



BSI Standards Publication

Ergonomics of human-system interaction

Part 940: Evaluation of tactile and haptic interactions

National foreword

This British Standard is the UK implementation of EN ISO 9241-940:2022. It is identical to ISO 9241-940:2017. It supersedes BS ISO 9241-940:2017, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PH/9, Applied ergonomics.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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© The British Standards Institution 2022
Published by BSI Standards Limited 2022

ISBN 978 0 539 18935 3

ICS 13.180; 35.180

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 November 2017.

Amendments/corrigenda issued since publication

Date	Text affected
30 June 2022	This corrigendum renumbers BS ISO 9241-940:2017 as BS EN ISO 9241-940:2022. The supersession details in the national foreword have also been updated.

English Version

Ergonomics of human-system interaction - Part 940:
Evaluation of tactile and haptic interactions (ISO
9241-940:2017)

Ergonomie de l'interaction homme-système
- Partie 940: Évaluation des interactions
tactiles et haptiques (ISO 9241-940:2017)

Ergonomie der Mensch-System-Interaktion -
Teil 940: Evaluation taktiler und haptischer
Interaktionen (ISO 9241-940:2017)

This European Standard was approved by CEN on 13 March 2022.

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COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

European foreword

The text of ISO 9241-940:2017 has been prepared by Technical Committee ISO/TC 159 "Ergonomics" of the International Organization for Standardization (ISO) and has been taken over as EN ISO 9241-940:2022 by Technical Committee CEN/TC 122 "Ergonomics" the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2022, and conflicting national standards shall be withdrawn at the latest by September 2022.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

Any feedback and questions on this document should be directed to the users' national standards body. A complete listing of these bodies can be found on the CEN website.

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Endorsement notice

The text of ISO 9241-940:2017 has been approved by CEN as EN ISO 9241-940:2022 without any modification.

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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).

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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

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

	Clause/annex	Content
	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](#).

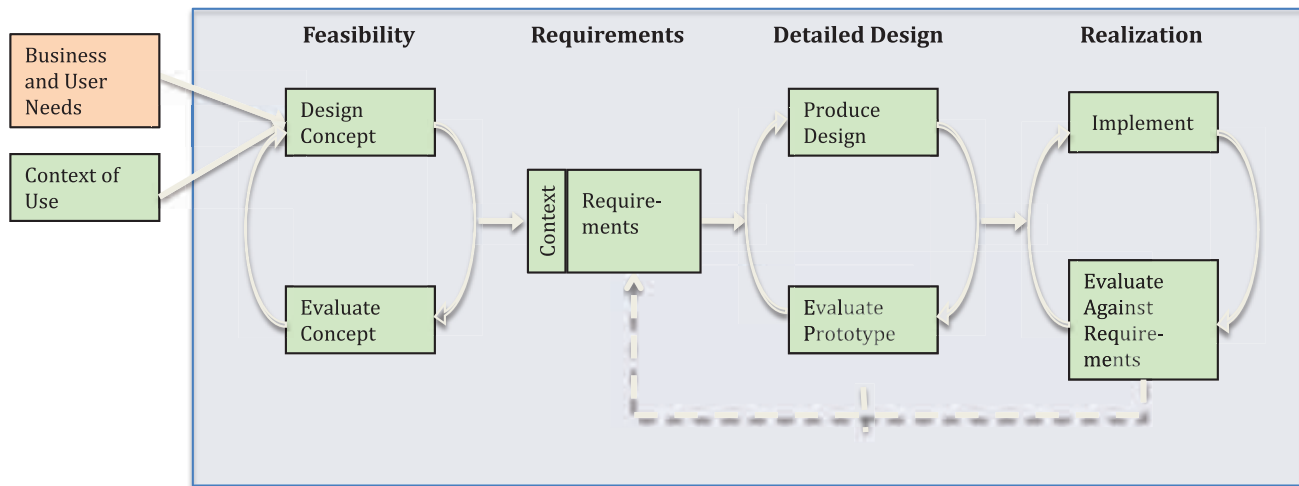


Figure 1 — Evaluation in the design and development lifecycle

5.4 Planning activities

This document provides guidance to support the following activities:

- establish the purpose of the evaluation (see [J.1](#) and [J.3.1](#), with examples in [J.9.2](#) to [J.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](#));
- the effect produced by the haptic device (see [7.2.3](#));
- 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 I](#)).

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.

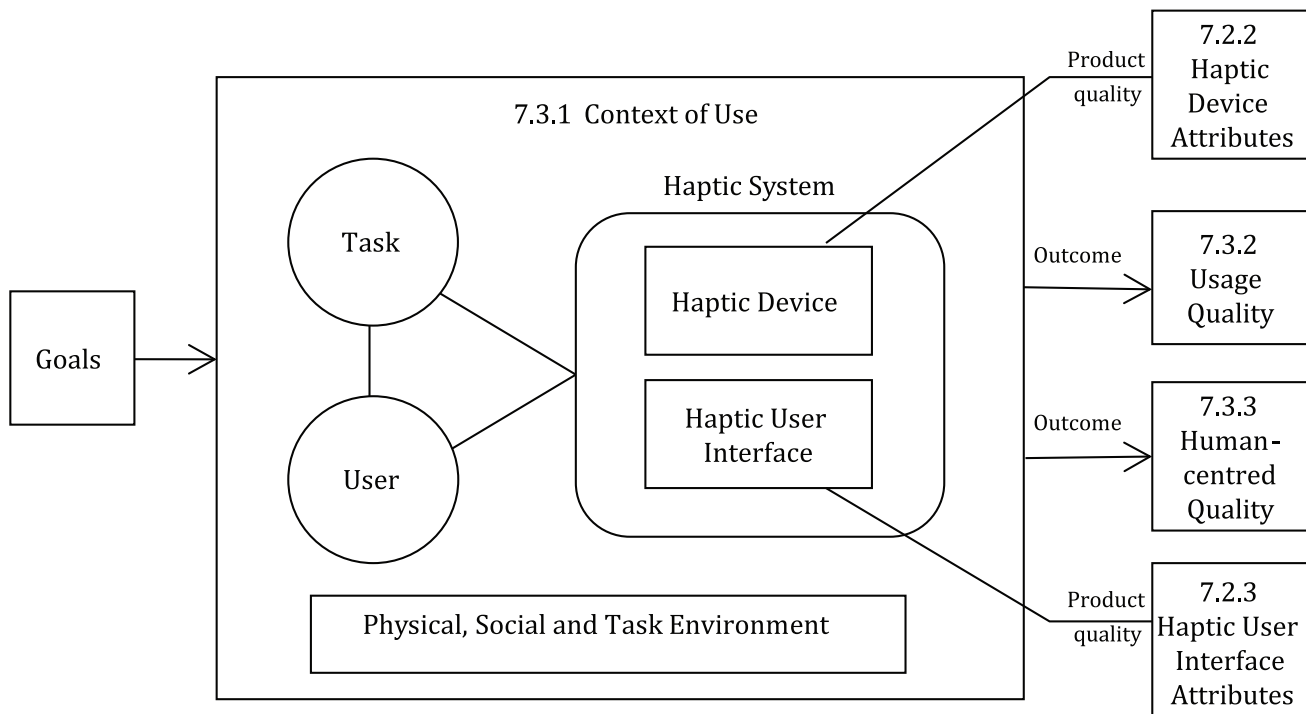


Figure 2 — Evaluating a haptic system

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	In-spect by an expert	Usability test				
							Measure context		Evaluation data		
							Test task	Obs use	Perform data	Physio 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	✓					✓	✓	✓		✓
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	✓				✓	✓		✓		✓

^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.

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
E.9	Safety	✓				✓		✓			✓
F	Human-centred quality (7.3.3)^a										
E.2	Usability ^a										
E.2.1	Effectiveness						✓		✓		✓
E.2.2	Efficiency						✓		✓		✓
E.2.3	Satisfaction						✓			✓	✓
E.3	Accessibility ^a										
E.3.2	Use as assistive technology				✓	✓					
E.3.3	Accessibility of tactile displays				✓	✓	✓	✓	✓	✓	✓
E.3.4	Accessibility of device documentation						✓	✓			✓
E.3.5	Accessibility with limited physical capabilities					✓	✓	✓			✓
E.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
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Text of sub-clause			Sub-clause number	Technical evaluation	Inspection	Task test	Observe use	Performance data	Physiological data	User reported data
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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](#).

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	In-spect	Task test	Obs use	Per-form	Phys-io	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	✓	✓					✓
^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> .										

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	In-spect	Task test	Obs use	Per-form	Phys-io	User rep
Mobility The device mobility required for the task should be considered when choosing a tactile/haptic device.	✓		9.2.1	✓	✓	✓				✓
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	✓		✓		✓	✓	✓
^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> .										

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	In-spect	Task test	Obs use	Per-form	Phys-io	User rep
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	✓	✓					✓
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	✓						
<i>Friction</i>	✓		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	✓	✓			✓		✓
<i>Temporal parameters</i>	✓		9.2.11							
^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> .										

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	In-spect	Task test	Obs use	Per-form	Phys-io	User rep
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 <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.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	In-spect	Task test	Obs use	Per-form	Phys-io	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		✓	✓	✓	✓		✓
^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> .										

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	In-spect	Task test	Obs use	Per-form	Phys-io	User rep
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	In-spect	Task test	Obs use	Per-form	Phys-io	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		✓					✓
<i>Designing physical space</i>	✓		6.2.3							
^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> .										

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	In-spect	Task test	Obs use	Per-form	Phys-io	User rep
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		✓					✓
^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> .										

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	In-spect	Task test	Obs use	Per-form	Phys-io	User rep
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	In-spect	Task test	Obs use	Per-form	Phys-io	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	In-spect	Task test	Obs use	Per-form	Phys-io	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	In-spect	Task test	Obs use	Per-form	Phys-io	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.		✓			✓					✓
^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> .										

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	In-spect	Task test	Obs use	Per-form	Phys-io	User rep
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.		✓			✓					✓
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> , 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 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	In-spect	Task test	Obs use	Per-form	Phys-io	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;		✓				✓				✓
^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> .										

Recommendation	Source ^a			Type of method ^b				Measures ^c		
	910	920	Sub-clause	Tech eval	In-spect	Task test	Obs use	Per-form	Phys-io	User rep
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 <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.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	In-spect	Task test	Obs use	Per-form	Phys-io	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							
^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> .										