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Ergonomic principles related to mental workload —

Part 3: Principles and requirements concerning methods for measuring and assessing mental workload

Principes ergonomiques relatifs à la charge de travail mental —

Partie 3: Principes et exigences concernant les méthodes de mesurage et d'évaluation de la charge de travail mental

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

ISO 10075-3 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 1, *Ergonomic guiding principles*.

ISO 10075 consists of the following parts, under the general title *Ergonomic principles related to mental workload*:

— *Part 1: General terms and definitions*

— *Part 2: Design principles*

— *Part 3: Principles and requirements concerning methods for measuring and assessing mental workload*

A Technical Report will accompany these parts to explain to non-experts the basic concepts and how to use these parts.

Introduction

This part of ISO 10075 specifies technical information relevant in the context of constructing, evaluating and choosing measurement instruments for assessing mental workload as defined and treated in ISO 10075 and ISO 10075-2. Familiarity with the concepts discussed in these two documents is required to understand the provisions of this part of ISO 10075.

Since mental workload is a part of the total workload, users of this part of ISO 10075 should also be familiar with the concepts and provisions presented in ISO 6385.

This part of ISO 10075 aims at providing information for the development of measurement instruments, about which specifications will be required to evaluate a given procedure with regard to its usability as a measuring instrument for assessing mental workload.

This part of ISO 10075 addresses requirements for instruments measuring different aspects of mental workload, but it does not specify which instruments should be used, e.g. psychological scaling or psychophysiological methods. The choice of which instruments to use can be facilitated by the provision of appropriate information.

Ergonomic principles related to mental workload —

Part 3: Principles and requirements concerning methods for measuring and assessing mental workload

1 Scope

This part of ISO 10075 establishes principles and requirements for the measurement and assessment of mental workload and specifies the requirements for measurement instruments. This part of ISO 10075 provides information for choosing appropriate methods and provides information on aspects of assessing and measuring mental workload to improve communication among the parties involved.

This part of ISO 10075 is intended for use mainly by ergonomic experts, for example, psychologists, occupational health specialists, and/or physiologists, with appropriate training in the theoretical background and usage of such methods, as well as in the interpretation of the results. They will find the information needed when developing or evaluating methods of mental-workload assessment.

Non-experts, e.g. employers, employees and their representatives, system managers and designers, and public authorities can find useful information for their orientation in the field of assessment and measurement of mental workload, e.g. what kinds of methods are available, which criteria are relevant in the evaluation of measurement instruments and what kind of information they should require and observe in deciding which instrument will be suitable for their purpose and which can be used.

NOTE A Technical Report on the terminology and use of this part of ISO 10075 will be available for further information for non-experts.

This part of ISO 10075 provides information on which to base a well-considered choice for an appropriate method in different situations. There are a large number of different methods available which are suitable for different purposes, situations and different levels of precision. There is a need for effective and efficient methods of measurement. The information provided in this part of ISO 10075 will allow users to evaluate the type of measurement approach most suitable for their specific purposes.

Conformance with the provisions of this part of ISO 10075 has to be provided by the documentation requirements.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 6385:2004, *Ergonomic principles in the design of work systems*

ISO 10075:1991[1)], *Ergonomic principles related to mental workload — General terms and definitions*

ISO 10075-2:1996, *Ergonomic principles related to mental workload — Part 2: Design principles*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 6385:2004, ISO 10075:1991 and ISO 10075-2:1996 and the following apply.

3.1
objectivity
degree to which results gained with an instrument are independent of the person administering the instrument, analysing and interpreting the data

3.2
reliability
degree of precision to which a method or instrument is able to measure what it measures

NOTE Reliability can be assessed as homogeneity, consistency or stability of measurement, or in the case of two or more raters, as inter-rater-reliability. Reliability is closely related to generalizability.

3.2.1
homogeneity
degree to which all parts or items of a measurement procedure measure the same characteristic

3.2.2
consistency
degree to which different parts or parallel forms of a measurement instrument lead to identical results, e.g. by dividing a scale into two or more parts or applying two or more parallel forms of an instrument

3.2.3
stability
degree to which a (usually time delayed) replication of a measurement procedure leads to identical results

3.2.4
inter-rater-reliability
degree to which two or more raters produce the same results in measuring the same characteristics

3.3
validity
degree to which a method or instrument is able to measure what it is intended to measure

NOTE Validity can be assessed via concurrent validation (e.g. by agreement of results with the results of a simultaneously applied procedure known to measure the intended aspect), criterion-related validation (e.g. by establishing a relation with a relevant criterion), or factorial validity (e.g. by demonstrating that a measurement procedure assesses specific facets of a construct).

3.4
sensitivity
degree to which a method or instrument is able to discriminate between different degrees of the object of measurement, e.g. different degrees of mental strain or fatigue

1) If revised, this International Standard will become ISO 10075-1.

3.5
diagnosticity
degree to which a method or instrument is able to discriminate between different kinds or sources of mental workload e.g. perceptual demands etc., or its effects, e.g. discriminating between fatigue, monotony, satiation or reduced vigilance

3.6
generalizability
degree to which an observed score (unit of measurement) can be generalized to a defined universe of situations (stress conditions) and/or population of workers

3.6.1
relative generalizability
degree to which rank ordering of workload conditions/people, e.g. from low to high, is replicable (as in decisions concerning relative positions)

3.6.2
absolute generalizability
degree to which an absolute level of stress/strain associated with specific work conditions/people without regard to the stress/strain associated with other conditions/people can be replicated (as in decisions concerning absolute values)

NOTE For more explanations concerning generalizability, see Annex A.

3.7
usability
extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use

[ISO 9241-11:1998, Definition 3.1]

NOTE In the case of this part of ISO 10075, a product is an instrument.

3.8
critical values
reference standard for the evaluation of measured scores and/or pass-fail decisions

NOTE The establishment of critical values presupposes that the scores of the measurement instrument in question allow absolute decisions with high precision. Furthermore, it has to be stated under which conditions the critical values are valid (for example, post-test measurements etc.)

4 Measurement and assessment of mental workload

4.1 General principles

Mental workload is not a unitary and not a unidimensional concept, so the assessment and measurement of mental workload cannot be a uniform procedure. There is no single best way to assess mental workload, since the most appropriate way to assess or measure mental workload will depend on the purpose of the assessment, which may require the assessment of different aspects of mental workload, the use of different techniques of measurement, and different degrees of precision.

Thus, the model of workload assessment used in this part of ISO 10075 has a three-dimensional structure. It takes into account

— *different aspects of mental workload*, e.g. mental stress, mental strain, mental fatigue, etc.,

— *different techniques of measurement*, e.g. task analysis, performance assessment, subjective ratings or psychophysiological measurement, and

— *different degrees of precision*, e.g. measurement at an orienting, screening or accurate level of measurement.

According to ISO 10075:1991, different aspects have to be differentiated: mental stress, mental strain, and the effects of mental strain within the individual. Assessment and measurement thus have to refer to these different steps in the stress-strain-effects process, i.e:

— assessment of work conditions producing mental stress, as in the design and evaluation of work system design;

— assessment and measurement of mental strain, produced by mental stress, e.g. in order to evaluate the tolerability of the strain;

— measurement of the effects of strain in the employee, e.g. fatigue, monotony, satiation or reduced vigilance;

which may affect her/his health and safety, well-being, performance and productivity.

Different purposes may require different approaches and/or degrees of precision, e.g. a risk analysis for hazardous technologies as opposed to a survey where the intention is to give a general overview over different work systems. This part of ISO 10075 does not prescribe which level of precision has to be used, since this is a matter of the purpose and conditions of measurement, depending, for example, on legal requirements or agreed regulations, or cost-benefits considerations.

Methods for the measurement and assessment of mental workload, independent of the technique to be used, will be classified in this part of ISO 10075 according to three, i.e. low, intermediate and high levels of precision:

— level 1: for accurate measurement purposes. The purpose of the mental-workload assessment at this high precision level is to obtain reliable and valid information about the nature of the source of under-overload in order to optimise work conditions. The methods at this level will most probably be applicable only by specialists, e.g. psychologists, ergonomists, occupational health specialists, and/or physiologists, with appropriate training in the theoretical background and usage of these methods, as well as in the interpretation of the results.

— level 2: for screening purposes. Measurement at this level represents an intermediate level of precision, and is most often used for screening purposes, which require more precision than orienting measurements, e.g. where problems of mental workload can be anticipated or where causes of inappropriate workload have to be identified. Procedures to be used at this level have higher reliabilities, and demonstrated validities, and should be able to indicate if corrective measures should be taken.

— level 3: for orienting purposes. Methods at this level allow the user to gather information about mental workload at a low level of precision. They provide general information about work conditions, subjective and psychophysiological states of the worker with respect to mental workload, without being excessively resource intensive. The information at this level should make it possible to prevent negative effects by making management decisions at an operational level such as to change work tasks and/or methods and conditions. Measurement at this level is usually restricted to orienting measurements, e.g. relating to rough measures (with moderate levels of reliability, validity, etc.) of task analysis, subjective ratings of acceptability of work conditions and subjective states with regard to all aspects of mental workload.

In specifying for which level of precision an instrument can be used, the object of measurement should be indicated. It should be stated whether the object of measurement is a person or a situational characteristic. If the intended object of measurement is the individual, psychometric properties have to be assessed and specified for the assessment of people. If the intended object of measurement is a situational characteristic, psychometric properties shall relate to assessing conditions. This will be demonstrated in more detail in the context of testing generalizability (see 4.2.7).

In specifying for which level of precision an instrument can be used, a differentiation is also required depending on whether the measurement is based on single scores/observations or mean scores/observations.

All assessment procedures will inevitably carry a measurement error which can be reduced by averaging over a number of scores/observations. An instrument which reaches the orienting level requirements for single scores/observations may attain screening level requirements for average scores/observations if a sufficient number of scores is used. The required number of scores/observations for attaining a higher level of precision shall thus be specified.

An instrument claiming to assess mental workload shall have demonstrated validity in the assessment of those aspects for which validity is claimed, and the domains of measurement, for which validity is claimed, shall be clearly stated (e.g. mental fatigue or monotony). If validity is claimed for more than one aspect, documentation of the validity shall include evidence for each field of measurement.

Different techniques may be used to assess mental workload, with some techniques being more suitable for some domains of measurement than others. In particular, the following techniques can be applied:

- physiological measurements: these methods provide information about physiological states of employees under given work conditions;
- subjective scaling: these methods provide information on how employees subjectively assess different aspects of mental workload at their work stations, e.g. using psychometric scales, and how they feel about their work conditions;
- performance assessment: these methods offer the possibility to evaluate human mental and psychomotor performance under given work conditions, e.g. in order to assess decrements or variations in performance due to the effects of mental workload;
- job and task analysis: these methods assess task elements, physical and psychosocial work conditions, environmental conditions and the organization of the work process as sources of mental workload.

Different methods will be required to achieve different levels of reliability, e.g. a short questionnaire may be sufficient for an orienting level measurement, whereas in order to verify that a system design does not lead to monotony, scales with sufficient reliability for that purpose will be required. In order to safeguard safety-critical or hazardous systems against any negative effects of mental workload, the highest reliabilities and validities will be required. Where such instruments are not yet available, they should be developed. Until then, those methods with the highest available psychometric criteria shall be used for such purposes. Precision is not determined by the measurement technique itself, but by the development, the psychometric properties, and the adequate application of the method or instrument.

If measurement methods have to be used which do not fulfil the requirements, special expertise in the field of mental workload and its measurement will be required

- to assess the risks associated with using a less than perfect instrument, and
- to achieve a sound evaluation of the results.

However, the selection of an appropriate instrument will also be influenced by legal or agreed regulations, as well as cost-benefit considerations.

4.2 Procedural requirements

4.2.1 General

Assessment of the objectivity, reliability, validity, sensitivity and diagnosticity of a measurement method can be done by any suitable and scientifically acceptable method. This part of ISO 10075 does not specify one single best way to be followed in this procedure. However, a clear account of the strategy used in assessing the psychometric properties of a measurement method shall be provided in order to allow for an evaluation of the adequacy of the procedure chosen and the results achieved. In fact, the validation procedure will depend on the measurement model assumed, e.g. assuming a probabilistic measurement model will require probabilistic psychometrics, whereas a generalizability approach will require the estimation of variance