommendations are made for the ergonomic factors that can influence localized fatigue, comfort and biomechanics. The recommendations are for gestures that will be repeated or sustained and, therefore, can lead to localized fatigue. The recommendations do not apply to gestures that are performed infrequently.

4.2 Large shoulder and elbow movements

Shoulder and elbow movements beyond the optimal posture range are inefficient and fatiguing if performed repeatedly. These movements involve large muscle groups and the metabolic demands are often high. Motion of the shoulders and elbows within their optimal range is efficient and comfortable. It is recommended that gestures avoid large shoulder and elbow movements outside of their optimal range.

4.3 Optimal hand location relative to body

The location of the hands during gesturing will be determined by shoulder and elbow postures. If the shoulder and elbow joints are within their optimal range, the hands will be located within a space between the waist and the chest, between the shoulders and near the torso. Avoiding reaching, by designing gestures so that the shoulder posture is within the optimal range, will prevent shoulder fatigue.

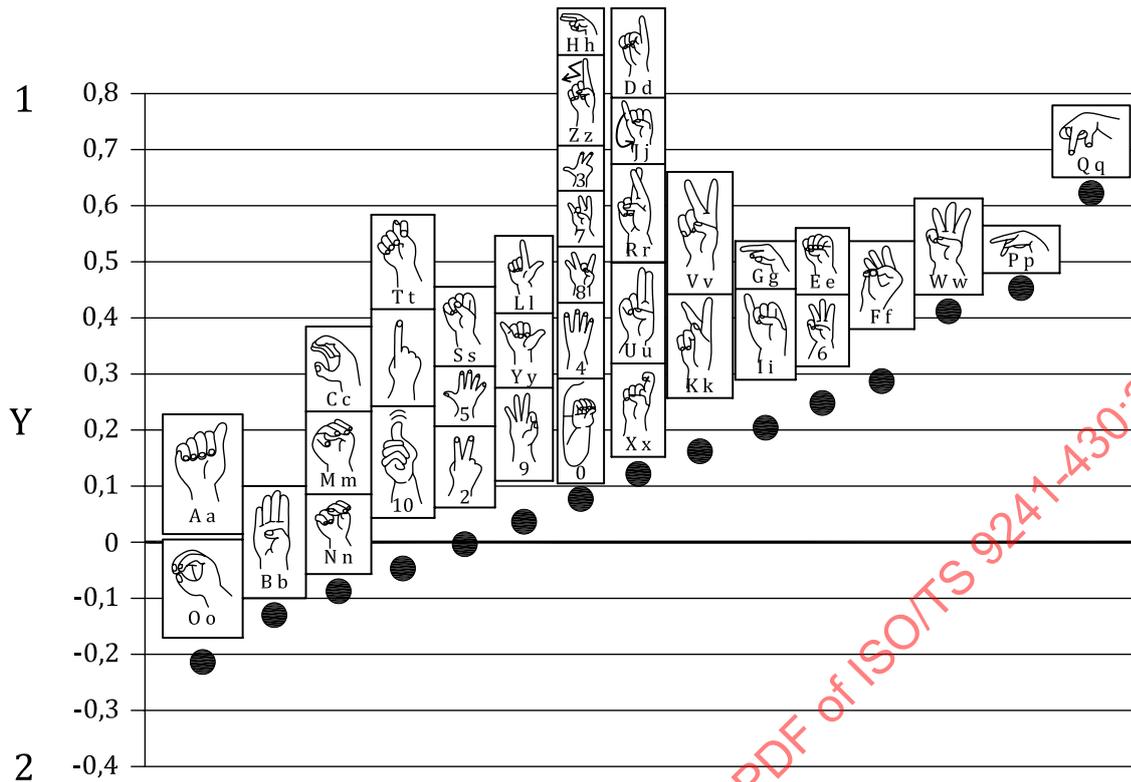
4.4 Wrist and forearm posture

Comfortable hand gestures are those where the wrist and forearm postures are within their optimal range. The range of hand postures is described by reference to the anatomical structures and landmarks of the hand.

4.5 Comfort of hand postures and motions

4.5.1 Fist, neutral and extended fingers

Avoid extreme hand, finger and thumb postures for commands that will be repeated frequently. Extreme hand postures include a tight fist (all finger joints in full flexion) and the opposite of the tight fist, an open or flat hand, or the open hand with fingers widely spread in abduction. A comfortable hand posture is with the fingers gently curled in flexion. An example of the ordering of finger postures from comfortable to uncomfortable is presented in [Figure 1](#).



Key
 Y discomfort scale
 1 uncomfortable
 2 comfortable

Figure 1 — Rank order of 37 alphanumeric characters by comfort
 [Source: Rempel et al. 2015^[21]. Reproduced with the permission of the copyright holder.]

4.5.2 Asynchronous adjacent finger postures

The tendons that control finger movements are tethered together, but the degree of tethering varies widely between people. The tethering makes it difficult or impossible for some people to form hand postures where adjacent fingers are in very different, or asynchronous, postures. Therefore, in general, hand gestures are designed so that adjacent fingers are in a similar degree of flexion. For example, a gesture involving flexing the small finger while extending the other fingers is difficult to form and would be avoided (see 'W' in Figure 1).

4.5.3 Thumb flexion or extension and abduction or adduction

The thumb tendons are often tethered to index finger tendons, so flexing the thumb while extending the index finger is difficult and uncomfortable (see K, U and V in Figure 1). Thumb motions in flexion or extension are easier to perform than thumb motions in abduction or adduction.

4.5.4 Speed of finger or hand movements and impact

Rapid finger movements with asynchronous adjacent finger movements are uncomfortable. Comfortable rapid finger movements are flexion and extension of the index, middle, ring and small finger moving together. Rapid motions that involve the impact of one hand striking the other hand or striking another body part or a surface can be uncomfortable.

4.5.5 Hand microgestures

Hand microgestures or finger gestures are generally less fatiguing than large gestures involving shoulder movement. Hand microgestures are motions or postures of the fingers and hand that do not require movements of the shoulder or elbow. They can be formed with the upper arm next to the torso or the forearms resting on a surface (e.g. chair arm rests or desk top) and, therefore, are less fatiguing for the shoulder muscles. Another advantage of hand microgestures is that they are often less visible to others and less distracting in a workplace or in a public setting.

5 Evaluation of non-contacting gestures

5.1 General

The ergonomic and usability evaluation of gestures is typically performed in a laboratory setting and follows well-established usability study evaluation methods. The purpose of these studies is usually to compare gesture sets on differences in outcome measures of, for example, productivity, error, fatigue and muscle activity, in order to improve the design of gestures for HCI.

5.2 Laboratory-based study design

Factors that should be considered in the design of laboratory-based usability and ergonomic studies on gesture design should include at least the following:

- within-subject experimental design (full-factorial);
- screen type (e.g. monitor, HMD, phone, watch; size, resolution);
- environment (temperature, humidity, noise, workstation, seating);
- randomization and counterbalancing of the order of independent variables across participants;
- randomized presentation of tasks or trials within a block as appropriate;
- counterbalanced order of blocks (i.e. task types, target size) across participants as appropriate.

5.3 Subjects for studies

- Select subjects for the laboratory study to reflect the intended user population distribution on age, sex, anthropometry, handedness, culture and race.
- Utilize an adequate sample size to detect expected changes in intended outcome measures.
- Select subjects who do not have an upper extremity injury or relevant upper extremity functional limitations.
- Use appropriate research ethics (subject notification of rights; appropriate work-rest-work patterns).

5.4 Independent variables

- Gesture sets, e.g. gesture set A vs B.
- Comparison or control input method
 - hand-held controller;
 - mouse;
 - voice recognition.

5.5 Example technologies for gesture capture

- Conventional camera(s).
- Depth camera(s).
- Data glove.
- Wizard of Oz.

Capturing and identifying non-contacting gestures can be done with various technologies, but each method has some limitations relative to ease of use and fidelity. For example, hand landmarks, such as fingernails, can be hidden from the camera in some hand postures. Such image shadows can lead to a distorted gesture recognition and a distorted feedback image of the gesture to the subject. In addition, if the system has a slow response time, the delayed feedback to the subject will influence their behaviour and their assessment of gesture usability. It is important to select a method for gesture capture that has minimal effect on the subject's behaviour. The Wizard of Oz approach involves video capture of the subject's gestures with a researcher interpreting the gesture in real-time in an adjacent room.

5.6 Dependent variables (outcome measures)

Subjective outcome measures:

- memorability;
- ease of use or execution;
- comfort;
- fatigue;
- preference;
- performance.

Objective outcome measures:

- task completion time;
- error;
- joint postures (static and dynamic);
- muscle activity (surface electromyography).

Typically, subjective outcome measures are assessed with questions administered after the completion of a test condition or in the case of questions comparing test conditions (e.g. preference), at the end of the study. The questions can be administered verbally, by paper or electronically. Questions are typically presented using a numerical or Likert scale with verbal anchors. Some examples of subjective questions are included in [Annex A](#).

Joint postures can be measured with automated or manual video analysis with or without passive markers placed on anatomical landmarks, an active marker system, depth-sensing cameras, electrogoniometers, electromagnetic sensors or other devices. Usually, the system is calibrated with the subject's joints in known postures. The final report includes calibration method, sampling rate and estimated accuracy. Summary results of joint posture measurements typically include mean, variance and some measure of distribution relative to optimal joint posture.

Surface electromyography (sEMG) is useful for estimating muscle activity; however, the process is complex and noise is a common problem. The quality of the sEMG signal is influenced by many factors, including electrode type and placement, skin preparation, ground electrode placement, signal filtering, signal rectification and sampling rate^[19]. Motion artefacts are common. sEMG values (mV) are typically

normalized to a maximum voluntary contraction (MVC) or a reference voluntary exertion (RVE). There is some debate about the value of sEMG for estimating muscle fatigue using amplitude or frequency shift. Because the sEMG signal is not normally distributed, summary measures are typically presented as amplitude probability distribution functions (APDF) of 90 % APDF (peak), 50 % APDF (median) and 10 % APDF (static) with the corresponding variance.

5.7 Examples of tasks

- Target acquisition (object selection)
 - selecting an icon from a desktop;
 - selecting an item from an array (e.g. menu selection);
 - selecting an object in 2D or 3D;
 - movement ballistics (moving back and forth between two targets; Fitts's Law);
 - undo the selection.
- Target manipulation (object manipulation)
 - scrolling a page or document;
 - zooming or panning a map or photo;
 - slide advancing a presentation;
 - dragging and dropping an object in 2D;
 - translating a 3D object (right or left, towards or away, up or down);
 - rotating a 3D object (yaw, pitch, roll);
 - shrinking or enlarging an object.
- Movement of self in 3D space
 - forwards or backwards;
 - turning right or left;
 - turning up or down.
- Controlling view
 - looking right or left;
 - looking up or down;
 - zooming in or out.
- Controlling background operations
 - adjusting system volume up or down;
 - toggling between media pause or play.
- Initiating a task or invoking a process
 - launching a gesture-enabled app;
 - initiating a phone call.

Examples of other commands or tasks:

- reset to initial conditions;
- duplicate;
- delete;
- open or close;
- accept or reject;
- start gesture input mode;
- close gesture input mode.

Table 1 lists some examples of static and dynamic gestures used in HCI.

Table 1 — Examples of assignments of static or dynamic gestures to HCI tasks

	Direct manipulation	Symbolic
Static gesture	Example tasks <ul style="list-style-type: none"> — hover to select an object — hover gesture to view a tool tip — point up to navigate one level higher in an information architecture 	Example tasks <ul style="list-style-type: none"> — media pause or play toggle via an open palm gesture — volume mute or unmute toggle via a closed fist gesture — launch an application or initiate a video call via a thumbs-up gesture — execute a copy, paste or undo operation via a raised digit gesture
Dynamic gesture	Example tasks <ul style="list-style-type: none"> — press to select an object — pinch to zoom (or pan) a map or photo — cursor control via finger tracking — swiping through presentation slides or cover art 	Example tasks <ul style="list-style-type: none"> — system volume adjustment via ‘spiral’ gesturing — display brightness adjustment via ‘slider’ gesturing — advancing to the next track in a playlist via ‘swipe’ gesturing

5.8 Target size

For many tasks, it is necessary to use a gesture to select an object, whether it is a point on a drawing, an icon, a menu cell or a window. The size of the object is likely to influence the usability of a gesture. A small object can be difficult to select with a gesture compared to selecting it with a mouse. Therefore, one of the conditions that might be evaluated when assessing the usability of gestures is target size. The time required to acquire a target for a particular input method (e.g. gesture vs mouse) can be assessed based on target size and distance between targets using a Fitts’s-Law-type test (see ISO/TS 9241-411:2012, B.6.2, B.6.3 and B.6.4) and Reference [15].

Report screen target size (e.g. 2,5 mm × 2,5 mm) along with the estimated distance from the eye to the screen so that an arc-minute size of the target can be calculated. For example, a 2,5 mm height character on a screen that is 50 cm from the eye has a height of 17 arc-minutes (e.g. $60 \cdot \arctan$ in degrees of target height/distance to target). Target size in arc-minutes is useful for comparing the effects of target size between studies. For typical 20/20 vision, the smallest visual angle of a font that can be accurately detected, such as visual acuity, is approximately 5 arc-minutes.

Table 2 shows examples of different target sizes evaluated for gesture usability^[14]. The arc-min size calculation assumes a 50 cm distance from the eye to the screen. The size of a typical icon is approximately 13 mm × 13 mm on the screen.

Table 2 — Examples of different target sizes evaluated for gesture usability

	Target size in mm	Target Size in arc-min
Small	2,5	17
Medium	5,0	34
Large	12,8	88

5.9 Data analysis, interpretation and reporting

In general, a summary of the outcome measure values (e.g. mean and standard deviation) by test conditions (e.g. gesture set and control) and tasks are presented in a table, chart or graph. The summary values can also be presented by subcategories, such as task and target size. Appropriate statistical tests are used to compare outcome measures by test condition. A number of factors are considered in the selection of the appropriate statistical tests, including variable distribution, sample size, number of test conditions and number of outcome measures. For example, typically, subjective measures are not normally distributed; therefore, non-parametric statistical tests would be used.

The interpretation of the study findings is guided by the statistical results with an evaluation of consistency across outcome measures. Typically, the interpretation also includes a comparison of the findings with other similar studies from the literature.

In general, a report includes an executive summary or abstract along with detailed methods, results, discussion and references. The methods section includes sufficient details so that the experiment can be replicated by others or list references of publications that describe the methods in adequate detail.

NOTE The Common Industry Format (CIF) (see ISO/IEC 25062) provides a standard but very detailed method for reporting findings of usability.

Annex A (informative)

Example of questionnaire for assessing subjective usability measures

Subject number _____

Date _____

Gesture set: A, B, C

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

	A Disagree Agree	B Disagree Agree	C Disagree Agree
I had excellent control	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
I had shoulder fatigue	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
I had hand fatigue	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
I feel sick	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Which one did you prefer the most (1) and least (3)?			
Do you have any comments about A, B or C?			