
**Ergonomics of human-system
interaction —**

**Part 940:
Evaluation of tactile and haptic
interactions**

Ergonomie de l'interaction homme-système —

Partie 940: Évaluation des interactions tactiles et haptiques



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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 on 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 the following URL: 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.

Introduction

Tactile and haptic interactions are becoming increasingly important as interaction modalities in special purpose computing environments and assistive technologies. This document explains how to evaluate attributes of the haptic device and the user interface, and the outcomes of interaction with a haptic device, along with an assessment of human-centred quality and other and more specific usage qualities.

This document can be used to identify the measures to be used when establishing requirements for haptic interaction, and to evaluate haptic interactions to identify problems, to establish benchmarks or to evaluate whether a haptic system meets requirements.

A haptic interaction involves sensory or motor activity in the skin, muscles, joints and tendons; a tactile interaction refers specifically to touch (sensory activity in the skin).

In a haptic interaction, a user typically employs a device to manipulate objects in the virtual world of the computer and also to feel the result of the manipulation through sensors in the skin and joints. This is the bidirectional sense of haptics. Haptics is important in the design of switches in traditional keyboards and mice, but here, we consider computer interaction by means other than keyboard, mouse and passive joysticks.

Haptic interactions can also work in a passive unidirectional sense, conveying information to the skin without active motion or exploration on the part of the user. A cell phone on vibration mode is one such unidirectional tactile device. They can also work in an active unidirectional sense, as the user makes gestures that send commands or data to a device.

Tactile and kinaesthetic haptic interactions are being developed in university and industrial laboratories in many countries, and a variety of commercial products exist that incorporate tactile and kinaesthetic interactions. Both the developer and the prospective purchaser of such interactions and their associated devices and software need a means of making comparisons between competing choices.

Other International Standards are cross-referenced in order to understand and point out the specific differences in evaluating haptic interactions. The nature of these interactions, whether bidirectional, unidirectional from the device to the skin or body of the user, or unidirectional as gestures from the body of the user to the device, sets them apart as a group of interactions that needs special consideration in relation to the forms of evaluation which are appropriate.

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

ISO 9241-920 provides basic guidance in the design of haptic interactions.

ISO 9241-960 provides guidance for the definition of gestures in human-machine interactions. It explains how to describe their features and what factors to take into account when defining gestures.

This document provides evaluation processes specific to haptic interactions and the devices that enable them. It shows how requirements set out in ISO 9241-910, ISO 9241-920 and other International Standards can be applied to actual haptic systems and specific interactions. In a parallel way, it shows how the usability of a haptic system can be evaluated, taking into account quality attributes such as effectiveness, efficiency, user satisfaction and avoidance of harm from use.

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Ergonomics of human-system interaction —

Part 940:

Evaluation of tactile and haptic interactions

1 Scope

This document

- describes the types of methods that can be used for the evaluation of haptic devices and of systems that include haptic devices,
- specifies a procedure for the evaluation of haptic interactions by a usability walkthrough or usability test (see [Annex J](#)), and
- provides guidance on the types of methods that are appropriate for the evaluation of specific attributes of haptic systems, cross-referenced to the guidance in the relevant clauses of other International Standards (see [Annexes A, B, C, D, E, F and G](#)).

It applies to the following types of interaction:

- augmented reality — information overlaid on a real scene, e.g. vibrating belt indicating distance;
- gesture control of a device or a virtual scenario;
- unidirectional interaction such as a vibrating phone or a vibrating belt;
- virtual environment — virtual space with which a user can interact with the aid of a haptic device.

This document applies to the following types of devices:

- gesture sensor, e.g. video that discerns 3D hand movements, touch screens that sense 2D touches;
- kinaesthetic haptic device, e.g. desktop haptic interface;
- tactile display, e.g. vibrating phone.

This document is not applicable to standard input devices such as keyboards, mice or track balls.

NOTE ISO 9241-400 covers standard input devices, and ISO 9241-411 applies to the evaluation of input devices such as keyboards and mice.

This document can be used to identify the types of methods and measures for

- establishing benchmarks,
- establishing requirements for haptic interaction,
- identifying problems with haptic interaction (formative evaluation), and
- use of the criteria to establish whether a haptic system meets requirements (summative evaluation).

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

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

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

3.1 accessibility

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

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

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

3.2 formative evaluation

evaluation designed and used to improve the object of evaluation, especially when it is still being developed

[SOURCE: ISO/TS 18152:2010, 4.6]

3.3 haptics

sensory and/or motor activity based in the skin, muscles, joints and tendons

Note 1 to entry: Haptics consists of two parts: touch and kinaesthesia.

[SOURCE: ISO 9241-910:2011, 2.1]

3.4 haptic appertaining to haptics

Note 1 to entry: In this document, “haptics” includes all touch sensations; “tactile” is used more specifically to refer to skin stimulation without kinaesthetic stimulus.

[SOURCE: ISO 9241-910:2011, 2.2, modified]

3.5 haptic interaction

sensory or motor activity in the skin, muscles, joints and/or tendons as part of human-computer interaction

3.6 haptic user interface HUI

one or more haptic effects that are designed in software to allow a user to experience a haptic interaction

3.7 requirement

condition or capability that must be met or possessed by a system, system component, product, or service to satisfy an agreement, standard, specification, or other formally imposed documents

Note 1 to entry: Requirements include the quantified and documented needs, wants, and expectations of the sponsor, customer, and other stakeholders.

[SOURCE: ISO/IEC/IEEE 24765:2010, 3.2506, modified]

3.8**summative evaluation**

evaluation designed to present conclusions about the merit or worth of the object of evaluation

Note 1 to entry: The results can be used to produce recommendations about whether it should be retained, altered, or eliminated.

Note 2 to entry: It is possible to design a method to provide a combined formative and summative evaluation.

Note 3 to entry: A summative test method is used to perform a summative evaluation.

[SOURCE: ISO/TS 20282-2:2013, 4.17]

3.9**usability**

extent to which a system, product, or service can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use

[SOURCE: ISO 9241-210:2010, 2.13]

3.10**usability requirement**

required level of usability expressed in terms of measures of effectiveness, efficiency, and satisfaction in a specified context of use

[SOURCE: ISO/TS 20282-2:2013, 4.20]

3.11**user**

person who interacts with a system, product, or service

Note 1 to entry: The person who uses a service provided by a work system, such as a customer in a shop or passenger on a train, can be considered a user.

[SOURCE: ISO/TS 20282-2:2013, 4.22]

3.12**user experience**

person's perceptions and responses that result from the use and/or anticipated use of a system, product or service

Note 1 to entry: User experience includes the user's emotions, beliefs, preferences, perceptions, comfort, behaviours and accomplishments that occur before, during and after use.

Note 2 to entry: User experience is a consequence of brand image, presentation, functionality, system performance, interactive behaviour, and assistive capabilities of a system, product or service. It also results from the user's internal and physical state resulting from prior experiences, attitudes, skills and personality, and from the context of use.

Note 3 to entry: Usability, when interpreted from the perspective of the users' personal goals, can include the kind of perceptual and emotional aspects typically associated with user experience. Usability criteria can be established to assess aspects of user experience.

[SOURCE: ISO 9241-210:2010, 2.15, modified — Reworded for clarification.]

3.13**user group**

<usability> group of users differentiated by characteristics of the users, tasks, or environments that are expected to influence usability

[SOURCE: ISO/TS 20282-2:2013, 4.24, modified — Note removed.]

3.14 workload

physical and cognitive demands placed on the system user(s) and/or staff

[SOURCE: ISO 11064-7:2006, 3.9]

4 Conformance

The evaluation of a haptic system is in conformance with this document if the report of the evaluation explains

- a) which quality attributes in [Table 2](#) have been evaluated and why these were chosen,
- b) the reason that any recommendations for the selected quality attribute have not been evaluated,
- c) whether the recommendations on haptics in the related annex clauses have been implemented, and
- d) which type of method(s) were used.

If a usability task test or usability walkthrough was used, it shall conform to [Annex J](#).

The recommendations and requirements from ISO 9241-910, ISO 9241-920 and ISO 9241-960 that are summarized in [Annexes A](#) to [G](#) shall be considered for potential inclusion in the evaluation.

NOTE The terms “recommendations” and “requirements” refer to the guidance and stipulations provided in the referenced standards and as applied to the system under evaluation. Conformance to this document is stipulated by this clause and the guidance contained in the main body of this document.

5 How to use ISO 9241-940

5.1 Structure

This clause describes the potential reasons for evaluating haptics and how these relate to the system development lifecycle.

[Table 2](#) can be used in conjunction with the explanatory material in [Clauses 5](#), [6](#) and [7](#) to decide which haptic qualities are to be evaluated and which type of method is going to be used.

Refer to the indicated clauses in the annexes for more information on evaluation of specific attributes of haptic interaction and to [Annex J](#) for how to carry out a usability task test or usability walkthrough.

[Table 1](#) summarizes the content of this document.

Table 1 — Content of ISO 9241-940

	Clause/annex	Content
5	How to use ISO 9241-940	Summarizes the instances where evaluation can be used, the planning of evaluation and the unique aspects of haptics evaluation
6	Types of evaluation methods	Summarizes the different types of methods that can be used to evaluate haptics
7	Quality of haptic interaction	Summarizes the quality characteristics of haptic interaction that can be evaluated
	Annexes A to G	Provides guidance on evaluating detailed aspects of each quality attribute; Clause 7 provides an overview of Annexes A to G .

Table 1 (continued)

	Clause/annex	Content
	Annex H	Provides examples of evaluation of device attributes
	Annex I	Describes the unique aspects of haptic interaction to keep in mind while planning and conducting an evaluation
	Annex J	Specifies the method to be used for evaluation by usability walkthrough or usability task test

5.2 Uses of this document

This document provides guidance on the methods that are appropriate for establishing criteria and the associated means of evaluation against which requirements are judged.

The types of methods and measures recommended in this document can be used to

- identify problems (formative evaluation),
- establish benchmarks, and
- establish suitability of the haptic system for its application (summative evaluation).

These uses apply to the following circumstances:

- a) Design and development of haptic devices to support the evaluation of:
 - design concepts and prototypes in order to refine the requirements for the system;
 - prototypes in order to check that design guidelines have been followed;
 - prototypes and working systems to check that the user and the stakeholder requirements have been met;
 - prototypes and working systems in order to improve the design by identifying problems;
 - working systems to establish a baseline level for subsequent comparison;
 - systems in use in order to ensure that they continue to satisfy stakeholder and user needs.
- b) Acquisition of haptic devices:
 - to check that candidate devices meet requirements;
 - to compare haptic devices and systems for possible operation in specified contexts of use.

5.3 Evaluation in the design and development lifecycle

Evaluation of haptic devices should take account of the intended or actual context of use of the device – the types of users (for example, casual or regular users), the types of tasks that it will be used for and the environments that it will be used in (for example, with vibrations or extreme temperatures).

[Figure 1](#) shows a typical design and development lifecycle, running from feasibility through requirements to detailed design and realization of the product. Evaluation is integral to each phase – a feasibility concept is evaluated, leading to requirements and a design to meet those requirements. A prototype could be evaluated during the detailed design stage, while the final product can be evaluated against the design requirements and also when it is in actual use.

NOTE The inputs to the process are business and user needs that initiated the project, together with the intended context of use, which inform the initial design concept in the feasibility phase.

Initial design concepts can be evaluated by an expert to identify potential problems, to determine if the device is consistent with the identified business and user needs, and if necessary, to refine the requirements.

Prototypes can be evaluated by testing the device with users and observing their behaviour to identify any problems or new needs that could lead to modification of the requirements. Prototypes should be evaluated in as realistic a context of use as possible.

The final system can be evaluated for conformance with requirements. More information on human-centred design can be found in ISO 9241-210. ISO/IEC 25063 explains the context of use and ISO/IEC 25064 explains how user needs can be identified. Requirements engineering is described in ISO/IEC/IEEE 29148. Attributes of haptic devices and haptic systems for which requirements can be specified and which can be evaluated are described in [Clause 7](#).

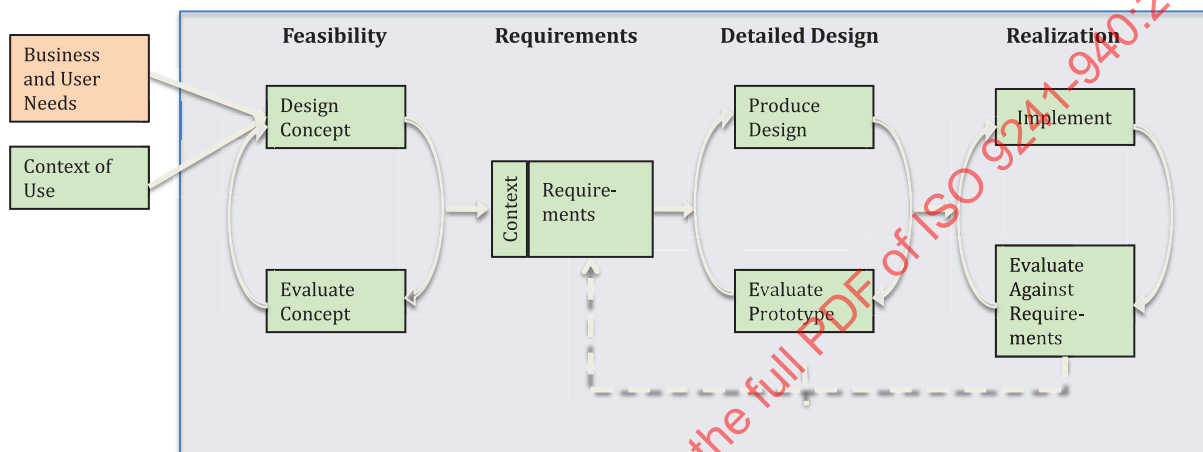


Figure 1 — Evaluation in the design and development lifecycle

5.4 Planning activities

This document provides guidance to support the following activities:

- establish the purpose of the evaluation (see [1.1](#) and [1.3.1](#), with examples in [1.9.2](#) to [1.9.5](#));
- decide what is to be evaluated;
- identify the context in which the haptic system will be used: the types of users, tasks and usage environments (see [7.3.1](#));
- carry out an initial assessment (see [5.5](#));
- decide which haptic qualities are to be evaluated (see [Clause 7](#));
- decide on the type of method(s) to be used. The most common types of methods are described in [Clause 6](#): physical measurements against requirements, inspection to identify deviations from established criteria, a usability walkthrough, and usability test.

[Annex J](#) specifies the procedure for a usability walkthrough or usability test.

5.5 Initial assessment

The quality attributes can be divided between those relating primarily to hardware, those relating to software and those that deal with a combination of the two. This leads to a way of evaluating by initial separation of the system and its subsequent evaluation from three perspectives:

- the physical properties of the haptic device (see [7.2.2](#));

- b) the effect produced by the haptic device (see 7.2.3);
- c) the user's experience of the overall haptic interaction (see 7.3).

Typical questions that can be asked of each perspective are the following.

- 1) Are the technical properties of the device appropriate for the intended context of use? Typical issues that could arise are the following:
 - the device is too heavy;
 - the device lacks force or force finesse (the ability to tell small forces from large ones);
 - there are confusing artefacts, such as extraneous noise or oscillations;
 - when moving the device, the user hits physical stops that take away the intended illusion.
- 2) Is the haptic effect appropriate for the intended context of use? Typical issues that could arise are the following:
 - the meaning of the haptic sensation is not clear;
 - haptic icons (or virtual touch points) are not appropriate – for example, too close or too soft;
 - the user gets lost in the virtual haptic space when this is not the intention of the system.
- 3) Does the system provide an appropriate haptic effect in the intended context of use? Typical issues that could arise are the following:
 - the device needs more or fewer degrees of freedom to match the haptic effect;
 - the applied force is too low or too high for the haptic effect;
 - the device output cannot be properly discerned in the context of use.

5.6 Unique aspects of haptic interaction

The evaluator should be aware of the unique aspects of haptic interaction:

- it is a personal experience that cannot be felt by the evaluator the way an image or sound can be sensed by both the user and the evaluator, so the user typically describes the haptic sensation to the evaluator;
- in a bidirectional haptic interaction, it can be difficult to separate the reaction of the user to the force from the logic and mechanics of the force pushing the user;
- in a unidirectional gesture interaction, it is possible to separate the ergonomics of the gesture from the effectiveness of the device interpreting the gesture;
- in a unidirectional tactile interaction, the user experience is tightly linked to the device characteristics, and this close association will show up in any evaluation of the user experience;
- haptics is one mode of interaction often blended with other modalities; the haptic effect can be difficult to interpret in the presence of visual and auditory cues;
- haptic interaction can take place anywhere on the body, a factor that can be taken into account to make tests culturally sensitive;
- adaptation can mask a haptic effect after an extended time; tests of sufficient duration can realistically mimic real usage scenarios where adaptation could play a role.

[Annex I](#) gives more background and examples on these points.

6 Types of evaluation methods

6.1 General

Haptic systems can be evaluated using one or more of the types of methods that are described in the following subclauses.

NOTE [Table 2](#) indicates which of these types of method can be used to evaluate each haptic system quality attribute described in [Clause 7](#).

Information on documenting these methods can be found in ISO/IEC 25066.

6.2 Physical measurements against requirements

- Comparison of a device or a haptic system with requirements. Measurement can entail simple instruments such as a linear scale or more complex test devices such as a digital load cell to analyse forces produced by the system.
- Requirements should be assigned after consideration of the application. ISO 9241-910 and ISO 9241-920 provide guidance for setting requirements for tactile/haptic systems, while ISO 9241-960 provides guidance on the use of gestures as a specific type of tactile/haptic interaction. [Annexes A to G](#) list requirements and recommendations derived from these International Standards.

6.3 Inspection by an expert

The methods that are most relevant for haptic evaluation are:

- inspection to identify deviations from criteria based on user requirements, principles, guidelines or established good practice for usability and accessibility. The evaluation can be based on a static representation or combined with a usability walkthrough;
- a usability walkthrough, identifying potential problems by stepping through interaction with the system in the same way as a user would be expected to carry out particular tasks (see [Annex J](#)).

6.4 Usability test

6.4.1 General

Usability tests involve collecting data from actual or intended users in situations that are the actual or proposed situations in which they are using or would use the haptic or tactile system.

6.4.2 Measurement context

6.4.2.1 Using a test task

- Task tests involve a trial use of the system by a set of users that are selected from a general population of users. The population can include both typical users and special case users.
- The tasks are ideally undertaken in the context of use of the haptic system. To isolate certain parameters of interest, they can be run in a laboratory setting.
- Tasks are specifically set, usually in a planned trial, and are amenable to assessment by a variety of measure types such as those listed in the following subclause.

[Annex J](#) specifies how to carry out a usability task test.

6.4.2.2 Observation of the performance of users in normal use of the haptic system

- Users of the haptic system can be observed as they undertake tasks of their own choosing.

- Observation, in either a lab setting or a natural context of use, can identify usability and accessibility problems as well as strengths.
- An expert observer can assess performance and user experience.

6.4.3 Evaluation data

6.4.3.1 Collection of performance data

- Performance measures are assessments or scores related to the task itself. They give measures of the effectiveness and efficiency of the haptic system in allowing a user to carry out a task in a given context of use (see ISO 9241-11).
- Typical performance data include the time taken to perform a task or the number of user errors that occurred during task completion.

6.4.3.2 Collection of physiological data

- Physiological data are objective assessments of the physiological state of the user in carrying out a task. Inferences on such parameters as the level of stress, discomfort or fatigue can be made from these data.
- Physiological data can be obtained from measurable body parameters such as facial expression and eye pupil diameter.

6.4.3.3 Collection of user-reported data

a) Questionnaires

- Questionnaires are typically employed to gather impressions of users of systems, by their own self-assessment of the device and of their experiences in using the device.

NOTE Questionnaires can also be filled in by expert observers of haptic systems, as a means of filing and categorizing relevant data on one or more haptic systems.

- Open-ended questionnaires to obtain reported problems, opinions and impressions provided by the user. Data from an open-ended questionnaires and interviews are typically qualitative.
- Closed-ended questionnaires to obtain measures of user satisfaction, opinions or perception (e.g. rating scale values for satisfaction or for subjectively perceived effectiveness or efficiency). Responses to rating scales provide measures of user satisfaction, opinions or perception of the haptic system. Rating scales can also record the user's subjectively perceived effectiveness or efficiency.

Questionnaires can be distributed before, during and after a test.

- Pre-test questionnaires capture information about the situation before system introductions,
- Questionnaires during a test (typically a longitudinal study) can capture information about the test situation and changes over time.
- Post-test questionnaires can capture retrospective impressions and assessments.

b) Interviews

Data similar to that provided by open-ended questionnaire can be obtained from structured interviews to collect reported problems, opinions and impressions.

7 Quality of haptic interaction

7.1 Quality model

The haptic interaction is influenced by a number of factors, both internal and external. These can be summarized in a quality model that is illustrated in [Figure 2](#) (the clause number is shown for each component).

The model consists of the following parts:

- goals – what is to be carried out with the system, shown as input to the system;
- the haptic system – the haptic device and the haptic user interface;
- a user carrying out a task with the haptic system – a mutual interaction among three components;
- the context of use – users, tasks and the physical and social environment within which the task will be carried out (this is shown by the large box in the middle, containing task, user, environment and the haptic system itself);
- quality attributes – features that can be identified during an evaluation process include the following:
 - system-specific attributes – device hardware and software interface (see [7.2.2](#) and [7.2.3](#));
 - overall usage attributes – specific usage qualities (e.g. learnability, safety and reliability; see [7.3.2](#)) and human-centred qualities in use (usability, accessibility, user experience and freedom from harm in use; see [7.3.3](#)).

Task goals combine with the context of use of the haptic system being evaluated to generate measurable quality attributes.

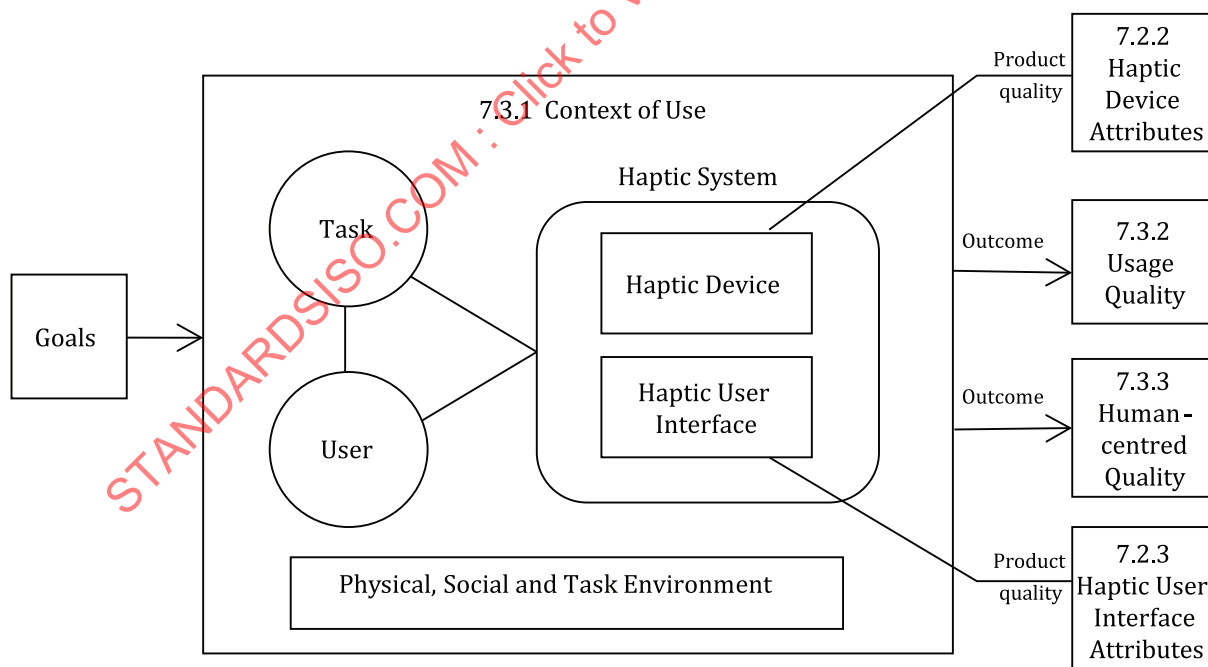


Figure 2 — Evaluating a haptic system

7.2 Haptic system attributes

7.2.1 Quality attributes

Quality attributes identified in other International Standards have been assigned to each section of the quality model.

A framework for defining haptics can be found in ISO 9241-910, while guidance in the field can be found in ISO 9241-920. These International Standards set out criteria by which a haptic interaction can be judged. Specific clauses relate to aspects of the haptic virtual environment and the haptic device.

A third International Standard, ISO 9241-960, provides a framework and guidance for the use of gestures. Gestures can be considered a type of haptic interaction because the positioning of the body part used in forming a gesture is controlled by the haptic system of the human body.

The haptic quality model is shown in [Figure 2](#). The components and their sources are summarized below and are described in detail in the indicated annexes. A summary of the contents of the annexes can be found in [Clause 8](#), and attribute top level groupings are listed in [Table 2](#).

a) Context of use

The human-centred quality and other usage qualities depend on the context of use (the users, tasks and environments), which also determines the nature of the product attributes that will contribute to the human-centred and other usage qualities (see [7.3.1](#)).

b) Product quality

The quality of the haptic device ([7.2.2](#)) and user interface ([7.2.3](#)) will contribute to achieving acceptable human-centred quality and other usage qualities.

c) Outcomes of interaction

The overall outcome of interaction is the human-centred quality (usability, user experience, accessibility and avoidance of harm from use; see [7.3.3](#)) and more specific usage qualities that can be relevant in specific circumstances ([7.3.2](#)).

7.2.2 Haptic device attributes (see [Annex A](#))

Haptic device attributes are the properties of the haptic device that can influence the quality of interaction:

- a) haptic device controls;
- b) haptic device interaction properties;
- c) movement;
- d) physical properties;
- e) physical space and logical space;
- f) prevention of undesirable consequences;
- g) tactile/haptic properties of objects.

ISO 9241-910:2011, Clause 9 describes the device attributes that influence haptic interaction.

[Annex A](#) provides more details, listing recommendations from ISO 9241-910 and ISO 9241-920 with the evaluation method and measurement type for each attribute.

7.2.3 Haptic user interface attributes

7.2.3.1 Haptic effect design principles (see [Annex B](#))

ISO 9241-920:2009, Clauses 4 to 7 contain guidelines for interaction with the haptic virtual environment. ISO 9241-920:2009, Clauses 4 and 5 give general principles for haptic design, including principles for:

- a) encoding of attributes;
- b) encoding of information;
- c) encoding of graphical data;
- d) optimizing performance.

[Annex B](#) provides more details.

7.2.3.2 Haptic effect task elements (see [Annex C](#))

ISO 9241-910:2011, Clause 7 describes the haptic task primitives that can be used to carry out complete application tasks. [Annex C](#) provides more details on the following attributes:

- a) manipulation;
- b) navigating;
- c) overviewing;
- d) searching;
- e) selection;
- f) targeting.

7.2.3.3 Gesture attributes (see [Annex G](#))

Gestures are movements or postures of the body; gestures can be interpreted as gesture commands to a suitably equipped haptic system. [Annex G](#) gives more details on the following attributes.

- a) documentation of gestures (suitable for intended users, unambiguous, easy to learn);
- b) ergonomics of gestures (awareness of constraints across a range of users, not creating unnecessary fatigue);
- c) features of gestures (mapping to functions, use of feedback, issues of timing and speed);
- d) gesture sets (consistent and discriminable, with available alternatives);
- e) process for gesture definition (suitable for learning, using the design space);
- f) sequences of gestures (clear beginning, transition between gestures and completion).

7.3 Usability attributes

7.3.1 Context of use (see [Annex D](#))

The context within which a haptic interaction takes place can affect the quality. [Annex D](#) gives more details on the following attributes:

- a) multi-sensory input (including sight, sounds, smell, taste and haptic input in different body parts);

- b) physical environment (including issues such as working position, limb support, acoustic noise, vibration, heat or cold, and humidity, as well as considerations of use on-the-move);
- c) social environment (including issues such as social support and social pressure);
- d) tasks (the purpose for using the haptic system, which could include situations such as relaxed amusement, scanning, focused attention, urgent work);
- e) users (such as novices, general public, experienced practitioners, researchers).

EXAMPLE 1 A haptic simulation of a neurological operating site, mapped to the brain of a patient, can allow a surgeon to explore the details of a particular pathology.

EXAMPLE 2 A haptic simulation of a laparoscopic operating site can give surgeons the opportunity to learn a new skill without endangering a patient in the process.

EXAMPLE 3 A haptic simulation of a macromolecule allows a theoretical biochemist to insert a model ligand molecule into its selected “docking” site.

EXAMPLE 4 A virtual science display of the earth allows participants at an exhibit to feel mountain ranges.

EXAMPLE 5 Vibration feedback from a mobile device or wearable accessory can provide navigation information for a person trekking in the wild.

EXAMPLE 6 A video game is enhanced by the combination of visual, auditory and haptic effects.

7.3.2 Specific usage qualities (see [Annex E](#))

Particular usage qualities can be relevant in specific circumstances. These are functions of the haptic system, including both the haptic device and the haptic effect. [Annex E](#) gives more details on the following attributes:

- a) adaptability (the effectiveness, efficiency and satisfaction with which a system can be adapted or individualized);
- b) ease of operations (the degree to which a product or system has attributes that make it easy to operate and control);
- c) installability (the effectiveness, efficiency and satisfaction with which a system can be installed);
- d) learnability (the effectiveness, efficiency and satisfaction with which a system can be learned);
- e) maintainability (the effectiveness, efficiency and satisfaction with which a system can be maintained);
- f) portability (the effectiveness, efficiency and satisfaction with which a haptic system can be moved to a different environment);
- g) reliability (the extent to which a system performs specified functions under specified conditions for a specified period of time);
- h) safety (the extent to which a system mitigates or avoids potential harm to the user, organization or project related to or arising from human use).

These quality characteristics are described in both ISO 9241-910:2011, 9.2.12 to 9.2.16 and ISO/IEC 25010:2011 (learnability, safety, reliability and others, as set out in ISO/IEC 25010:2011, Figure 4).

7.3.3 Human-centred quality (see [Annex F](#))

Human-centred quality is the overall quality as experienced by the user. [Annex F](#) gives more details on the following attributes:

- a) accessibility (which as an outcome of interaction can be assessed as usability for people with the widest range of capabilities);
- b) avoidance of harm from use (the extent to which the quality of a system mitigates or avoids potential harm from use);
- c) ethical considerations (an assessment of the ethics of the end-use of the haptic interaction);
- d) usability, as in ISO 9241-11:
 - 1) effectiveness;
 - 2) efficiency;
 - 3) satisfaction;
- e) user experience (a person's perceptions and responses that result from use and/or anticipated use).

Human-centred quality is described in ISO 9241-220, with more details on usability in ISO 9241-11, accessibility in ISO 9241-171, risk reduction in ISO/IEC 25010 and ISO/IEC 25022, and avoidance of harm from use in ISO 9241-220. Guidance on social responsibility is given in ISO 26000.

7.4 Evaluation matrix

7.4.1 Types of attributes

[Table 2](#) shows the types of evaluation methods that are most appropriate to evaluate each quality attribute in the rows of the [Table 2](#).

The quality attributes are grouped into the following categories, in the following order:

- A. Haptic device attributes;
- B. Haptic effect design principles;
- C. Haptic effect task elements;
- D. Context of use;
- E. Specific usage qualities;
- F. Human-centred quality;
- G. Gesture attributes.

Quality attributes in Group A are related to the haptic device, B and C to the haptic effect, and D to F the haptic system in the context of use. [Annexes A](#) to [G](#) list specific quality attributes for each quality characteristic.

7.4.2 Measures of haptic quality

For each type of quality attribute, the columns in [Table 2](#) and in the tables in the annexes give the following information:

- subclause (subclause in the annexes that relates to this quality characteristic);
- quality attributes (the quality attributes described in [7.2](#) and [7.3](#));

- source [the sources of information about the attributes (ISO 9241-910, ISO 9241-920 or ISO 9241-960)];
- evaluation method (see [Clause 6](#)) [technical evaluation of physical attributes in a lab (“Tech Eval of device”), inspection by an expert (“Inspect by an expert”), or a “Usability test” (see [J.8](#)).

For a usability test, the measurement context can be a “Test task” or observation of normal use (“Obs use”) and the data used in evaluation (“Evaluation data”) can be performance measures (“Perform data”), physiological measures (“Physio data”) and/or user-reported data (often by means of a questionnaire) (“User rep data”).

Table 2 — Evaluation matrix

Sub-clause	Quality attributes	Source: ISO 9241-			Type of evaluation method						
		910	920	960	Tech eval of device	Inspect by an expert	Usability test				
							Measure context		Evaluation data		
						Test task	Obs use	Per-form data	Phys-io data	User rep data	
A	Haptic device attributes (7.2.2)	✓									
A.2	Physical properties	✓			✓	✓				✓	
A.3	Haptic effect controls	✓		✓	✓	✓				✓	
A.4	Physical space and logical space	✓		✓	✓	✓				✓	
A.5	Tactile/haptic properties of objects	✓			✓	✓				✓	
A.6	Haptic device interaction properties	✓				✓				✓	
A.7	Prevention of avoidable harm	✓		✓	✓						
B	Haptic effect design principles (7.2.3.1)		✓								
B.2	Performance optimization		✓	✓		✓	✓		✓	✓	
B.3	Virtual environment attributes		✓	✓		✓	✓		✓	✓	
B.4	Encoding of information		✓	✓		✓	✓		✓	✓	
B.5	Encoding of attributes		✓	✓		✓	✓		✓	✓	
B.6	Encoding of graphical data		✓			✓	✓		✓	✓	
C	Haptic effect task elements (7.2.3.2)	✓				✓	✓				
C.3	Searching	✓					✓	✓	✓	✓	
C.4	Overviewing	✓					✓	✓	✓	✓	
C.5	Navigation	✓					✓	✓	✓	✓	
C.6	Targeting	✓					✓	✓	✓	✓	
C.7	Selection	✓					✓	✓	✓	✓	
C.8	Manipulation	✓					✓	✓	✓	✓	
a Item is a heading derived from ISO 9241-11 and is not matched to an evaluation column; detailed attributes are listed below the heading, and related evaluation types are indicated by checkmarks next to the detailed attributes.											

Table 2 (continued)

Sub-clause	Quality attributes	Source: ISO 9241-			Type of evaluation method						
		910	920	960	Tech eval of de- vice	In- spect by an ex- pert	Usability test				
							Measure context		Evaluation data		
							Test task	Obs use	Per- form data	Phys- io data	User rep data
D	Context of use (7.3.1)										
D.2	Physical environment					✓	✓	✓			✓
D.3	Other aspects of the context of use					✓	✓	✓		✓	✓
E	Specific usage qualities (7.3.2)	✓									
E.2	Installability	✓					✓		✓		✓
E.3	Learnability	✓		✓		✓	✓		✓		✓
E.4	Ease of operation	✓		✓		✓	✓		✓		✓
E.5	Adaptability	✓		✓		✓	✓		✓		✓
E.6	Portability	✓				✓	✓		✓	✓	✓
E.7	Reliability	✓		✓		✓	✓		✓		✓
E.8	Maintainability	✓				✓	✓		✓		✓
E.9	Safety	✓				✓		✓			✓
F	Human-centred quality (7.3.3)^a										
F.2	Usability ^a										
F.2.1	Effectiveness						✓		✓		✓
F.2.2	Efficiency						✓		✓		✓
F.2.3	Satisfaction						✓			✓	✓
F.3	Accessibility ^a										
F.3.2	Use as assistive technology				✓	✓					
F.3.3	Accessibility of tactile displays				✓	✓	✓	✓	✓	✓	✓
F.3.4	Accessibility of device documentation						✓	✓			✓
F.3.5	Accessibility with limited physical capabilities					✓	✓	✓			✓
F.3.6	Accessibility with limited cognitive capabilities					✓	✓	✓			✓
G	Gesture attributes (7.2.3.3)			✓							
G.2	Ergonomics of gestures			✓		✓	✓	✓		✓	✓
G.3	Process for gesture definition			✓		✓	✓	✓			
G.4	Features of gestures			✓		✓					✓
G.5	Timing and speed			✓	✓		✓	✓	✓	✓	
G.6	Sequences of gestures			✓		✓	✓	✓	✓	✓	✓
G.7	Gesture sets			✓		✓	✓	✓	✓	✓	✓
G.8	Documentation of gestures			✓		✓					✓

^a Item is a heading derived from ISO 9241-11 and is not matched to an evaluation column; detailed attributes are listed below the heading, and related evaluation types are indicated by checkmarks next to the detailed attributes.

Key to the columns in [Table 2](#)

The abbreviations used in the [Table 2](#) column headers are underlined.

Sub-clause	Quality attribute	Source			Type of evaluation method				
Annex or annex sub-clause	Title of annex sub-clause	ISO 9241-910	ISO 9241-920	ISO 9241-960	Technical evaluation of device	Inspection by an expert	Usability test		
							Measure context		Evaluation data
							Test task	Observe use	Performance data Physiological data User reported data

Key to the columns in the annexes

The abbreviations used in the column headers in the annexes are underlined.

The source column headers differ from one annex to the next, as described in [Clause 8](#).

Recommendation	Source			Type of method				Measures		
Text of sub-clause	ISO 9241-910	ISO 9241-920 or 20	Sub-clause number	Technical evaluation	Inspection	Task test	Observe use	Performance data	Physiological data	User reported data

8 Guide to the annexes

[Annexes A](#) to [E](#) are comprised of tables of attributes that have been drawn from ISO 9241-910 and ISO 9241-920. They are organized according to the grouping of attributes shown in [Table 3](#).

[Table 3](#) provides a cross-reference between the clauses of ISO 9241-910 and ISO 9241-920 and the tables in [Annexes A](#) to [E](#).

Table 3 — Tables of haptic qualities

Standard	Clause	Table	What is verified	Examples
ISO 9241-910	6	Tables A.3 and A.4	General design	Dialogue style, logic space
ISO 9241-910	7	Tables C.1 to C.4	Task primitives	Navigating, searching, selecting
ISO 9241-910	8	Table A.5	Interaction elements	Spring, friction, magnetic effects
ISO 9241-910	9	Tables A.1 , D.1 , E.1 to E.4	Haptic devices	Mobile, desktop devices
ISO 9241-920	3	Tables A.4 and B.1	General design	Labelling, alternative inputs
ISO 9241-920	4	Table B.2	Information encoding	Text, graphics by shape, location
ISO 9241-920	5	Tables A.2 and B.3	Content-specific encoding	Maps, trend curves, pushbuttons
ISO 9241-920	6	Tables A.3 and A.4	Display space	Display layout, object shapes
ISO 9241-920	7	Table C.3	Support for haptic tasks	Navigation, reconfiguration

[Annex G](#) is comprised of tables of attributes, drawn from ISO 9241-960, on gestures.

[Annex H](#) gives examples of measurements of a desktop haptic device, either by inspection or by measurement.

[Annex I](#) sets out the unique aspects of haptic interaction and their effect on the evaluation process.

[Annex J](#) specifies the procedure to be used for conducting a usability evaluation of a haptic system either by a usability task test or inspection to identify potential usability problems when attempting to complete one or more tasks.

The columns in each table are the same as those of [Table 2](#), except for variations in the source columns.

Sources are ISO 9241-910 and ISO 9241-920 for [Annexes A, B and C](#).

Sources are ISO 9241-910, ISO 9241-20 and ISO/IEC 25010 for [Annex D](#).

Sources are ISO 9241-910, ISO 9241-920 and ISO/IEC 25023 for [Annex E](#).

Sources are ISO 9241-11, ISO 9241-20, ISO 9241-171, ISO 9241-220 and ISO/IEC 25022 for [Annex F](#).

Source is ISO 9241-960 for [Annex G](#).

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Annex A (informative)

Haptic device attributes

A.1 General

A.1.1 Overview

This annex lists recommendations from ISO 9241-910 and ISO 9241-920 on haptic device attributes, together with types of methods and measurement types appropriate for each recommendation.

A.1.2 Contents of the annex

- [A.2](#) Physical properties: parameters of the haptic device;
- [A.3](#) Haptic effect controls: properties of haptic icons that control a virtual scenario;
- [A.4](#) Physical space and logical space: relationship between device and virtual scenario;
- [A.5](#) Tactile/haptic properties of objects: guidance on parameters of virtual haptic objects;
- [A.6](#) Haptic device interaction properties: displaying virtual haptic parameters to a user;
- [A.7](#) Prevention of avoidable harm: advice on effects such as sensory adaptation.

See [Tables A.1](#) to [A.6](#).

A.2 Physical properties

Table A.1 — Physical properties

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Weight The weight of a haptic device that might have to be transported during the task should be considered when choosing a haptic device. (e.g. Is it to be carried, mounted on a desk, or anchored to the building?)	✓		9.2.12.2	✓	✓					✓
Size The size of a haptic device should be considered when choosing a haptic device.	✓		9.2.12.3	✓	✓					✓
Mobility The device mobility required for the task should be considered when choosing a tactile/haptic device.	✓		9.2.1	✓	✓	✓				✓
^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

Table A.1 (continued)

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Device-body interface The point(s) of contact between the body and the device should be considered when choosing a tactile/haptic device. (e.g. What body parts will be used in the interaction?)	✓		9.2.2		✓			✓	✓	
Degrees of freedom (DOF) The number of degrees of freedom required for the task should be considered when choosing a tactile/haptic device. (e.g. Will a single DOF suffice, or are more degrees of freedom necessary?)	✓		9.2.3		✓			✓		
Maximum stiffness The maximum stiffness required for a task should be considered when choosing a tactile/haptic device. (e.g. Can hard objects be sensed with sufficient stiffness?)	✓		9.2.4	✓		✓				✓
Motion range The motion range appropriate to a task should be considered when choosing a tactile/haptic device. (e.g. Is it to be manipulated over 0,1 m, 1 m or 2 m, or held in place while being felt?)	✓		9.2.5	✓		✓		✓		
Force and torque			9.2.6							
Peak force and torque The peak force and torque required for a task should be considered when choosing a tactile/haptic device.	✓		9.2.6.1	✓		✓		✓	✓	✓
Max continuous force and torque The maximum continuous force and torque required for a task should be considered when choosing a tactile/haptic device.	✓		9.2.6.2	✓		✓		✓	✓	✓
Min displayable force and torque The minimum displayable force and torque required for a task should be considered when choosing a tactile/haptic device.	✓		9.2.6.3	✓		✓		✓	✓	✓
Force and torque resolution The displayable force and torque resolution appropriate to a task should be considered when choosing a tactile/haptic device.	✓		9.2.6.4	✓		✓		✓	✓	✓
Dynamic force and torque range The dynamic range of displayable force and torque appropriate to a task should be considered when choosing a tactile/haptic device.	✓		9.2.6.5	✓		✓		✓	✓	✓
Free space motion resistance The free space resistance appropriate to a task should be considered when choosing a tactile/haptic device.	✓		9.2.7	✓	✓					✓
^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

Table A.1 (continued)

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Inertia The inertia of the device-body interface in a tactile/haptic device should be considered when choosing a tactile/haptic device.	✓		9.2.8	✓	✓			✓		✓
Peak acceleration The peak acceleration of the device-body interface in a tactile/haptic device should be considered when choosing a tactile/haptic device.	✓		9.2.9	✓						
Friction	✓		9.2.10							
Static friction The static friction limits of a task should be considered when choosing a tactile/haptic device. (e.g. Does the device have low friction where free space motion is expected?)	✓		9.2.10.1	✓	✓			✓		✓
Kinetic friction The kinetic friction limits of a task should be considered when choosing a tactile/haptic device.	✓		9.2.10.2	✓	✓			✓		✓
Temporal parameters	✓		9.2.11							
Bandwidth The bandwidth appropriate to the task should be considered when choosing a tactile/haptic device. (e.g. Does the handle vibrate when the virtual probe is touched to a surface with desired stiffness?)	✓		9.2.11.1	✓						
System latency The system latency may be considered as an alternative expression of the bandwidth of a haptic system.	✓		9.2.11.2	✓						
Device latency The device latency may be considered as a device-specific contribution to the bandwidth of a haptic system.	✓		9.2.11.3	✓						
^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009. ^b Methods are technical evaluation, inspection, task test and observe use. ^c Measures are performance data, physiological data and user-reported data.										

A.3 Haptic effect controls

Table A.2 — Haptic effect controls

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Using tactile/haptic controls When using tactile/haptic controls:		✓	5.3.1							
a) the tactile/haptic controls should be selectable without activating their associated functionality;		✓			✓	✓	✓			✓
b) the system should provide the user with feedback that indicates the selection and the activation of a tactile/haptic control.		✓			✓					✓
Size and spacing of controls The system should use sizing and spacing to reduce the likelihood that a user will accidentally activate an adjacent control.		✓	5.3.2		✓	✓	✓			✓
Avoiding difficult control actions The system should avoid using very small controls or controls which require rotation of the wrist or pinching and twisting.		✓	5.3.3		✓					✓
Using force to avoid accidental activation Where avoidance of inadvertent operation is necessary, the operating force should not be less than 5 N.		✓	5.3.4		✓					✓
Interacting with controls The actuating force and torque of virtual controls should not be greater than the maximum values in ISO 9241-920:2009, Table 1.		✓	5.3.5		✓					✓
^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

A.4 Physical space and logical space

Table A.3 — Physical space and logical space

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
<i>Designing tactile/haptic space</i>			6.2							
<i>General</i>	✓		6.2.1							
The design of tactile/haptic interactions should consider both the physical space and the logical space in which they occur.	✓		6.2.1.2		✓					✓
a) Physical space	✓				✓					✓
b) Logical space	✓				✓					✓
<i>Designing logical space</i>	✓		6.2.2							
Logical space should be modality-free.	✓		6.2.2.1		✓					✓
The design should expose and clearly reflect the relationships within the information.	✓		6.2.2.2		✓					✓
^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

Table A.3 (continued)

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
<i>Designing physical space</i>	✓		6.2.3							
The dimensions and contents of the physical space where tactile/haptic interactions take place should consider the ability of users to act and react within this space.	✓		6.2.3.2		✓					✓
<i>Addressability and resolution in tactile/haptic interaction</i>	✓		6.3							✓
Addressability and resolution should be considered in the design of tactile/haptic interactions.	✓		6.3.1		✓					✓
<i>Tactile/haptic display spaces</i>			6.1							
Ease of perceiving multiple tactile/haptic objects The system should ensure an easily perceivable presentation of multiple tactile/haptic objects.		✓	6.1.1	✓	✓	✓				✓
Ease of identifying adjacent tactile/haptic objects Where multiple tactile/haptic objects are adjacent, it should be possible to identify them individually as well as together.		✓	6.1.2		✓	✓				✓
Maintaining separation between surfaces of objects Individual objects should be sufficiently separated so that the user is able to perceive the boundaries between them.		✓	6.1.3	✓	✓	✓				✓
Separating tactile/haptic elements Where not required to be contiguous, tactile/haptic elements should be separated by perceivable spaces.		✓	6.1.4	✓	✓	✓				✓
Avoiding empty spaces The tactile/haptic space should avoid an excess of "empty space" as this is a significant source of confusion.		✓	6.1.5	✓	✓	✓				✓
Avoiding volume limits Restricting surfaces should be used in all directions in order to avoid tactile/haptic hardware volume limits being mistaken for an object.		✓	6.1.6		✓					✓
Avoiding falling out of the tactile/haptic space Users should not be able to involuntarily "fall out" of the haptic/tactile environment.		✓	6.1.7			✓	✓			✓
^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

A.5 Tactile/haptic properties of objects

Table A.4 — Tactile/haptic properties of objects

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Distinguishability All patterns created should be tested for distinguishability by the user.	✓		8.7	✓	✓	✓	✓			✓
Objects			6.2							
Using appropriate object size The size of a tactile/haptic object should be appropriate for the task and to the user's perceptual capabilities.		✓	6.2.1		✓	✓				✓
Creating distinguishable tactile/haptic symbols Tactile/haptic symbols should be easily distinguishable.		✓	6.2.2	✓	✓	✓				✓
Creating tactile/haptic symbols from visual symbols Tactile symbols should be chosen for their tactual, rather than for their visual, distinguishability.		✓	6.2.3		✓					✓
Tactile/haptic object angles Tactile/haptic angles and perspectives should be close to those found naturally.		✓	6.2.4		✓					✓
Tactile/haptic object corners When using a single point interaction style, rounded corners should be used rather than sharp ones.		✓	6.2.5		✓					✓
^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

A.6 Haptic device interaction properties

Table A.5 — Haptic device interaction properties

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Tactile/haptic functional effects			8.2							
Activation and deactivation of effects All tactile/haptic functional effects available for a certain tactile/haptic device should be able to be activated and deactivated independently and should not influence each other.	✓		8.2.2			✓				✓
Spring effect A spring effect should generate a force proportional to a given factor and the distance of the probe's position to a defined point.	✓		8.2.5			✓				✓
Damping effect A damping effect should generate a force proportional to a given factor and the velocity of the probe's movement.	✓		8.2.6			✓				✓
Mass effect A mass effect should generate a force proportional to a given factor and the acceleration of the probe's movement.	✓		8.2.7			✓				✓
^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

A.7 Prevention of avoidable harm

Table A.6 — Prevention of avoidable harm

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Limiting acoustic output of tactile/haptic display Acoustic energy emissions created by a tactile/haptic display should not interfere with:		✓	3.3.1							
— the user perceiving presented auditory information;		✓			✓	✓				✓
— nearby equipment and/or persons;		✓			✓	✓				✓
— security requirements.		✓			✓					✓
Limiting heat gain of contact surface The heat gain of the contact surface (not intentionally generated) should not:		✓	3.3.2							
— deform the contact surface;		✓			✓					✓
— disturb the user's haptic perception;		✓			✓					✓
— cause thermal discomfort;					✓					✓
— injure the user's skin;		✓			✓					✓
— damage the haptic interface.		✓			✓					✓
^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

Table A.6 (continued)

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Avoiding sensory adaptation The system should minimize the effects of sensory adaptation to vibration.		✓	3.3.3		✓	✓				✓
Recovering from sensory adaptation The system should enable the user to recover from sensory adaptation to stimuli.		✓	3.3.4		✓	✓				✓
Preventing unintended perceptual illusions The system should minimize the occurrence of unintended perceptual illusions.		✓	3.3.5		✓	✓				✓
Preventing temporal masking The system should prevent the occurrence of temporal masking.		✓	3.3.6		✓	✓				✓
Avoiding unintended oscillation The system should avoid oscillations related to control loop instability.		✓	7.3.2		✓	✓	✓			✓
^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , <u>task test</u> and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

Annex B (informative)

Haptic effect design principles

B.1 General

B.1.1 Overview

This annex lists recommendations from ISO 9241-920 on haptic effects, together with types of methods and measurement types appropriate for each recommendation.

B.1.2 Contents of the annex

- [B.2](#) Performance optimization: elements related to efficient operation of the haptic system;
- [B.3](#) Virtual environment attributes: advice on parameters that help the user interact effectively;
- [B.4](#) Encoding of information: ways to clarify the meaning of the haptic commands;
- [B.5](#) Encoding of attributes: means by which haptic icons can convey information;
- [B.6](#) Encoding of graphical data: guidance on presenting shapes in a tactile display.

See [Tables B.1](#) to [B.5](#).

B.2 Performance optimization

Table B.1 — Performance optimization

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Optimizing performance The system should be optimized to take into account:		✓	3.1.1							
a) the accuracy of available devices,		✓				✓				✓
the accuracy of the user, and		✓				✓				✓
the required accuracy of the task;		✓				✓				✓
b) the ability of a user to control the speed and the force involved in operations;		✓				✓				✓
c) active exploration over passive exploration, when appropriate;		✓				✓				✓
d) multiple point-of-contact operation, when possible and appropriate;		✓				✓				✓
e) the overall amount and distributed nature of cognitive and sensory task demands.		✓				✓				✓
^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009. ^b Methods are technical evaluation, inspection, task test and observe use. ^c Measures are performance data, physiological data and user-reported data.										

B.3 Virtual environment attributes

Table B.2 — Virtual environment attributes

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Accessible information The system should provide accessible descriptions of all tactile/haptic user interface elements, whether those descriptions are automatically presented or not.		✓	3.1.2		✓					✓
Contextual information The system should provide context to help the user to understand the meaning of the tactile/haptic perception and the environment or program.		✓	3.1.3		✓	✓				✓
Consistent labels Labels of user interface elements that are presented in a tactile/haptic modality should:		✓	3.1.4							✓
— be consistent in size and distances from other tactile objects;		✓			✓					✓
— be located according to a consistent rule;		✓			✓					✓
— be uniformly oriented.		✓			✓					✓
Identifying system state The system should provide information that allows the user to know which task or function is active.		✓	3.1.5		✓	✓				✓
Minimizing fatigue The system should:			3.1.6							
— ensure user comfort over extended periods of time;		✓			✓	✓	✓	✓	✓	✓
— avoid or minimize user fatigue.		✓			✓	✓	✓	✓	✓	✓
Alternative input methods The system should enable users to accomplish the same function in a number of ways, with at least one of these not requiring fine manipulation skills on the part of the user.		✓	3.1.7		✓	✓				✓
Coherence between modalities The system should maintain coherence, where appropriate, between the tactile/haptic modality and other modalities, including the descriptions of actions.		✓	3.1.8		✓					✓
Isolation of individual interface elements The system should prevent unintended effects on non-activated interface elements due to the activation of a nearby interface element.		✓	3.1.11			✓				✓
^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

B.4 Encoding of information

Table B.3 — Encoding of information

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
High level guidance			4.1							
Using unfamiliar tactile/haptic elements Where available, well-known tactile/haptic patterns, which are familiar in daily life, should be used for presenting information.		✓	4.1.1		✓					✓
Making tactile/haptic encoding obvious Where possible, tactile/haptic encoding should be made obvious to the users by ensuring cues are:		✓	4.1.2							✓
— simple and intuitive;		✓			✓	✓	✓			✓
— easy to learn and discriminate.		✓			✓	✓	✓			✓
Conformity to user expectations System behaviour should conform to user expectations.		✓	4.1.3			✓				✓
Using sensory substitution The system should use the most appropriate sensory substitutions for presenting/receiving the information to/from the user.		✓	4.1.4			✓				✓
Appropriate spatial addressability and resolution The system's spatial addressability and resolution should be appropriate for the task and the user's perceptual capabilities.		✓	4.1.5			✓				✓
Using distal body parts for high spatial resolution Where high spatial resolution is needed, the user should interact with the system only with the distal body parts.		✓	4.1.7			✓				✓
Preventing spatial masking The system should avoid spatial masking.		✓	4.1.10			✓		✓		✓
^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

B.5 Encoding of attributes

Table B.4 — Encoding of attributes

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Guidance on specific attributes		✓	4.2							
Discriminating between attribute values Attribute values should be discriminable.		✓	4.2.2			✓				✓
Limiting the number of attribute values Unless proven that a user can discriminate between a larger number of values, the number of different values (as for vibration and thermal conductivity) used for encoding any single attribute should be limited to three, significantly different from each other.		✓	4.2.3			✓				✓
Limiting complexity All purposeful combinations of attribute values within a system should be discriminable.		✓	4.2.5			✓	✓			✓
Encoding by object shape When encoding information by shape, the system should employ recognisable shapes.		✓	4.2.6			✓				✓
Encoding information by temporal pattern When encoding information in a temporal pattern, the time between signals should be perceivable and adjustable.		✓	4.2.7			✓	✓			✓
Encoding information by vibration amplitude When encoding information using different discrete vibration amplitude levels, the system should allow setting a number of levels between the detection threshold and the comfort/pain threshold.		✓	4.2.8		✓					✓
Encoding information by vibration frequency When encoding information by vibration frequency, the system should:			4.2.9							
— use not more than seven different levels of frequency;		✓			✓					✓
— use a difference of at least 20 % of the lower frequency between levels;		✓			✓					✓
— use frequencies between 10 Hz and 600 Hz unless a lower frequency can be discriminated.		✓			✓					✓
Encoding information by location When encoding information by location, the system should take into account the spatial resolution of the body part that is intended to perceive the information.		✓	4.2.10		✓	✓	✓			✓
Encoding information by temperature When encoding information by temperature:			4.2.11							
— the range of temperature values to be used should be well within the comfort limits of the users;		✓			✓	✓	✓			✓
^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009. ^b Methods are technical evaluation, inspection, task test and observe use. ^c Measures are performance data, physiological data and user-reported data.										

Table B.4 (continued)

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
— the values of temperature used should remain discriminable over the duration of exposure.		✓			✓	✓	✓			✓
Encoding information by thermal conductivity The values of thermal conductivity used should:			4.2.12							
— make due allowance for users' adaptation to them;		✓				✓	✓	✓		✓
— be limited to four in number.		✓			✓					✓
Identifying information values The system should aid the user in identifying the values of individual attributes.		✓	4.2.13		✓					✓
Content-specific encoding			5							
Encoding and text data The speed of presentation of dynamic text information should be controllable.		✓	5.1		✓					✓
^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

B.6 Encoding of graphical data

Table B.5 — Encoding of graphical data

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Displaying tactile/haptic graphs			5.2.1							
Tactile/haptic graphics should be sufficiently simple to be recognized without long exploration.		✓	5.2.1.1			✓	✓	✓		✓
The important elements of a tactile/haptic graphic should be readily perceived by users of the tactile/haptic display.		✓	5.2.1.2		✓	✓	✓	✓		✓
Using grids on tactile graphs Grids on tactile graphs may be used when exact reading of values is required, but should not interfere with the information on the graph.		✓	5.2.2		✓	✓		✓		✓
Providing landmarks on tactile maps When appropriate to the use of the map, a tactile map should emphasize landmarks.		✓	5.2.3							
Providing scales for tactile maps Where distance scales are provided on tactile maps, they should		✓	5.2.4							
— be presented in the orientation most relevant to the map contents;		✓			✓					✓
— make use of units that are most accessible to the intended user group.		✓			✓					✓
^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

Annex C (informative)

Haptic effect task elements

C.1 General

C.1.1 Overview

This annex lists recommendations from ISO 9241-910:2011, Clause 7 and ISO 9241-920:2009, Clause 7 on haptic task elements, together with types of methods and measurement types appropriate for each recommendation.

C.1.2 Contents of the annex

- [C.2](#) Presence of haptic task elements: basic tasks that a user can do in a haptic interaction;
- [C.3](#) Searching: finding a haptic virtual object;
- [C.4](#) Overviewing: understanding the haptic virtual scenario;
- [C.5](#) Navigation: guidance in helping users get around a haptic virtual scenario;
- [C.6](#) Targeting: helping a user get to an intended virtual icon;
- [C.7](#) Selection: selecting the intended virtual icon;
- [C.8](#) Manipulation: help in creating, deleting and modifying a virtual icon or haptic scenario.

See [Tables C.1](#) to [C.7](#).

C.2 Presence of haptic task elements

Table C.1 — Primitives in haptic tasks

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
In any task, the user should be able to:	✓		7.1							
— search;	✓					✓		✓		
— gain an overview;	✓					✓		✓		
— navigate;	✓					✓		✓		
— target;	✓					✓		✓		
— select;	✓					✓		✓		
— manipulate.	✓					✓		✓		

^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009.

^b Methods are technical evaluation, inspection, task test and observe use.

^c Measures are performance data, physiological data and user-reported data.

C.3 Searching

Table C.2 — Search

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
The system should allow users to initiate a search for a specified tactile/haptic object, for part of an object or for an item of information and, once the search has been conducted, have the required result presented to them.	✓		7.2			✓		✓		
^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

C.4 Overviewing

Table C.3 — Overview

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
The system should allow users to get a rapid overview of the tactile/haptic objects, their layout and relationships to each other and the user.	✓		7.3		✓	✓				✓
^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

C.5 Navigating

Table C.4 — Navigation

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
The system should allow users to move in and between tactile/haptic objects in order to find an object and to explore the space;	✓		7.4.1			✓		✓		✓
The system should allow users to identify their location in tactile/haptic space and find the optimal path to get to required objects or information.	✓		7.4.2			✓		✓		✓
Providing navigation information Navigation information support should be available to assist users of tactile/haptic space.		✓	7.1.1		✓	✓				✓
Supporting path planning The display should enable the user to plan the shortest path to a target.		✓	7.1.2		✓	✓				✓
^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

Table C.4 (continued)

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Providing well-designed paths The system should ensure that paths between objects have a clear structure, as well as clear start and end points.		✓	7.1.3		✓	✓				✓
Making landmarks easy to identify and recognize The system should provide well-defined and easy-to-find reference points or landmarks in the environment and ensure that landmarks are easily identifiable and recognizable.		✓	7.1.4		✓	✓				✓
Providing appropriate navigation techniques The system should provide the most appropriate navigation technique (e.g. stylus, fingertip, multiple fingers, both hands) based on:		✓	7.1.5		✓	✓				✓
a) the target users, domains, and task goals;										
b) the size of the real or virtual space, density of objects, and object properties;										
c) the layout of the tactile/haptic space.										
Understanding the tactile/haptic space The system should allow users to move about and explore the tactile/haptic space, acquiring an accurate understanding of the objects and their arrangement in the space.		✓	7.1.7		✓	✓				✓
Supporting exploratory strategies (procedures) The system should:			7.1.8							
a) enable users to use their natural strategies for exploring the presented information;		✓			✓	✓	✓			✓
b) provide support for learning additional exploratory strategies appropriate to the user, application, and/or device.		✓			✓					✓
^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

C.6 Targeting

Table C.5 — Target

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
The system should allow users to identify and find an object or item of information accurately and rapidly.	✓		7.5			✓		✓		✓
^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

C.7 Selection

Table C.6 — Selection

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Selection in general The system should allow users to select objects singly or in multiples.	✓		7.6.1			✓		✓		✓
The system should allow users to select any object or function to which they currently have access.	✓		7.6.2.1			✓				✓
The system should allow users to [select any object] separately from performing any action on the object, for example, activation.	✓		7.6.2.2			✓				✓
It should be clear to which objects or functions a user currently has access.	✓		7.6.2.3			✓				✓
Clear feedback on selection should be given.	✓		7.6.2.3			✓				✓
Group selection The system should allow users to select any defined group of objects to which they currently have access.	✓		7.6.3			✓				✓
Space selection The system should allow users to select any defined portion of the tactile/haptic space to which they currently have access.	✓		7.6.4			✓				✓
System property selection The system should allow users to select any property of the system to which they currently have access and change that property where permitted.	✓		7.6.5			✓				✓
^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , <u>task test</u> and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

C.8 Manipulation

Table C.7 — Manipulation

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Introduction The system should allow users to operate on, manage or, in some way, influence an object in ways that are appropriate to the task.	✓		7.7.1			✓				✓
Zooming The system should allow users to change the scale of the tactile/haptic space in which they are performing a task.	✓		7.7.2			✓				✓
Reorienting The system should allow users to change the orientation of the tactile/haptic space in which they are performing a task.	✓		7.7.3			✓				✓
^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , <u>task test</u> and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

Table C.7 (continued)

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Moving The system should allow users to move an object within the tactile/haptic space.	✓		7.7.4			✓				✓
Sizing The system should allow users to change the size of an object within the tactile/haptic space.	✓		7.7.5			✓				✓
Attribute inspection			7.7.6							
The system should allow users to inspect the attributes of objects within the tactile/haptic space without activating them;	✓			7.7.6.1		✓				✓
The system should allow users to determine which properties are modifiable and which are not.	✓			7.7.6.2		✓				✓
Creation and deletion The system should allow users to create and delete objects in the tactile/haptic space, where appropriate to the task.	✓		7.7.7			✓				✓
Modifying attributes The system should allow users to modify attributes of tactile/haptic objects, where appropriate to the task.	✓		7.7.8			✓				✓
^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

Annex D (informative)

Context of use

D.1 General

D.1.1 Overview

This annex lists recommendations from ISO 9241-910:2011, 9.2 and ISO 9241-20:2008, 10.2 on context of use attributes, together with types of methods and measurement types appropriate for each recommendation.

D.1.2 Contents of the annex

- [D.2](#) Physical environment: physical conditions of the workspace of the haptic interaction;
- [D.3](#) Other aspects of the context of use: task complexity, user skills and social pressure.

See [Tables D.1](#) and [D.2](#).

D.2 Physical environment

Table D.1 — Physical environment

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	20	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Working position The working position required by a haptic device should be considered when choosing a haptic device. (e.g. Is the operator in a comfortable position, sitting or standing?)	✓		9.2.14.1		✓			✓	✓	✓
Limb support Human limb support to assist the user during the task should be considered when choosing a haptic device. (e.g. Is there an appropriate rest place for limbs and joints involved in interaction?)	✓		9.2.14.2		✓			✓	✓	✓
Acoustic noise The acoustic noise of a haptic device should be considered when choosing a haptic device. (e.g. Is there distracting noise from the device?)	✓		9.2.12.1		✓			✓	✓	✓
Designing environments Special consideration should be given to the needs of users in respect of the following when designing environments:		✓	10.2							
^a Sources are ISO 9241-910:2011 and ISO 9241-20:2008. ^b Methods are technical evaluation, inspection, task test and observe use. ^c Measures are performance data, physiological data and user-reported data.										

Table D.1 (continued)

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	20	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
a) lighting and surface treatments (e.g. indirect lighting to reduce glare);		✓	10.2 a)	✓	✓	✓	✓	✓	✓	✓
b) layout and use of space (e.g. wheelchair access);		✓	10.2 b)	✓	✓	✓	✓	✓		✓
c) acoustics (e.g. echo reduction);		✓	10.2 c)	✓	✓	✓		✓	✓	✓
d) thermal characteristics (e.g. protective mitts in cold weather).		✓	10.2 d)		✓	✓	✓	✓	✓	✓
^a Sources are ISO 9241-910:2011 and ISO 9241-20:2008. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

D.3 Other aspects of the context of use

Table D.2 — Other aspects of the context of use

Recommendation	Source ^a		Type of method ^b				Measures ^c		
	ISO/IEC 25063	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
The haptic device should operate appropriately with the supporting hardware and software. (e.g. Are complementary visual and acoustic effects synchronized with haptic effects?)	✓	5.6.2	✓						
Implementation of the haptic system should take account of the motivations and skills of the intended users and their frequency of use.	✓	5.3.2		✓	✓		✓	✓	✓
Implementation of the haptic system should take account of the frequency, length and complexity of the tasks it will be used for.	✓	5.5.1		✓	✓		✓	✓	✓
Implementation of the haptic system should take account of the effects of social pressure if there is more than one user.	✓	5.6.3		✓	✓		✓	✓	✓
Implementation of the haptic system should take account of the effects of external vibration, e.g. while in a moving vehicle.	✓	5.6.4		✓	✓		✓	✓	✓
^a Source is ISO/IEC 25063:2014. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .									

Annex E (informative)

Specific usage qualities

E.1 General

E.1.1 Overview

This annex lists recommendations from ISO 9241-910:2011, Clause 9 and ISO 9241-920:2009, Clause 3 and measures for usage qualities from ISO/IEC 25023.

E.1.2 Contents of the annex

- [E.2](#) Installability;
- [E.3](#) Learnability;
- [E.4](#) Ease of operation;
- [E.5](#) Adaptability;
- [E.6](#) Portability;
- [E.7](#) Reliability;
- [E.8](#) Maintainability;
- [E.9](#) Safety.

See [Tables E.1](#) to [E.8](#).

E.2 Installability

Installability measures are used to assess the degree of effectiveness and efficiency with which a product or system can be successfully installed and/or uninstalled in a specified environment.

Table E.1 — Installability

Recommendation or measure	Source ^a				Type of method ^b				Measures ^c		
	910	920	ISO/ IEC 25023	Sub- clause	Tech eval	In- spect	Task test	Obs use	Per- form	Phys- io	User rep
Ease of installation may be considered when choosing a haptic device.	✓			9.2.15.3		✓			✓		✓
Installation time efficiency: The time required to install the system should be considered.			✓	8.9.2			✓	✓	✓		
^a Sources are ISO 9241-910:2011, ISO 9241-920:2009 and ISO/IEC 25023:2016. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance</u> data, <u>physiological</u> data and <u>user-reported</u> data.											

E.3 Learnability

Learnability measures are used to assess the degree to which a product or system can be used by specified users to achieve specified goals of learning to use the product or system with effectiveness, efficiency, avoidance of harm from use and satisfaction in a specified context of use.

Table E.2 — Learnability

Recommendation	Source ^a				Type of method ^b				Measures ^c		
	910	920	ISO/ IEC 25023	Sub- clause	Tech eval	In- spect	Task test	Obs use	Per- form	Physio	User rep
Self-explanatory user interface: for public systems, the ability of new users to complete common tasks without prior study or training or seeking external assistance should be considered.			✓	8.5.2		✓	✓	✓	✓		✓
The ability of the intended users to learn to use the system with acceptable levels of effectiveness, efficiency and satisfaction should be considered.			✓	8.5.2		✓	✓	✓			✓
Error messages understandability: The extent to which error messages state the reason why the error occurred and how to resolve it should be considered.			✓	8.5.2		✓					
^a Sources are ISO 9241-910:2011, ISO 9241-920:2009 and ISO/IEC 25023:2016. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .											

E.4 Ease of operation

Operability measures are used to assess the degree to which a product or system has attributes that make it easy to operate and control.

Table E.3 — Ease of operation

Recommendation or measure	Source ^a				Type of method ^b				Measures ^c		
	910	920	ISO/ IEC 25023	Sub- clause	Tech eval	In- spect	Task test	Obs use	Per- form	Physio	User rep
Operational consistency: the extent to which interactive tasks have a behaviour and feel that are consistent both within the task and across similar tasks should be considered.			✓	8.5.3		✓	✓	✓	✓		✓
Message clarity: the extent to which messages from the system convey the right outcome or give instructions to the user should be considered.			✓	8.5.3		✓	✓	✓	✓		✓
Undo capability: the extent to which tasks that have a significant consequence should provide an option for re-confirmation or undo capability should be considered.			✓	8.5.3		✓	✓	✓	✓		
The fidelity of a device in carrying out the task (the ability of the haptic system to simulate real-world interactions) should be considered when choosing a tactile/haptic device.	✓			9.2.16		✓					✓
^a Sources are ISO 9241-910:2011, ISO 9241-920:2009 and ISO/IEC 25023:2016. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .											

E.5 Adaptability

Adaptability measures are used to assess the degree to which a product or system can effectively and efficiently be adapted for different or evolving hardware, software or other operational or usage environments.

One means of achieving accessibility ([E.3](#)) is to enable a system to be adapted to support use by the widest range of capabilities of people.

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Table E.4 — Adaptability

Recommendation	Source ^a				Type of method ^b				Measures ^c		
	910	920	ISO/ IEC 25023	Sub- clause	Tech eval	In- spect	Task test	Obs use	Per- form	Physio	User rep
Functional customizability: the extent to which users and maintainers are able to customize functions and operational procedures for the convenience of users should be considered.			✓	8.5.3		✓	✓	✓	✓		
User interface customizability: the extent to which users and maintainers are able to customize the user interface for the convenience of users should be considered.			✓	8.5.3		✓	✓	✓	✓		
Enabling users to change modalities The system should enable the user both to disable tactile output and/or have output presented in another modality.		✓		3.2.1		✓	✓	✓			✓
Enabling force feedback override The system should allow any force feedback to be overridden by the user.		✓		3.2.2			✓				✓
Enabling users to individualize tactile parameters Options to adjust tactile/haptic parameters should be provided to prevent discomfort, pain or injury to users of interactive systems.		✓		3.2.3		✓	✓				✓
Modifiable to a task Modification of the haptic device required by the task should be considered when choosing a haptic device.	✓			9.2.15.1		✓			✓		✓
Controllably adaptable to a task Special control of the haptic device appropriate to the task should be considered when choosing a haptic device.	✓			9.2.15.2		✓			✓		✓
Reconfiguring the tactile/haptic space The system:				7.2.1							
— may provide an option for reconfiguring the tactile/haptic space.		✓				✓					✓
— should obtain user confirmation before changing the frame of reference of the tactile/haptic space.		✓				✓	✓				✓
^a Sources are ISO 9241-910:2011, ISO 9241-920:2009 and ISO/IEC 25023:2016. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .											

E.6 Portability

Portability measures are used to assess the degree of effectiveness and efficiency with which a system, product or component can be transferred from one hardware, software or other operational or usage environment to another.

Table E.5 — Portability

Recommendation	Source ^a				Type of method ^b				Measures ^c		
	910	920	ISO/ IEC 25023	Sub- clause	Tech eval	In- spect	Task test	Obs use	Per- form	Physio	User rep
Operational environment adaptability: the extent to which it is possible to implement the haptic system in different operational environments should be considered.			✓	8.9		✓	✓	✓	✓		
^a Sources are ISO 9241-910:2011, ISO 9241-920:2009 and ISO/IEC 25023:2016. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance</u> data, <u>physiological</u> data and <u>user-reported</u> data.											

E.7 Reliability

Reliability measures are used to assess the degree to which a system, product or component performs specified functions under specified conditions for a specified period of time.

Table E.6 — Reliability

Recommendation	Source ^a				Type of method ^b				Measures ^c		
	910	920	ISO/ IEC 25023	Sub- clause	Tech eval	In- spect	Task test	Obs use	Per- form	Physio	User rep
The reliability of the haptic device should be considered when choosing a haptic device.	✓			9.2.15.4		✓					✓
Failure rate: the extent to which the number of failures during a defined period is acceptable should be considered.			✓	8.6.1				✓	✓		
Down time: the extent to which the time that a system stays unavailable when a failure occurs is acceptable should be considered.			✓	8.6.2				✓	✓		
^a Sources are ISO 9241-910:2011, ISO 9241-920:2009 and ISO/IEC 25023:2016. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance</u> data, <u>physiological</u> data and <u>user-reported</u> data.											

E.8 Maintainability

Maintainability measures are used to assess the degree of effectiveness and efficiency with which a product or system can be modified by the intended maintainers.

Table E.7 — Maintainability

Recommendation	Source ^a				Type of method ^b				Measures ^c		
	910	920	ISO/ IEC 25023	Sub- clause	Tech eval	In- spect	Task test	Obs use	Per- form	Physio	User rep
Modification capability: the extent to which it is possible to make needed modifications to the system in an acceptable length of time should be considered.			✓	8.8.4		✓	✓	✓	✓		
The ease of maintenance of the device should be considered when choosing a tactile/haptic device.	✓			9.2.15.5.1		✓	✓	✓	✓		✓
The required time and difficulty of maintenance are acceptable.	✓			9.2.15.5.2		✓	✓	✓	✓		✓
Ideally, routine maintenance tasks should be carried out locally, while more complex tasks should be undertaken by an appropriate service with minimal time delay.	✓			9.2.15.5.3		✓	✓	✓	✓		✓
When purchasing a device, there should be a clear understanding as to the details of the manufacturer's warranty — what is covered and how long the warranty lasts.	✓			9.2.15.5.4		✓	✓	✓	✓		✓
^a Sources are ISO 9241-910:2011, ISO 9241-920:2009 and ISO/IEC 25023:2016. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .											

E.9 Safety

International Standards relevant to the safety of human-computer interactions include:

- IEC 60950-1[37];
- ISO 16484-2:2004[Annex A25];
- ISO 13482[23];
- ISO 10218-1[22].

Table E.8 — Safety

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Subclause	Tech eval	Inspect	Task test	Obs use	Per- form	Physio	User rep
Mechanical safety The mechanical safety of a haptic device should be considered when choosing a haptic device.	✓		9.2.13.1.1		✓					✓
The risk of actuators propelling parts of the device into violent contact with a user should be avoided or reduced.	✓		9.2.13.1.2		✓		✓			✓
Ways of shutting down the device when it is not being held should be considered.	✓		9.2.13.1.3		✓		✓			✓
The user of the device should be able to disengage from the device.	✓		9.2.13.1.4		✓		✓			✓
^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

Table E.8 (continued)

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Subclause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Electric safety The electrical safety of a haptic device should be considered when choosing a haptic device.	✓		9.2.13.2.1		✓					✓
It should be ensured that the user is shielded from dangerous electrical voltages.	✓		9.2.13.2.2		✓					✓
Internationally recognized electrical codes (rules) should be followed to ensure the device's safety.	✓		9.2.13.2.3		✓					✓
If the electrical power fails, the device should enter a safe state.	✓		9.2.13.2.4		✓					✓
Thermal safety The thermal safety of a haptic device should be considered when choosing a haptic device.	✓		9.2.13.3		✓					✓
^a Sources are ISO 9241-910:2011 and ISO 9241-920:2009. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

Annex F **(informative)**

Human-centred quality

F.1 General

F.1.1 Overview

This annex lists recommendations and requirements from various usability standards on human-centred quality aspects of haptic interactions, together with types of methods and measurement types appropriate for each recommendation.

Human-centred quality is a collective term for the outcomes of interaction when a system is used: usability (effectiveness, efficiency and satisfaction), accessibility, user experience and avoidance of harm from use.

Human-centred quality can be evaluated when a haptic system is used in a given context of use (i.e. for given user groups, tasks and environment). Human-centred quality can be influenced not only by the quality of the haptic system, but also by the characteristics, capabilities or personal style of the users, and by the tasks that they perform. It can also depend on the physical environment (for example, use of a product inside or outside a building) or the social environment (for example, use alone or as part of a group).

[Annex J](#) describes how usability (see [E.2](#)) can be evaluated by a usability walkthrough or usability test. It is also possible to evaluate whether a system conforms to established ergonomic design guidance for usable systems, such as that in ISO 9241 standards.

F.1.2 Contents of the annex

- [F.3.2](#) Haptic interaction as assistive technology: potential modification of the user interface;
- [F.3.3](#) Accessibility of tactile displays: alternative modalities, altering parameters for the user;
- [F.3.4](#) Accessibility of device documentation: understandable, on-line, on accessibility features;
- [F.3.5](#) Accessibility for those with limited physical capabilities: for limited motor force or control;
- [F.3.6](#) Accessibility for those with limited cognitive capabilities: assisting understanding and action.

See [Tables F.1 to F.7](#).

F.2 Usability

F.2.1 Effectiveness

Recommendation	Source ^a			Tech eval	Type of method ^b			Measures ^c		
	ISO 9241-11	ISO/IEC 25022	Sub-clause		Inspect	Task test	Obs use	Per-form	Physio	User rep
The accuracy and completeness with which users can achieve their goals should be considered.	✓		6.2		✓	✓	✓	✓		✓
		✓	8.2							
^a Sources are ISO 9241-11:2017 and ISO/IEC 25022:2016. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

F.2.2 Efficiency

Recommendation	Source ^a			Tech eval	Type of method ^b			Measures ^c		
	ISO 9241-11	ISO/IEC 25022	Sub-clause		Inspect	Task test	Obs use	Per-form	Physio	User rep
The resources (including time, human effort, costs and materials) used in relation to the results achieved should be considered.	✓		6.3			✓	✓	✓		✓
		✓	8.3							
^a Sources are ISO 9241-11:2017 and ISO/IEC 25022:2016. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

F.2.3 Satisfaction

Recommendation	Source ^a			Tech eval	Type of method ^b			Measures ^c		
	ISO 9241-11	ISO/IEC 25022	Sub-clause		Inspect	Task test	Obs use	Per-form	Physio	User rep
The user's physical, cognitive and emotional responses that result from the use of a system, product or service should be considered.	✓		6.4			✓	✓			✓
		✓	8.4							
^a Sources are ISO 9241-11:2017 and ISO/IEC 25022:2016. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

F.3 Accessibility

F.3.1 General

Accessibility is the extent to which products, systems, services, environments and facilities can be used by people from a population with the widest range of user needs, characteristics and capabilities to achieve identified goals in identified contexts of use. For a haptic system to be usable by the widest range of potential users, it needs to be designed for accessibility (see, for example, ISO 9241-20). Accessibility can be evaluated by testing the usability of the system by people at the extremes of the range of potential physical and cognitive abilities. It is also possible to evaluate whether a system

conforms to established design guidance for accessible systems, such as those given in ISO 9241-20 and ISO 9241-171.

NOTE Some countries have accessibility requirements suitable for public procurement (such as Reference [5]).

F.3.2 Haptic interaction as assistive technology

Table F.1 — Haptic interaction as assistive technology

Requirements	Source ^a			Type of method ^b				Measures ^c		
	ISO 9241-20	ISO 9241-171	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
User interface element information Software shall provide assistive technology with information about individual user interface elements. (In its role as assistive technology, does the haptic interaction allow access to individual interface elements?)		✓	8.5.4	✓	✓					
Change focus and selection Software shall allow assistive technology to modify focus and selection attributes of user interface elements. (In its role as assistive technology, does the haptic interaction modify the focus and selection attributes of user interface elements?)		✓	8.5.5	✓	✓					
Event notification Software shall provide assistive technology with notification of events relevant to user interactions. (In its role as assistive technology, does the haptic interaction operate seamlessly with the other elements of user interaction?)		✓	8.5.7	✓	✓					
^a Sources are ISO 9241-20:2008 and ISO 9241-171:2008. ^b Methods are <u>technical evaluation</u>, <u>inspection</u>, task test and <u>observe use</u>. ^c Measures are <u>performance</u> data, <u>physiological</u> data and <u>user-reported</u> data.										

F.3.3 Accessibility of tactile displays

Table F.2 — Accessibility of tactile displays

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	ISO 9241-20	ISO 9241-171	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Not by tactile alone Software should not use tactile output alone as the only way to convey information or indicate an action.		✓	10.9.1		✓					
Use familiar tactile patterns Software should use well-known tactile patterns (familiar in daily life) for presenting tactile messages.		✓	10.9.2		✓					✓
Enable tactile output to be adjusted Software should allow users to adjust tactile output parameters to prevent discomfort, pain or injury.		✓	10.9.3	✓	✓		✓		✓	✓
^a Sources are ISO 9241-20:2008 and ISO 9241-171:2008. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

F.3.4 Accessibility of device documentation

Table F.3 — Accessibility of device documentation

Recommendation and requirement	Source ^a			Type of method ^b				Measures ^c		
	ISO 9241-20	ISO 9241-171	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Understandable documentation Product documentation and help for software should be written using a clear and simple language to the extent that this can be done using the vocabulary of the task.		✓	11.1.1		✓	✓	✓			✓
In accessible electronic form All user documentation and help shall be provided in an electronic form that meets applicable documentation accessibility standards.		✓	11.1.2	✓	✓					
Online in accessible forms Information presented in pictures and graphics by software shall also be provided as descriptive text suitable for screen reading, printing, or Braille conversion so that it can be read by an alternative method[39][44].		✓	11.1.3	✓	✓					
^a Sources are ISO 9241-20:2008 and ISO 9241-171:2008. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

Table F.3 (continued)

Recommendation and requirement	Source ^a			Type of method ^b				Measures ^c		
	ISO 9241-20	ISO 9241-171	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Without unnecessary device references a) Not device-specific Instructions and help for software should be written so that they refer to the users' actions and resulting output without reference to a specific device.		✓	11.1.4	✓	✓					
b) Reference device only when necessary References to devices should only be made when they are integral to and necessary for understanding of the advice being given.		✓	11.1.4	✓	✓					
On accessibility features Help or documentation for software shall provide general information on the availability of accessibility features and information about the purpose of and how to use each feature.		✓	11.1.5	✓	✓					
^a Sources are ISO 9241-20:2008 and ISO 9241-171:2008. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

F.3.5 Accessibility for those with limited physical capabilities

Table F.4 — Accessibility for those with limited physical capabilities

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	ISO 9241-20	ISO 9241-171	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
For limited physical movement ICT equipment and services should support users who have limited physical movement.	✓		7.5.1		✓	✓	✓			✓
Adjustable location of controls The placement of controls and displays should be adjustable to heights and locations that the users can reach.	✓		7.5.2		✓	✓	✓			✓
Supporting use of either hand Controls should be operable using either hand.	✓		7.5.3		✓	✓	✓			✓
^a Sources are ISO 9241-20:2008 and ISO 9241-171:2008. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

Table F.4 (continued)

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	ISO 9241-20	ISO 9241-171	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Avoid simultaneous use of both hands Controls should avoid the need for simultaneous use of both hands.	✓		7.5.3		✓	✓	✓			✓
Limiting required physical force Controls should be movable with the minimum force required, within the constraints of the operation being performed.	✓		7.5.4		✓	✓	✓			✓
Limiting required motor control ICT equipment and services should support users with limited motor control and should not require high dexterity (e.g. by providing a voice control alternative).	✓		7.5.5		✓	✓	✓			✓
Compensating for limited motor control Controls should be designed to compensate for limitations in fine motor control capabilities (e.g. tremors).	✓		7.5.6		✓	✓	✓			✓
User control of response timing If a task requires users to make responses (e.g. press a button or type information) within a limited time in order for that response to be valid, the time range should be adjustable by the user, including the option to turn off all timing requirements.	✓		7.5.7		✓	✓	✓			✓
^a Sources are ISO 9241-20:2008 and ISO 9241-171:2008. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

F.3.6 Accessibility for those with limited cognitive capabilities

Table F.5 — Accessibility for those with limited cognitive capabilities

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	ISO 9241-20	ISO 9241-171	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
For limited cognitive capabilities ICT equipment and services should support users who have limitations in their cognitive capabilities.	✓		7.6.1		✓	✓	✓			✓
Limited cognitive demands ICT equipment and services should avoid unnecessarily high cognitive demands on users by ensuring that the basic activities required to operate the equipment or to use the service are as straightforward and simple as possible.	✓		7.6.2		✓	✓	✓			✓
Aiding understanding Information should be presented and organized in a manner that will aid understanding by users.	✓		7.6.3		✓	✓	✓			✓
Using understandable vocabulary The vocabulary used to describe and operate ICT equipment and services should use expressions and terminology that are as easy as possible to understand, irrespective of the level of expertise and cognitive capabilities of users.	✓		7.6.4		✓	✓	✓			✓
Providing information pictorially Where possible, information should be provided in symbolic or pictorial form to enhance the user's ability to comprehend the information.	✓		7.6.5		✓	✓	✓			✓
Providing appropriate cues ICT equipment and services should provide appropriate cues to assist users in paying attention to important information (e.g. control status).	✓		7.6.6		✓	✓	✓			✓
Adjusting speed of interaction Where possible, the speed of interaction should be adjustable by the user.	✓		7.6.7		✓	✓	✓			✓
^a Sources are ISO 9241-20:2008 and ISO 9241-171:2008. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

Table F.5 (continued)

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	ISO 9241-20	ISO 9241-171	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Enabling pausing or stopping Whenever moving, blinking, scrolling or auto-updating information is presented, the user should be enabled to pause or stop this dynamic presentation.	✓		7.6.8		✓	✓	✓			✓
Minimizing the need for training The design of ICT equipment and services should relate to common user experiences and thus minimize the need for special training.	✓		7.6.9		✓	✓	✓			✓
Supporting cultural and linguistic differences The vocabulary used to describe and operate ICT equipment and services should use expressions that can be understood by users with differences in culture or language.	✓		7.6.10		✓	✓	✓			✓
^a Sources are ISO 9241-20:2008 and ISO 9241-171:2008. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

F.4 User experience

User experience can be understood by studying the aspirations and experiences of individual users, and can be measured by using questionnaires for outcomes such as pleasure and engagement.

Table F.6 — User experience

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	ISO 9241-210	ISO/IEC 25022	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Design user tasks, user-system interaction and user interface to meet user requirements, taking into consideration the whole user experience: the person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service, including all the users' emotions, beliefs, preferences, perceptions, physical and psychological responses, behaviours and accomplishments that occur before, during and after use.	✓	✓	8.4.4 6.4.2 with 2.15			✓	✓			✓
^a Sources are ISO 9241-210:2010 and ISO/IEC 25022:2016. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

F.5 Avoidance of harm from use

Improved usability can mitigate or remove the potential harm from use that can arise from inappropriate forms of interaction or inappropriate outputs (see A.6). Potential harm from use that can be assessed includes:

- a) harm to the user:
 - harm during interaction including stress, fatigue, frustration or lack of empowerment and other potential hazards to health and safety;
 - harm from failure to achieve the intended outcome including inconvenience, wasted time or financial costs;
 - other harm including lack of trust, security or privacy;
- b) harm to the manufacturing organization:
 - design and development of the product, system or service not meeting intended targets for usability, accessibility, and/or user experience;
 - the delivered system not supporting operational needs in the customer organization;
 - economic or reputation consequences resulting from a developed system not being purchased or a developed service not being used;
 - harm from inadequate operational safety;
- c) harm to the wider community;
- d) harm to the environment.

Table F.7 — Avoidance of harm from use

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	ISO 9241-11	ISO/IEC 25022	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
The potential for adverse consequences to the user or organization within which the user is working, resulting from human use, including risks of harm to economic status, human life, health, or the environment, should be considered.	✓	✓	A.6	✓	✓	✓	✓	✓	✓	✓
			8.5							
^a Sources are ISO 9241-11:2017 and ISO/IEC 25022:2016. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

F.6 Ethical considerations

The final use of a haptic interaction should be assessed for conformance to standard ethical guidelines. Ethical use is codified in ISO 26000, mainly pertaining to the role of states and enterprises in social responsibility. The bibliography of that standard contains a list of standards and conventions relevant to ethical considerations. A general awareness of the field would assist a reviewer in making this judgement. The various standards and conventions, including the Declaration of Helsinki, should be consulted as required.

Annex G (informative)

Gesture attributes

G.1 General

G.1.1 Overview

This annex lists recommendations from ISO 9241-960 on gesture attributes, together with types of methods and measurement types appropriate for each recommendation.

G.1.2 Contents of the annex

- [G.2](#) Ergonomics of gestures: constraints of both body position and gesture sensing;
- [G.3](#) Process for gesture definition: recommended ways to define gestures;
- [G.4](#) Features of gestures: feedback, feedforward and variability of gestures;
- [G.5](#) Timing and speed: recognition of gestures at different speeds;
- [G.6](#) Sequences of gestures: beginning, middle and end of gestures; gesture transitions;
- [G.7](#) Gesture sets: purpose and relationship between gestures in a gesture set;
- [G.8](#) Documentation of gestures: guidance for descriptions of gestures.

See [Tables G.1](#) to [G.7](#).

G.2 Ergonomics of gestures

Table G.1 — Ergonomics of gestures

Recommendation	Source ^a			Type of method ^b				Measures ^c		
		960	Sub-clause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Ergonomic constraints Gestures that are performed repetitively should not create unnecessary fatigue in the body parts which are to be posed or moved during the gesture.		✓	5.1	✓	✓	✓	✓		✓	✓
a) Users should be involved in determining the need for such repetitions.		✓	5.1 a)	✓						
b) If repetitive gesturing is unavoidable, hazard identification, risk estimation, risk evaluation and risk reduction should be performed in order to avoid musculo-skeletal disorders.		✓	5.1 b)	✓						
Device capabilities A device for receiving gestures should have the capability of detecting the trajectory of a stroke or a pose within all conditions imposed by the environment.		✓	5.2	✓		✓	✓	✓		
Device constraints A device for receiving gestures can restrict the trajectory or pose that a human intends to form. The user should be made aware of these restrictions.		✓	5.3				✓			✓
^a Source is ISO 9241-960:2017. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .										

G.3 Process for gesture definition

Table G.2 — Process for gesture definition

Recommendations and requirements	Source ^a		Type of method ^b				Measures ^c		
	960	Subclause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Gestures should be suitable for learning.	✓	6.1.1 c)			✓				✓
Only intentional gestures should be processed in a gestural interface.	✓	6.1.1 g)			✓	✓			✓
Users should be made aware of the device's capability to process intentional gestures.	✓	6.1.1 g)		✓					✓
Explore the design space The potentially available design alternatives, including the design rationale, should be explored for the intended users and contexts of use.	✓	6.1.2.1		✓		✓			✓
Explore widely human movements The investigation should include not only the hands, but also limbs and full body movements, as well as head and eye movements and other facial expressions.	✓	6.1.2.2 a)	✓	✓	✓	✓	✓	✓	✓
^a Source is ISO 9241-960:2017. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .									

Table G.2 (continued)

Recommendations and requirements	Source ^a		Type of method ^b				Measures ^c		
	960	Subclause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Alternative body parts for gestures, range of motion, tolerance of tremors, ability for simultaneous action, and ability to walk should be considered for better accessibility.	✓	6.1.2.2 b)	✓	✓	✓	✓	✓	✓	✓
Explore single and synchronized movements Exploration of gestures should consider not only movement of single body parts but also synchronized coordinated movements of multiple body parts.	✓	6.1.2.3	✓	✓		✓	✓	✓	✓
Explore simultaneous and synchronized movements Exploration of gestures should consider both simultaneous and sequential movements.	✓	6.1.2.4	✓	✓		✓	✓	✓	✓
Explore movements made by multiple users a) The design should include consideration of gestures performed by multiple users independently as well as gestures formed collaboratively by two or more users. b) Social acceptance of gestures should be considered.	✓	6.1.2.5	✓			✓	✓	✓	✓
Identifying purposes Developers shall identify the purposes for which humans need to express gestures in relation to the information and communication technology (ICT) system.	✓	6.1.3		✓					
Developers should identify at least one gesture for each gesture command based on the following sources of gestures, in order of descending priority: a) pre-existing gesture in the culture; b) internationally standardized gestures; c) gestures suggested by one or many users; d) gestures suggested by the context of use; e) gestures from other contexts of use; f) gestures typical to the devices being used; g) gestures suggested within a design team.	✓	6.1.4.1		✓		✓			✓
When designing a gesture set, pre-existing gestures [in the cultural or social setting] should be identified and considered for inclusion in a gesture set.	✓	6.1.4.1		✓		✓			✓
Matching gestures and functionality Mappings should take existing manual operations such as handwriting into account.	✓	4.4		✓	✓	✓		✓	✓
User-defined gestures User-defined gesture sets should be available over a wide range of contexts of use and across devices when appropriate.	✓	6.1.4.2		✓	✓	✓		✓	✓
^a Source is ISO 9241-960:2017. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .									

Table G.2 (continued)

Recommendations and requirements	Source ^a		Type of method ^b				Measures ^c		
	960	Subclause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Identify variability of gestures The error tolerance of the gesture movement should be determined and shall be commensurate with 6.6.4. (Gesture sets should be designed to allow the user to discriminate between gestures.).	✓	6.1.4.3		✓	✓	✓		✓	✓
Evaluating gestures Developer-defined gestures shall be evaluated to ensure they meet the needs of the intended users within the intended contexts of use.	✓	6.1.6		✓	✓	✓	✓	✓	✓
Iterating the gesture interface The design process of the gesture interface should be iterative according to ISO 9241-210, taking both the interactive system and its context of use into account.	✓	6.1.7		✓					✓
Training users in gestures a) Users should be able to explore gestures without adversely affecting system content. b) Users should be able to explore the possible trajectories or poses involved in a gesture.	✓	6.1.9		✓		✓	✓		
^a Source is ISO 9241-960:2017. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .									

G.4 Features of gestures

Table G.3 — Features of gestures

Recommendation	Source ^a		Type of method ^b				Measures ^c		
	960	Subclause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Mapping of gesture commands to functions Designers of gestures should ensure that the mapping of the gesture command to a function is consistent with user expectations.	✓	6.2.1		✓		✓	✓		✓
Feedback for stroke gestures If feedback is generated for a gesture, the user should be made aware of strokes not recognized as part of a gesture.	✓	6.2.3		✓		✓	✓		✓
Continuous feedback for gesture commands Continuous gesturing should not require interruptions or pauses in the movement in order to gain feedback.	✓	6.2.4		✓		✓			✓
^a Source is ISO 9241-960:2017. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .									

Table G.3 (continued)

Recommendation	Source ^a		Type of method ^b				Measures ^c		
	960	Subclause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Feedforward information When designing feedback for stroke gestures, information should be considered from the feedforward feature.	✓	6.2.5		✓		✓			✓
Once the gesture interface identifies a gesture command, the user should not be required to continue the gesture to the end of the movement.	✓	6.2.5		✓		✓			✓
Parameters of gesture commands Variations of gestures can be used as modifications of a gesture command. Users should be able to identify such parameters.	✓	6.2.6		✓		✓			✓
^a Source is ISO 9241-960:2017. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .									

G.5 Timing and speed

Table G.4 — Timing and speed

Recommendation	Source ^a		Type of method ^b				Measures ^c		
	960	Subclause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Recognition of gesture at different speeds A device should be able to recognize the same gesture made at different speeds.	✓	6.3.1		✓		✓		✓	✓
Use of the speed of a gesture The duration of a gesture should not affect its functionality, unless speed is included as a parameter of the gesture.	✓	6.3.2		✓		✓		✓	✓
Tolerance of gesture interface The gesture interface should be designed to support a sufficient variety of movements while being able to distinguish between intentional and unintentional gestures.	✓	6.4		✓		✓	✓		✓
^a Source is ISO 9241-960:2017. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .									

G.6 Sequences of gestures

Table G.5 — Sequences of gestures

Recommendation	Source ^a		Type of method ^b				Measures ^c		
	960	Subclause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Beginning a gesture Users should be able to indicate the beginning of an intentional gesture clearly, so that the user is able to avoid the unintentional start of some functionality of the interactive system.	✓	6.5.1		✓		✓			✓
Feedback of gesture initiation The information and communication technology (ICT) system's ability to interpret gesture commands should be clearly indicated to the user.	✓	6.5.2		✓		✓			✓
Completing the purpose of a gesture The user should be made aware of the completion of the gesture command.	✓	6.5.3		✓		✓			✓
Need for transition between gestures If the device for gestural input needs to be reset to its initial state for further gestural input, the user should be made aware of any extra movements needed.	✓	6.5.5		✓		✓			✓
The effect of transitions between gestures Extra movements that form a transition between gestures should be considered.	✓	6.5.6		✓		✓			✓
State changes Where changing states impact the functionality of a gesture, the system should notify the user that the state has changed and provide the user with a means of identifying the current state of the system.	✓	6.5.8		✓		✓			✓
^a Source is ISO 9241-960:2017. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , <u>task test</u> and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .									

G.7 Gesture sets

Table G.6 — Gesture sets

Recommendation	Source ^a		Type of method ^b				Measures ^c		
	960	Subclause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Introduction Gestures should be grouped within a gesture set.	✓	6.6.1		✓					
Purpose of a set of gestures Each gesture within a gesture set should be designed for a purpose, a device and a context.	✓	6.6.2		✓					
Consistency among gestures Gestures within a gesture set should be sufficiently similar so that remembering one gesture should enable the ready recall of another gesture in the set.	✓	6.6.3		✓		✓			✓
Discriminability of gestures Gesture sets should be designed to allow the user to discriminate between gestures.	✓	6.6.4		✓		✓			✓
Alternative subsets within a gesture set Alternative gestures should be provided for the needs of specific users.	✓	6.6.6		✓					✓
^a Source is ISO 9241-960:2017. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .									

G.8 Documentation of gestures

Table G.7 — Documentation of gestures

Recommendation or requirement	Source ^a		Type of method ^b				Measures ^c		
	960	Subclause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Documentation of gestures Documentation of gestures should be suitable for the intended users and contexts of use.	✓	6.1.8		✓		✓			✓
Explaining gestures Gestures and gesture commands shall be described in documentation available to the user. This documentation should be offered at the initialization of the gestural interface.	✓	6.1.9		✓		✓			✓
Documentation The documentation of each gesture should include: — the name of the gesture; — a visual description of the shape of the gesture, e.g. drawing, animation or video; — a textual description of how to form the gesture; — a description of the gesture's mapping to the purpose.	✓	6.7.1		✓					
Naming a gesture The name should be: — specified in the language of the intended users; — unambiguous within the context of use; — easy to learn and memorize; — concise.	✓	6.7.2		✓					
Visualization of gestures Visual documentation of gestures should indicate: — a start point; — an end point; — the trajectory of any motion in the gesture; — the direction of any motion along the trajectory; — which body parts are involved; — the sequence of any forces involved in the gesture.		6.7.3		✓					
^a Source is ISO 9241-960:2017. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance</u> data, <u>physiological</u> data and <u>user-reported</u> data.									

Table G.7 (continued)

Recommendation or requirement	Source ^a		Type of method ^b				Measures ^c		
	960	Subclause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Textual documentation of a gesture a) Textual documentation of a gesture should include: — the physical interaction considered as the start of the gesture; — the physical interaction components (e.g. body parts or device manipulated by the users) involved in this gesture, including: — their physical relationships; — their temporal relationships; — a description of the movement and forces involved: — start points and end points; — the trajectory of a gesture and the direction of motion along the trajectory; — timing (including speed, pauses, acceleration); — force, if appropriate; — variability of these properties; — additional information as appropriate, e.g. ergonomic and technical capabilities influencing the gesture.	✓	6.7.4 a)		✓					
b) A description of a gesture should be described from the user's perspective in compliance with the characterization of orientation and direction of movements as described in ISO 1503.	✓	6.7.4 b)		✓					
c) A description of a gesture may include reference to the limitations or capabilities of a device.	✓	6.7.4 c)		✓					
d) If there are intellectual-property ownership factors to consider with any gestures not defined by the users themselves, documentation of gestures should include information on such ownership.	✓	6.7.4 d)		✓					
^a Source is ISO 9241-960:2017. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .									

Table G.7 (continued)

Recommendation or requirement	Source ^a		Type of method ^b				Measures ^c		
	960	Subclause	Tech eval	Inspect	Task test	Obs use	Per-form	Physio	User rep
Describing the purpose of a gesture The expected response or outcome of the system in response to the gesture should be described in the documentation and comply with the purpose identified in ISO 9241-960:2017, 6.1.3 (see Table G.2).	✓	6.7.5		✓					
Documenting a gesture set a) Where applicable, gestures should be grouped into appropriate sets according to G.7. b) Where applicable, all gestures within a gesture set should be identified and made available to the user. c) A gesture set should have a meaningful and unique name within the context of use.	✓	6.7.6		✓					
Documenting gestures with common movements If gestures within a gesture set have commonalities in their trajectories, the documentation should indicate clearly both the commonality and how each gesture within the gesture set is unique.	✓	6.7.7		✓					
^a Source is ISO 9241-960:2017. ^b Methods are <u>technical evaluation</u> , <u>inspection</u> , task test and <u>observe use</u> . ^c Measures are <u>performance data</u> , <u>physiological data</u> and <u>user-reported data</u> .									

Annex H (informative)

Examples of evaluation of device attributes

H.1 Examples of device assessment by inspection

H.1.1 General

The following are examples of methods for testing, but are not the only possible methods that can be used. These examples are derived from ISO 9241-910:2011, Clause 9. They relate generally to desktop kinaesthetic devices. Each sample test should be carried out with the intended application in mind; some tests will be more important than others for the intended application.

Following the categories set out in [Table 2](#), they have been split between attributes specific to the haptic aspects of the device and specific qualities that are auxiliary to the haptic aspects.

H.1.2 Haptic device attributes

H.1.2.1 Device-body interface

Is the device to be handled by the hands and fingers, or by another part of the body? Consider your application carefully to determine how the device will be interfaced to the user.

Is that part of the body sufficiently sensitive or dexterous to deal with the interaction?

H.1.2.2 Degrees of freedom

Generally, count translation directions and rotation angles along independent axes and add them up to get the degrees of freedom.

The following indicate typical meanings of the degrees of freedom (DOF) in a haptic device. All “movements” relate to the device-body interface.

- 1 DOF moves in only one direction or angle (like a straight line or a simple rotation);
- 2 DOF moves in a plane, or twists in two angles about independent axes;
- 3 DOF moves in a volume, or twists in three angles about independent axes;
- 4 DOF moves in a volume and twists in one angle;
- 5 DOF moves in a volume and twists in two angles about independent axes;
- 6 DOF moves in a volume and twists in three angles about independent axes;
- 7 DOF moves in a volume, twists in three angles, and carries a scissors-type handle.

Further degrees of freedom are possible. The device should be observed carefully and the motions on independent axes counted. (Independent axes are generally at right angles to one another.)

H.1.2.3 Maximum stiffness

The maximum stiffness required for a task should be considered when choosing a haptic device.

Maximum stiffness along a degree of freedom is the highest stiffness that can be imparted to a virtual surface or a virtual angular stop without inducing vibration in the device.

To assess this, a computer model is needed to make the virtual surface or angular stop. The user controls a virtual probe (within the computer model) by means of the device. The user presses the virtual probe into the surface while controlling the elastic constant of the surface. By trial and error with different elastic constants, the user finds the maximum elastic constant (or stiffness) that will not excite vibration.

H.1.2.4 Motion range

The range of motion can be estimated by handling the device, moving it between the extremes of the motion range in each independent coordinate.

Motion in the different degrees of freedom can be coupled. For example, note the limits of rotational motion at various locations in the translational workspace.

Motion range can be linked to the movements of the limbs. For example, workspaces could be termed “whole arm”, “forearm”, “wrist” or “finger”, depending on the part of the limb that is kept still while manoeuvring the device. These descriptions might relate very well to the intended operation of the device.

H.1.2.5 Peak force and torque

A well-trained arm could estimate peak force, but this would be difficult for most observers. The device force could be compared with the felt weight of a known mass to gain a better idea of the value of the peak force.

It might suffice for most applications to command peak force and classify it as “strong”, “medium” and “weak”.

If peak force is important to the application, the duration should be noted for which the peak force can be sustained before it is relaxed by the device’s responding to motor overheating.

H.1.2.6 Maximum continuous force and torque

Like peak force, the estimate of maximum continuous force by an observer may be quite approximate. It is the force which can be sustained by the device indefinitely. Some experimentation will suffice to give the continuous force or torque as the load (imposed by the observer) that does not trigger motor overheating.

Force can be classified heuristically as “strong”, “medium” or “weak”. Some idea of motor overheating might be given by carefully feeling the motor temperature, if it is accessible.

H.1.2.7 Minimum displayable force and torque

Minimum force is a quantity that can be felt intuitively, by comparison with typical light forces with which the observer is already familiar. Reasonable comparisons can be made if objects of known weight are available.

The observer should try to discern if different small forces can be displayed. If there is no felt difference between such forces, then they might be masked by friction.

H.1.2.8 Free space motion resistance

Friction can be estimated by moving the device-body interface in free space. Steady friction will be a constant resistance to motion. It can be distinguished from inertia by the fact that it stops as soon as pressure from the user’s hand is stopped, while inertia will continue to go in the same direction.

Friction might come with a random force or torque component. Because of this component, this friction can be distinguished from inertia.

Components of force or torque in free space can appear as periodic functions of spatial position. These could be from magnets in brushless motors or from gears being driven in reverse by force or torque from the user.

These motion-resisting forces may feel different with and without the electrical parts of the apparatus turned on, since there could be some software or electrical compensation of the effects. Generally, the device should feel acceptable in its free space motion without the activation of the electrical components. Software or electrical compensation could deteriorate over time. However, there may be cost savings with this type of compensation. The user will have to judge cost benefits versus device reliability.

H.1.2.9 Inertia

Inertia can be felt as motion that continues after the user stops forcing the device in a certain direction. It is difficult to tell inertia from frictional force resistance, except for the smoothness of the inertia and its tendency to “overshoot” the intended motion.

Inertia can be compensated by software, but it is a potentially unstable algorithm, difficult to implement successfully over a wide range of conditions.

Inertia can stabilize user tremors and smooth out the motion. It does impart an unnatural sluggishness to a device if the application involves simulating a real-world interaction.

H.1.2.10 Peak acceleration

If a hard virtual surface is set up, peak acceleration can be tested by moving in free space against the virtual surface. High peak acceleration is revealed by a solid tap on the surface without attendant noisy vibrations.

Such a tap is also indicative of high bandwidth, low system latency and low device latency. These parameters cannot be determined on their own by the observer without measuring instruments, but they do add up to a high peak acceleration.

H.1.2.11 Static friction

Static friction is resistance to starting a device from rest. It can have components of inertia and gear backlash and noise, but it adds up to the same effect. The user should judge carefully if resistance to startup motion is important to the intended application. High static friction can cause a position overshoot when first applying force.

H.1.2.12 Kinetic friction

Kinetic friction is resistance to motion once motion is underway. It can have components of gear backlash and noise, but it adds up to the same effect – a general resistance to motion. The user should judge carefully if resistance to startup motion is important to the intended application. High static friction can cause a position overshoot when first applying force.

H.2 Examples of device assessment by lab measurement

H.2.1 General

Certain tests can be applied to a device that probe its characteristics beyond the level of a visual, audio or haptic inspection. The tests described here assume access to software that can control the device and simple instruments such as load cells (or laboratory weigh scales) and clamps to hold linear measurement scales. The equipment setup is described for each test, along with examples of typical outcomes.

H.2.2 Maximum stiffness measurements

H.2.2.1 General

When the maximum stiffness of a motorized haptic system is exceeded, unintended vibration will occur. For example, rather than making a passive presentation of touch, the system introduces energy into the interaction that reveals it to be a poor simulation of what it is trying to represent.

A convenient test for maximum stiffness is to present the device with a virtual wall with adjustable spring constant and no damping. The maximum stiffness is the highest spring constant of the wall that can be explored by the device without generating vibration.

The handle has to be gripped by the user in the same manner that it would be gripped during normal operation. If held in a rigid grip, the measured stiffness will be slightly higher than its actual value in normal operation; if held loosely, the measured stiffness will be slightly lower than it would be in normal operation.

The concept of a standard testbed with a mechanical grip that duplicates the human grip is a subject of research. The impedance of the human arm and hand could be mimicked with an appropriate mechanism or mass of elastic material at the device-user interface. This could give an objective measure without the subjectivity of user damping by gripping more or less firmly (see References [7], [43] and [44]).

The following implicitly assumes a kinaesthetic device.

H.2.2.2 Equipment

A control computer with a simulation of a virtual wall with a variable amount of springiness – the surface of the wall is modelled by a spring governed by Hooke's law. The haptic device is connected to a small virtual sphere, so that the sphere moves synchronously with the movement of the haptic device. The wall has a return force, F , proportional to the depth of penetration, d , by the virtual probe into the wall, where k is the constant of proportionality (also known as the spring constant).

$$F = -kd$$

The computer software should be set up so as to

- a) give the user control over a point virtual probe by means of the haptic device under test,
- b) locate a virtual wall, typically the local x, y or z Cartesian reference plane,
- c) allow the user to place the virtual probe onto the surface of the wall, but to pull it back at will, and
- d) allow the user to increase or decrease the spring constant of the wall.

H.2.2.3 Test procedure

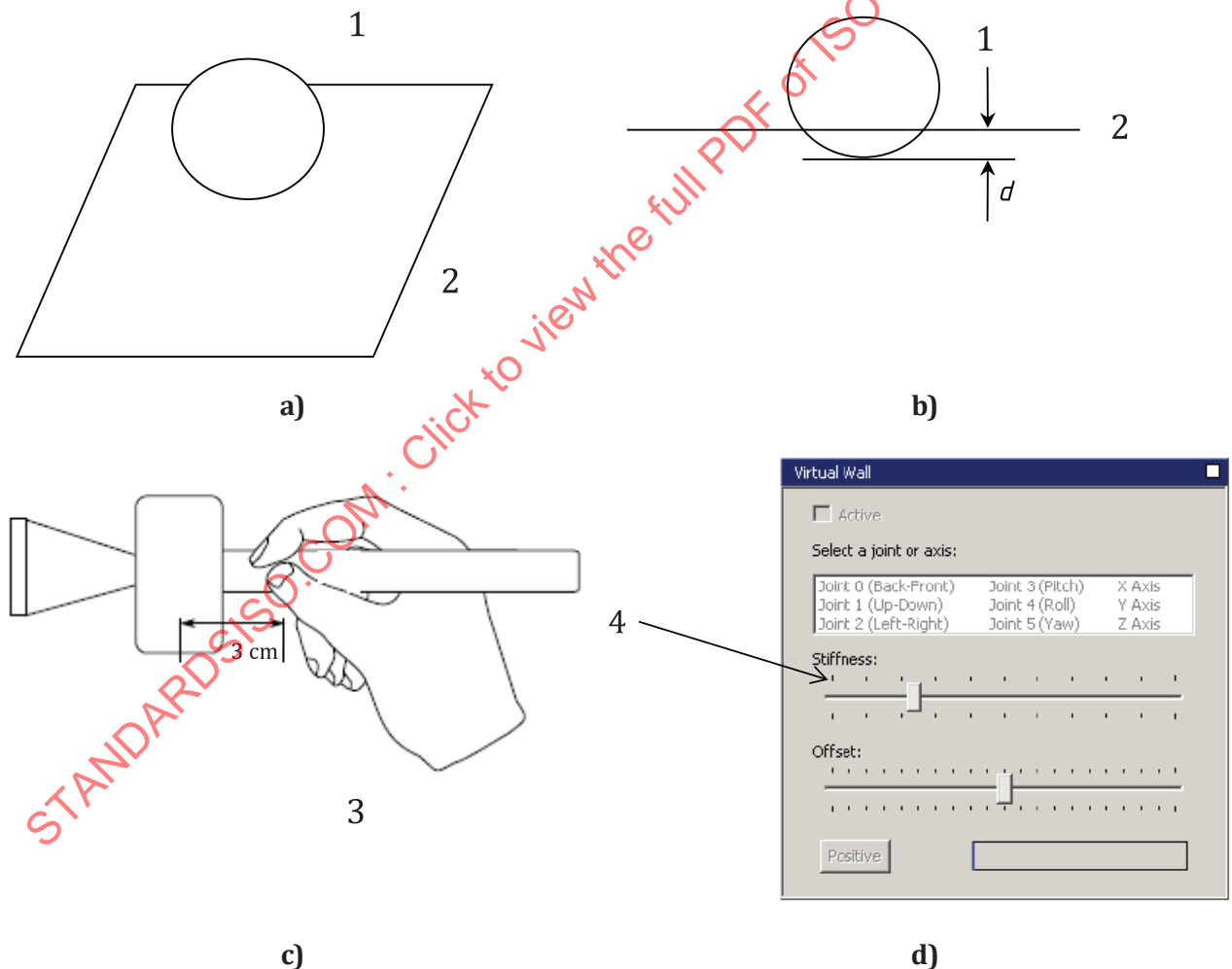
Find the maximum spring stiffness that does not cause vibration. Use a bifurcation technique as follows.

- a) Set the wall spring stiffness to any value near the expected maximum stiffness.
- b) If vibration occurs, reduce the spring constant.
- c) If vibration does not occur, increase the spring constant.
- d) Continue increasing and decreasing the spring constant, bracketing ever closer the maximum stiffness where vibration does not occur.
- e) When the smallest iteration crosses the line between vibration and no vibration, the maximum stiffness where vibration does not occur has been located.

A convenient way to vary the stiffness is to use a slide bar. When the mouse is used to select the slide bar, the roller on top of the mouse will move the slide bar, thus changing the stiffness. The user can vary the stiffness with one hand, sight unseen, while focusing attention on the device while it is controlled with the other hand.

Figure H.1 a) shows a sphere touching a surface in isometric view. The sphere is termed a “ball-probe”, and it is shown just touching the surface. Figure H.1 b) shows a side view of the ball and the surface, with the ball-probe pushed into the surface by a distance d . Figure H.1 c) shows a user’s hand with a pencil-like grip on the handle of a haptic device. The device handle is linked to the virtual ball, so when the user presses down on the handle, she feels an opposing force, F , that is proportional to the distance, d .

Figure H.1 d) shows a graphic user interface with two slide bars. One of the slide bars controls the stiffness, k , of the haptic interaction between the ball and the surface. This slide bar can provide the stiffness control that will give the highest stiffness possible for the virtual surface as probed by the virtual ball. It can be operated by the keyboard cursor keys with one hand, while the tester probes the virtual surface with his other hand on the haptic device. This way, the highest stiffness value can be found strictly by feel and sound, without reading the stiffness values in the panel until the test is complete.



Key

- 1 ball-probe
- 2 surface
- 3 haptic/tactile device where vibration could be felt
- 4 stiffness slide bar

Figure H.1 — Virtual probe set to measure haptic/tactile display vibration

H.2.3 Motion range measurements

H.2.3.1 General

Motion range is also known as workspace. The appropriate device motion range is typically determined by the planned range of motion of the device-body interface.

Motion range typically consists of translational and rotational components. These can be partitioned, as in serial devices, or coupled, as in parallel devices.

Typically, in a device with three translational degrees of freedom, the translational workspace of a device will be defined by three orthogonal axes. These might be defined relative to the observer, vertically bottom to top, horizontally left to right, and horizontally forward and backward.

Similarly, if there are three rotational degrees of freedom, the rotational workspace could be defined by rotation about three orthogonal axes.

H.2.3.2 Equipment

The equipment for measurement of the translational workspace consists of a linear measurement scale (a "ruler") and an independent means of support for the scale. For example, in devices in which the user swings his arm at the elbow, a meter stick would suffice for the measurement. It could be held by a pair of clamps, each attached to a single vertical support pole. Such clamps are used in chemistry labs for holding glassware.

The equipment for measurement of the rotational workspace consists of a protractor (typically a scale of angles over 180° drawn on a clear plastic surface). It could be held by a single of clamps attached to a single vertical support pole.

It is useful to note the values of the positions as noted by the device sensors, for comparison with the values record from measurements based on an external scale.

H.2.3.3 Test procedure

The extent of the translation workspace is found by noting the position of the motion extremes of the device-user interface. For each axis,

- a) arrange for the ruler to be supported independently of the device under test,
- b) set the ruler just under but not touching the device as it moves, spanning the motion extremes,
- c) move the device to the extreme in one direction,
- d) note the position of the device on the fixed ruler, being careful to look at right angles to the ruler,
- e) move the device to the extreme in the other direction,
- f) note the position of the device on the fixed ruler, being careful to look at right angles to the ruler, and
- g) the motion range is the difference of the two measurements.

The extent of the rotational workspace is found by noting the position of the motion extremes of the device-user interface. For each rotational degree of freedom,

- 1) arrange for the protractor to be supported independently of the device under test,
- 2) set the protractor just under but not touching the device as it moves, its origin at the rotation axis,
- 3) move the device to the extreme in one direction,
- 4) note the rotation of the device on the fixed protractor, looking at right angles to the protractor,

- 5) move the device to the extreme in the other direction,
- 6) note the rotation of the device on the fixed protractor, looking at right angles to the protractor, and
- 7) the motion range is the difference of the two angular measurements.

H.2.4 Force and torque measurements

H.2.4.1 General

Force refers to the force along a given direction. Typically, the force of a device with three translational degrees of freedom may be defined along three orthogonal axes.

Similarly, if there are three rotational degrees of freedom, torque could be defined by about three orthogonal axes.

For each force and torque direction, it is possible to define the peak instantaneous value, the maximum continuous value, the minimum displayable value and the resolution of the parameter.

A peak force could last as short as 10 ms, while a continuous force could last an indefinite time (5 min to hours if necessary).

The dynamic range of force and torque can be defined as the ratio of the highest to the lowest values in the force or torque along or around a given axis. It is typically expressed in decibels.

H.2.4.2 Equipment

Force or torque is measured typically with a load cell, a device that measures force in compression or tension. A widely available load scale is found in lab scales, or even personal bathroom scales. A scale with a range appropriate to the forces imposed by the device under test should be selected.

Ideally, the load cell output would be readable by a computer, so that a series of values can be taken quickly and efficiently as force is applied.

The device control software should be set up so as to

- a) give the user control over the output force or torque of the haptic device under test,
- b) record the applied force or torque as perceived by the device, and
- c) record the measured force or torque as perceived by the load cell.

H.2.4.3 Test procedure

The peak translational force is found by noting the force reading of an external load cell being pressed or pulled by the device-user interface of the device.

- a) Choose the component of force or torque to be measured. Identify its direction.
- b) Set up the load cell with support independently supported and fixed relative to the device.
- c) Arrange to the device so as to press or pull on the load cell, as appropriate.
- d) Set the force to maximum and record the results. Hold it long enough to record several data points.
- e) Set the force to a series of decreasing values and note the internally perceived and externally measured values.
- f) Continue down to nearly zero, noting the minimum force that makes a reading.
- g) Set the force to the expected continuous maximum value. Leave recording for 30 min.

- h) If the force is sustained for 30 min, increase the value and record for 30 min.
- i) Continue increasing the value until an unsustainable force is reached.
- j) The highest sustainable value is the maximum continuous force.

Repeat for other degrees of freedom as appropriate.

If a weigh-scale is used for the tests, it should typically be kept horizontal with the device under test arranged to bear down on the scale vertically.

H.2.5 Inertia measurements

H.2.5.1 General

Inertia shows itself in free space motion resistance. It is a perceived mass at the device-body interface.

Depending on the degree of freedom and its design, inertia can be translational inertia, expressed in units of mass, or rotational inertia, expressed in units of mass times distance squared.

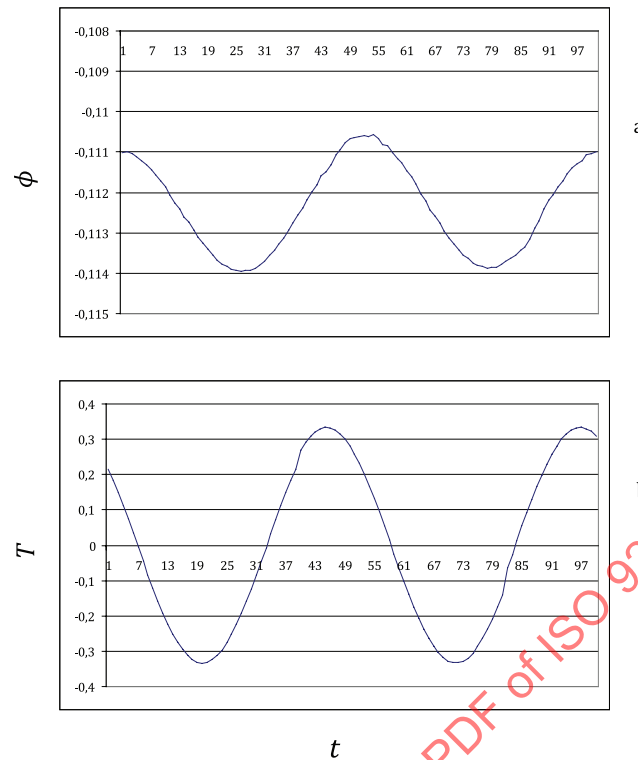
Inertia can be measured by oscillating the device with its own motors, while recording both the driving force or torque and the measured position. The necessary instrumentation can typically be found on the device itself.

H.2.5.2 Example measurement

Both viscous friction and inertia may be derived from oscillation experiments.

[Figure H.2](#) shows the results of applying an oscillating torque signal to Joint 0 at a frequency of nearly 20 Hz. (This is well below resonance, but a slower oscillation may have been desirable. It does not change the principles of the calculation.) The plots show two sinusoidal functions. The lower plot marked "Joint 0 Torque" represents the driving function, while the upper plot marked "Joint 0 Angle" shows the resulting angle oscillation. Each plot shows two cycles of the function during the 100 ms time duration of the plots.

Note that the angle oscillation lags the torque oscillation by about 5 ms. This represents a phase angle ϕ , about 0,1 of a full 50 ms cycle. The information is contained in this phase lag and in the amplitude of the angle oscillation.

**Key**

- T torque, N·m
 ϕ angle, rads
 t time, ms
a Joint 0 Angle.
b Joint 0 Torque.

Figure H.2 — Oscillating Joint 0 at 19,5 Hz

According to the theory developed below, inertia is given by

$$I = \frac{\tau_o}{\theta_{\max} \omega^2} \cos \phi \quad (\text{H.1})$$

while damping is given by

$$C_\rho = \frac{\tau_o}{\theta_{\max} \omega} \sin \phi \quad (\text{H.2})$$

where

ϕ is the phase lag between angle and torque oscillation;

$\theta_{\max}$ is the amplitude of the angle oscillation;

τ_o is the amplitude of the torque oscillation;

ω is the frequency of the torque oscillation.

In the example given in [Figure H.2](#), the following parameters can be derived:

Torque amplitude	τ_0	0,33 N.m
Torque period	T	0,053 s, so frequency $f = 18,96$ Hz
Angle amplitude	$\theta_{\max}$	1,67 mrad
Angle phase lag	ϕ	0,70 radians

Inserting these values into [Formulae \(H.1\)](#) and [\(H.2\)](#), we find angular inertia $I = 0,010\ 65\ \text{kg}\cdot\text{m}^2$ and the coefficient of friction $C_p = 1,086\ \text{kg}\cdot\text{m}^2/\text{s}$ for Joint 0. These angular quantities may be converted to linear quantities by dividing by the upper arm length, 0,2 m, to yield inertia $m = 266\ \text{g}$ and damping constant $c = 26,7\ \text{kg/s}$.

H.2.5.3 Derivation of formulae for inertia and damping

The derivation of the two formulae involves an assumption of freedom from extraneous spring forces, other than the oscillating motor, and also of oscillating at a frequency well below the resonance frequency for the structure.

A general oscillator equation for a one-dimensional oscillator with viscous damping is shown in [Formula \(H.3\)](#):

$$m\ddot{x} + c\dot{x} + kx = F_0 \sin \omega t \quad (\text{H.3})$$

where m is the mass (or inertia), c is the damping coefficient, k is the spring constant restoring force, and the right side is a force of amplitude F_0 and frequency ω .

If the oscillating frequency is near a resonance, then the structure acts like a spring, giving a restoring force that causes large oscillations. We assume explicitly that we are well below any such resonance. By assuming that there is no restoring force, the oscillation equation takes on the following form:

$$m\ddot{x} + c\dot{x} = F_0 \sin \omega t \quad (\text{H.4})$$

As a joint is oscillated, a sinusoidal motion appears, shifted in phase from the driving function. This solution may be written as shown in [Formula \(H.5\)](#):

$$x = A \sin(\omega t + \phi) \quad (\text{H.5})$$

Substituting this back into [Formula \(H.4\)](#), we get

$$-mA\omega^2 \sin(\omega t + \phi) + bA\omega \cos(\omega t + \phi) = F_0 \sin \omega t \quad (\text{H.6})$$

Using the identities shown in [Formula \(H.7\)](#)

$$\sin(x + y) = \sin x \cos y + \cos x \sin y \quad (\text{H.7})$$

$$\cos(x+y) = \cos x \cos y - \sin x \sin y$$

[Formula \(H.6\)](#) can be written as [Formula \(H.8\)](#):

$$-mA\omega^2 [\sin \omega t \cos \phi + \cos \omega t \sin \phi] + bA\omega [\cos \omega t \cos \phi - \sin \omega t \sin \phi] = F_o \sin \omega t \quad (\text{H.8})$$

Collecting terms in $\sin \omega t$ and $\cos \omega t$, we get [Formula \(H.9\)](#):

$$[-mA\omega^2 \cos \phi - bA\omega \sin \phi] \sin \omega t + [-mA\omega^2 \sin \phi - bA\omega \cos \phi] \cos \omega t = F_o \sin \omega t \quad (\text{H.9})$$

Equate terms in $\cos \omega t$ and $\sin \omega t$ to get components in phase with force and in quadrature as shown in [Formula \(H.10\)](#):

$$[-mA\omega^2 \cos \phi - bA\omega \sin \phi] \sin \omega t = F_o \cos \phi \quad (\text{H.10})$$

$$[-mA\omega^2 \sin \phi + bA\omega \cos \phi] \sin \omega t = 0$$

Equating coefficients of $\cos \omega t$ and $\sin \omega t$

$$-mA\omega^2 \cos \phi - bA\omega \sin \phi = F_o \quad (\text{H.11})$$

$$-mA\omega^2 \sin \phi + bA\omega \cos \phi = 0$$

Multiplying the first of [Formula \(H.11\)](#) by $\cos \phi$ and the second by $\sin \phi$, and adding, we get [Formula \(H.12\)](#):

$$-mA\omega^2 (\cos^2 \phi + \sin^2 \phi) = F_o \cos \phi \quad (\text{H.12})$$

which simplifies to a formula for inertia shown in [Formula \(H.13\)](#):

$$m = \frac{F_o}{A\omega^2} \cos \phi \quad (\text{H.13})$$

Multiplying the first of [Formula \(H.11\)](#) by $\sin \phi$ and the second by $\cos \phi$, and subtracting, we get [Formula \(H.14\)](#):

$$-bA\omega (\cos^2 \phi + \sin^2 \phi) = F_o \sin \phi \quad (\text{H.14})$$

which simplifies to a formula for damping coefficient shown in [Formula \(H.15\)](#):

$$b = -\frac{F_o}{A\omega} \sin \phi \quad (\text{H.15})$$

H.2.6 Free space resistance measurements

Low free space motion resistance indicates the ability to move the haptic device with minimal opposition throughout the workspace. Ideally, the device does not produce forces on the user's hand when there is no interaction with an object in the virtual world.

Free space motion resistance can be composed of both steady forces and variable forces. Steady forces can include friction and inertia; variable forces may include gear noise, backlash (unwanted free motion in gears) and elasticity in the transmission.

Free space resistance is measured with a load cell pushing the device or connected in series with a string or rope pulling the device-user interface.

H.2.7 Acceleration measurements

The ability of a device to deliver high peak acceleration is evident in crisp contacts and impulses that involve rapid changes of velocity.

Peak acceleration may be measured by placing accelerometers at the device-user interface. As a check on other measurements, it is equal to peak force divided by inertia.

H.2.8 Friction measurements

Friction is resistance to motion in a haptic device. It is exhibited in two distinct categories – friction felt while the device-user interface is moving and friction felt when the device is starting to move from a static position. These are known as kinetic and static friction, respectively, and static friction is the higher of the two.

Kinetic friction is typically divided between Coulomb friction (friction independent of velocity) and viscous friction or damping (friction proportional to velocity).

Both static and Coulomb friction may be measured with a load cell pushing or pulling on the device-user interface.

Viscous friction, on the other hand, is measured as a by-product of the inertia measurements. Inertia is derived from the position component in-phase with a driving sinusoidal force, while viscous friction is derived from the position component in quadrature (90° out of phase) with the driving force (as set out in [H.2.5](#)).

H.2.9 Bandwidth measurements

Bandwidth refers to the frequency range over which the haptic device provides feedback to the user. Commonly, we also refer to the upper frequency as the bandwidth, but the lower frequency is also part of the specification of bandwidth.

The bandwidth of a haptic device typically refers to the whole haptic feedback loop. It is the number of times that the haptic loop can be implemented per second (also known as the update rate).

The bandwidth is affected by factors such as the rate of digitization of sensor signals in the haptic device, latency in the communications between the haptic device and the control computer, and the time taken to iterate the haptic simulation and compute information to be returned to the haptic device. There can also be limits on the ability of the device to display force and torque over the required frequency range.

Bandwidth can be measured by oscillating a device with a force signal with a user-controllable oscillation frequency. Well within the bandwidth, the envelope of the position sine wave perceived by the device matches the envelope of the forcing frequency. That is, if the amplitude of the forcing signal is doubled, then the amplitude of the perceived position signal should also be doubled. The maximum bandwidth is the forcing frequency at which the increase of the positioning signal is only half of what would be expected – rather than doubling in amplitude, it increases by a factor of only 1,5.

System latency is the total time lag of the components of the haptic loop. System latency is the inverse of the bandwidth.

Device latency is the time delay between sending a command to a haptic device and receiving a response from that device. The device latency may be considered as a device-specific contribution to the bandwidth of a haptic system. It can be separated from bandwidth only by applying an external control system to the device itself – using a forcing signal from an oscillator, for example, and sampling the device angle sensors in a digital sampler of known high bandwidth (or equivalently, low latency).

Annex I (informative)

Unique aspects of haptic interaction

I.1 General

The evaluator should be aware of the unique aspects of haptic interaction. Haptic interaction involves perception by sensory and motor activity based on the skin, muscles, joints and tendons.

The following elements present challenges to the evaluator of haptic interactions.

I.2 Personal nature of haptics

Haptic interaction is generally personal and private to the user, often having direct contact with the user's skin; this is in contrast to visual or auditory signals, that can be immediately shared with other users.

Because of the private nature of haptics, the evaluator who is interested in the haptic experience of the user should employ methods that elicit a description of the effect. The user could describe it as intuitive pushing against an obstacle, or like running a pencil through a grove, or touch my hand to the floor.

This research into the user's experience does not preclude evaluating the efficiency and effectiveness of the interaction in performing a task. Such efficiency can be deduced by analysing the task and its outcome.

EXAMPLE A surgeon is learning to stitch nerves together with the aid of a virtual reality surgical simulator. The size of the movements and the muscle control that she is learning are entirely personal to her own sense of movement. As explained in [1.3.6.1](#), a verbal protocol will help to communicate the user's feeling to the evaluator. Auxiliary measurement instruments could help assess sensed force and torque (see [1.3.6.2.3](#)).

I.3 Bidirectional interaction

In a bidirectional interaction, the system pushes back in ways that instruct the user. In a bidirectional interaction, it can be difficult for the user to separate haptic effects that he senses from force or torque that he delivers (see [1.4.2.3](#)), the whole tactile/haptic interaction, rather than parts of the whole. With further observation and experience, the effect of the device and the logic and structure of the software can be separated.

I.4 Unidirectional interactions

Many types of haptic interaction are unidirectional. They share this characteristic with visual and audio displays, but differ in that sense from keyboard and mouse.

Unidirectional haptic interaction can be initiated by a user. In the case of a gesture, it is typically unidirectional from the user toward the device. An inspector could judge the efficiency of a gesture without the use of an electronic receptor. In this case, it is possible to separate the gesture from the gesture-detecting device.

In the case of a tactile unidirectional interaction, it is unidirectional from the device to the user. Action can be required as a result of a signal, but the signal itself is passively received. An evaluator can

interrogate the user on what she feels or observe the user's response to the implied command. In this case, it is not possible to separate the experience from the device producing the tactile stimulus.

EXAMPLE 1 A tactile vest can be used by a supervisor to quietly signal a worker. The haptic effect could be on the front, back or either side of the torso. The signal is passively received, but could result in some agreed action or motion on the part of the individual receiving the signal.

EXAMPLE 2 An electric wire is buried around the perimeter of a property. It carries a signal that activates a shock device carried in the collar of a dog. The dog learns not to cross or approach the perimeter, in order to avoid the electric shock. Thus, the dog is trained in a passive way to stay within the bounds of a yard. The action is personal to the dog and is not shared or felt by other animals or people.

I.5 Sensory substitution

Haptic interaction can be employed to enhance other types of human-computer interaction. It is one more modality in a suite of senses that increase the bandwidth between the user and the computer.

Having an alternative modality can be especially important in assistive applications. If one or more senses are not usable, then a suitable haptic environment can provide an alternative. An evaluator should keep in mind the full context of the haptic interaction, including the ability of the user to find substitutes.

EXAMPLE 1 A person who is partially deaf keeps a fire alarm receiver on a bedside table and a vibrator pad under the pillow. Vibrations can then alert the user to potential danger and confirms a barely heard audible alarm. The evaluator of such a system can observe its effect on alerting a user, then determine what modality gave rise to the most immediate response.

EXAMPLE 2 Other haptic devices can enable a person to perceive music through rhythmic sensations sent to different parts of the body. Some of the enjoyment can come from the view of the orchestra or the visual effects of an accompanying light show. The evaluator needs to keep in mind these auxiliary effects while assessing the usefulness of a haptic music display.

I.6 Distributed contact points

Haptic devices within the scope of this document include force feedback joysticks, vibrating cell phones and vibrators embedded in clothing, distributed over the human body. They include devices that detect and interpret movements of the human body that are interpreted as gesture commands in human-computer interaction.

Haptic interaction could use any part of a user's body, depending on the design of the system and the planned interaction. It tends to direct attention to some part of the user's body when it is used or activated.

Since haptic interactions could address any part of the body, test design should be sensitive to cultural and gender aspects of such touching. The user sample should be broad enough that cultural and gender issues are addressed (see [I.4.2.7](#)).

I.7 Adaptation

Haptic interactions can be altered by adaptation and masking over an extended time. This is especially true for vibrotactile feedback to the user's skin. Tests should be long enough to determine if adaptation or masking will be issues (see [I.4.2.6](#)).

Annex J

(normative)

Evaluation by usability walkthrough or usability task test

J.1 General

A usability test consists of evaluating representative users carrying out representative tasks to identify any usability problems and/or to obtain measures of effectiveness, efficiency and/or satisfaction. The purpose of the evaluation can be “formative”: to improve the object of evaluation, and/or “summative”: to produce conclusions about the merit or worth of the object of evaluation.

A usability walkthrough consists of an expert inspection where the expert identifies potential usability problems while attempting to complete tasks playing the role of a user. This can be combined with inspection to identify deviations from criteria based on user requirements, principles, guidelines or established good practice for usability and accessibility.

J.2 Steps in a usability walkthrough or usability test

The steps to evaluate haptic interaction by a usability test or by expert evaluation using a usability walkthrough are listed in [Table J.1](#), together with special issues related to the evaluation of haptic interactions.

NOTE This procedure is adapted from ISO/TS 20282-2 and ISO/IEC 25066.

Table J.1 — Evaluation steps

Evaluation activity	Haptic issues
1) Plan the evaluation	
a) Establish the purpose of the evaluation	Is the evaluation intended to improve the haptic system (formative) or to verify or validate requirements such as those listed in this document (summative)?
b) Decide what is to be evaluated	Is the haptic system a finished device, a prototype, or a concept?
c) Decide on the type of evaluation	This annex describes the usability walkthrough and usability testing methods.
d) Identify the types of user groups to be included in the evaluation	Which are the most frequent or most important types of users?
e) Specify goals to be evaluated	What are the most frequent or most common tasks that this device will be used for?
f) Identify the data to be collected during evaluation	How to describe sensation that is sensed haptically?
g) Decide on the number of users for testing or evaluators for inspection	Are there limitations on time or device access?
h) Check that the product is capable of being used in the identified scenario	Will a prototype substitute for the real thing?
i) Consider ethical issues and assess potential harm from use	Will a user be placed out of her comfort zone during a test?
2) Prepare the evaluation	
a) Recruit the users or identify the inspectors	Users should be representatives of the target population.
b) Configure the product or prepare the prototype	Set up a reliable demonstration.
c) Specify test scenarios and goal criteria	For usability testing, how to measure the effect of the use of the haptic system on the person's performance and satisfaction?
d) Specify the environmental characteristics to be used	Carry out test in the intended context of use to assess if the haptic effect is discernable.
e) Establish the test or inspection procedure	Be methodical with test procedures and device preparation.
f) When testing, carry out a pilot test	A pilot test will ensure stakeholders of the evaluation process.
g) When testing, inform the user of the intended goal	
h) Create the evaluation environment	Set up prototype or product in test environment.
3) Carry out the evaluation	
a) Run the tests or carry out the walkthrough as planned	Be prepared for unexpected events with complex devices.
b) Analyse the results	Be open to all possible reactions to haptic devices.
c) Establish conclusions	Make allowances for the condition of the prototype.
4) Document and disseminate the results	
a) Prepare a report	Include an executive summary as haptics might not be fully understood.
b) Ensure that the report is given appropriate distribution to stakeholders	Follow up with readers of the report to obtain a response.

J.3 Plan the evaluation

J.3.1 Establish the purpose of the evaluation

The purpose of the evaluation (see [Clause 5](#)) and scope of the evaluation shall be defined to enable an appropriate evaluation to be designed that provides the required information.

J.3.2 Decide what is to be evaluated

Decide on which of the general categories of attributes from [Table J.1](#) are to be evaluated.

NOTE 1 Haptic interactions typically make use of a device that helps a user interact with a synthetic environment. Determine if the whole interaction is to be evaluated, or just the device or the synthetic environment on their own.

NOTE 2 [J.3.5](#) gives further help on deciding on the scope of tasks and contexts of use that are to be evaluated.

J.3.3 Decide on the type of evaluation

This annex describes

- a) a usability walkthrough by experts (note that this could be combined with inspection to identify deviations from predefined criteria; see [6.3](#)), and
- b) a usability test to identify usability problems and/or to measure user performance and/or to obtain physiological data about the user's experience (see [7.3](#)).

J.3.4 Identify the intended user groups

J.3.4.1 General

Identify the range of actual or potential users of the product. Different user groups may use the product to achieve different goals. It is important to consider use by people who are towards the end of the range of user characteristics within the user population, especially for products made available for use by the public. Relevant user characteristic, including vision, hearing, cognition, strength, dexterity and locomotion, can vary over a wide range of capabilities.

Inspections should take account of the intended types of users. Users or inspectors are selected in [J.4.1](#).

J.3.4.2 User physiology

Variations in user physical characteristics should be taken into account.

Users can vary greatly in the size and sensitivity of the body part engaged in the device-user interface. Gender and age can make for differences in hand size or the size of other relevant parts of the body.

Users can vary greatly in their sensory characteristics. Haptic sensitivity can differ between male and female participants, both for skin touch and for a sense of limb and body location.

EXAMPLE For tests with tactors in contact with user bodies, it is recommended that the evaluator ask test users how ticklish they are in general and for the particular area of the tactor, and if they have any skin rash or sensitivities in that body area.

J.3.4.3 User psychology

Variations in user perceptual and cognitive characteristics should be taken into account. Some of these are related to the physiological capabilities of the user, while others are more related to their brain development. This is especially true in testing children, who undergo growth in a wide range of mental capabilities as they grow toward maturity.

J.3.5 Specify goals to be evaluated

The user goals to be evaluated shall be defined. The goals need to be defined in conjunction with the identification of user groups, as different user groups can have different goals. It is usually appropriate to evaluate the most frequent or most important goals.

For the goals to be used for evaluation, it should be possible to:

- identify typical contexts of use that are representative of the use of the system for that goal;
- identify criteria for successful achievement of the goal.

Achievement of a goal can depend on achievement of sub-goals.

EXAMPLE 1 A mobile device has been designed to guide a person through city streets. It makes use of GPS to compare its present location with the destination. It is carried in a pocket, and it starts to vibrate if the person walks in the wrong direction. The frequency of the vibration is higher according to the deviation of the direction of walking from the predicted direction. The goal is to arrive safely and efficiently at the destination.

EXAMPLE 2 A tactile vest has been designed to support spatial orientation in pilots. Tactors are embedded throughout a vest and are activated to alert pilots with regard to “which way is up”. It can also be programmed to alert helicopter pilots with regard to altitude and orientation during hover. The goal is for the aircraft pilot to maintain awareness of aircraft position and orientation.

EXAMPLE 3 A tactile belt, integrated with GPS and android map-based technology, has been designed to support user navigation, wayfinding and communication. The tactors on the belt indicate the correct direction and arrival at destination, and tactile patterns represent communications from another user. The goal is to navigate to a location and receive covert communications from others without having to attend to hand-held devices (i.e. hands-free and eyes-free).

EXAMPLE 4 A tactile driver's seat has been designed to support automobile driving and navigation. The tactors can be programmed as driver alerts (e.g. driving speed) or as navigation aids (e.g. take the next left turn). The goal is to support driving effectiveness while reducing driver workload.

J.3.6 Identify the data to be collected during usability testing

J.3.6.1 Verbal protocol

A verbal protocol to describe the haptic interaction should be established.

A user's vocabulary for haptic experiences might be limited, making it difficult to describe what is felt. This limitation should be taken into account when evaluating user satisfaction, and indeed for all communication involving verbal information. Interviews, spoken descriptions or diaries may be solicited, but the user should be offered some assistance in expressing their feeling and describing their sensations.

NOTE 1 A user might find suggested analogies helpful. The feeling of not knowing the next step in a sequence can be compared to being lost while driving. Fatigue can be likened to exhaustion after an intense sprint or downhill ski run, or holding a bag of groceries too long while waiting.

NOTE 2 Psychometric rating scales can be used to assess the degree to which the user can feel a sensation, and whether they found the sensation distracting, annoying, too noisy, too difficult to feel and so on. This can be useful for devices such as tactors (designed for unidirectional tactile interaction).

J.3.6.2 Measures

J.3.6.2.1 General

If measures are to be taken, it is important that the evaluation is as realistic as possible, and that the participant is not given any hints during interaction.