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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

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Foreword

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

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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.

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, right, 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.

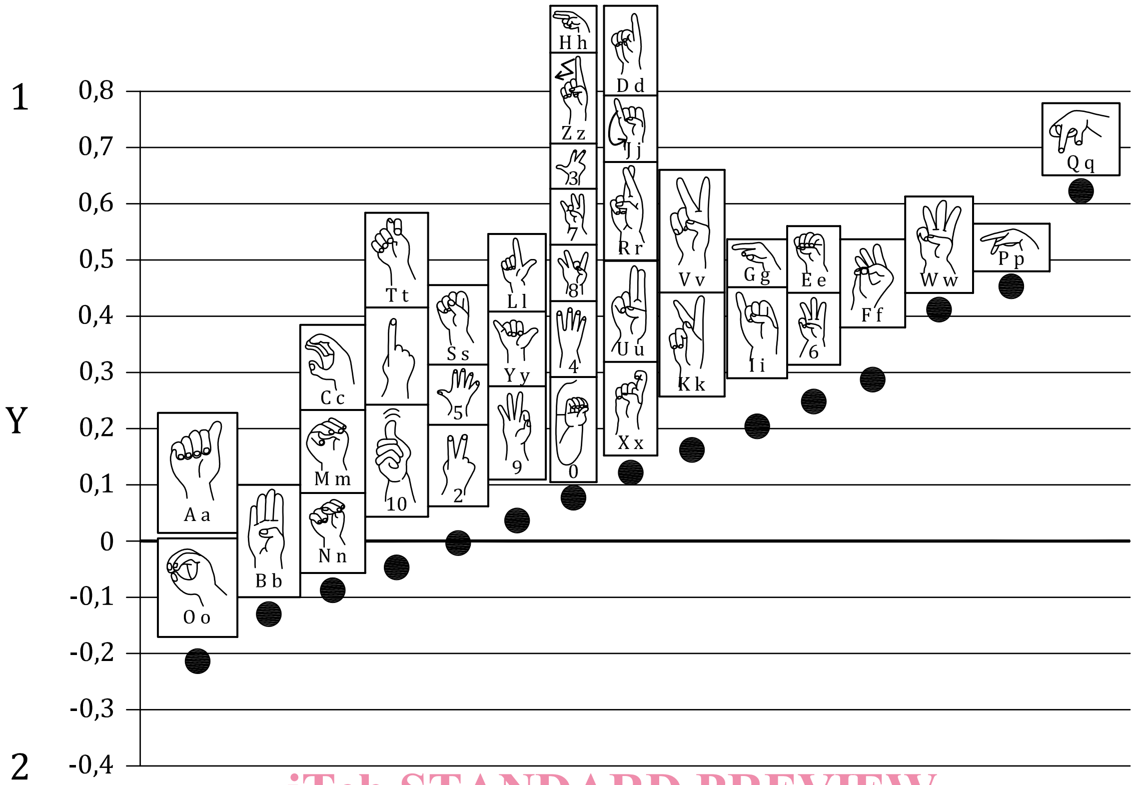
4.4 Wrist and forearm posture

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.