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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

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

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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.

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 kinaesthesis.

[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.

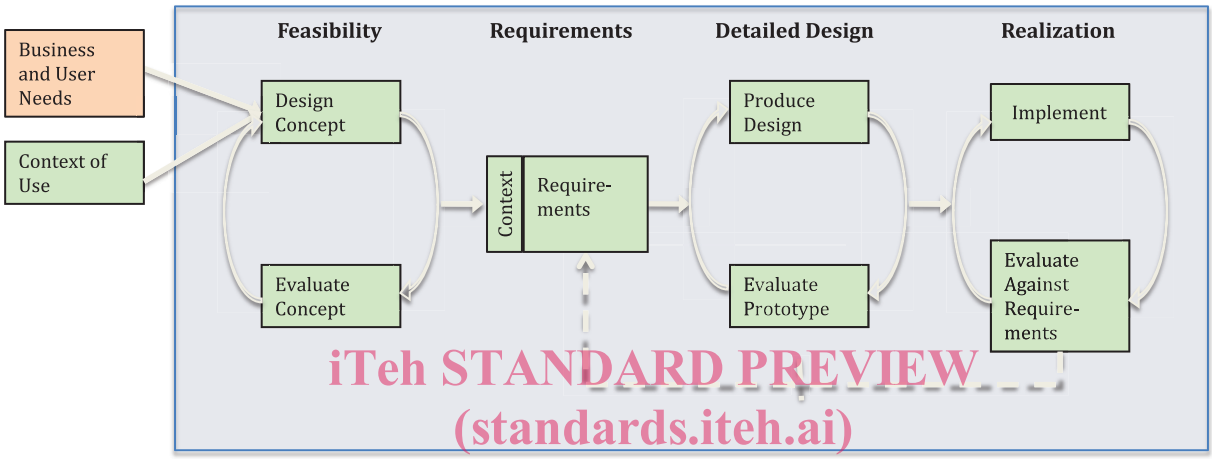

Figure 1 — Evaluation in the design and development lifecycle

5.4 Planning activities

This document provides guidance to support the following activities:

a) establish the purpose of the evaluation (see J.1 and J.3.1, with examples in J.9.2 to J.9.5);

b) decide what is to be evaluated;

c) identify the context in which the haptic system will be used: the types of users, tasks and usage environments (see 7.3.1);

d) carry out an initial assessment (see 5.5);

e) decide which haptic qualities are to be evaluated (see Clause 7);

f) 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:

a) 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.