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Ergonomic principles related to mental workload —

Part 2:
Design principles

Principes ergonomiques concernant la charge de travail mental — Partie 2: Principes de conception

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Contents

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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.

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.

International Standard ISO 10075 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: Measurement and assessment*

Annex A of this part of ISO 10075 is for information only.

Introduction

This part of ISO 10075 represents an extension of ISO 6385, providing design principles for work systems with special reference to mental workload as defined in ISO 10075.

Ergonomic principles related to mental workload —

Part 2:
Design principles

1 Scope

This part of ISO 10075 gives guidance on the design of work systems, including task and equipment design and design of the workplace, as well as working conditions, emphasizing mental workload and its effects, as specified in ISO 10075. It applies to the adequate design of work and use of human capacities, with the intention to provide for optimal working conditions with respect to health and safety, well-being, performance, and effectiveness, preventing over- as well as underload in order to avoid the impairing effects described in ISO 10075.

Mental workload is the effect of a complex interaction of individual, technical, organizational and social factors. Thus personal, technical and organizational factors and the effects of their interactions have to be taken into account in the design of work systems. However, this part of ISO 10075 includes the design of technical and organizational factors only, and does not apply to problems of selection, training or social factors.

This part of ISO 10075 provides guidelines for system design. It does not address problems of measurement of mental workload or its effects.

This part of ISO 10075 refers to all kinds of human work activities (see ISO 10075), not only to those which would be described as cognitive or mental tasks in a restricted sense, but also to those with primarily physical workload.

This part of ISO 10075 is thus relevant to all those engaged in the design and use of work systems, e.g. system and equipment designers, employers' and employees' representatives.

This part of ISO 10075 is applicable to the design of new work systems as well as to the redesign of existing ones undergoing substantial revision.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 10075. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 10075 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 6385 : 1981, *Ergonomic principles in the design of work systems*

ISO 10075 : 1991[*)], *Ergonomic principles related to mental work-load - General terms and definitions*

3 Definitions

For the purposes of this part of ISO 10075, the definitions given in ISO 6385 and ISO 10075 apply.

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

4 Design principles

4.1 General principles

In order to avoid impairing effects of work system design on users, it is necessary to fit the work system to the user. Designing or redesigning work systems requires taking into account people, technology and organizational conditions and their interaction right from the beginning. This means that ergonomists should be integrated into the design process as early as possible. If there are users, as in system redesign, their experiences and competences should be integrated into the design or re-design process in order to achieve and verify an optimal level of design quality. This can be done by using methods of participation, by which user expectations with respect to design quality can be incorporated into the design process. This will provide for user-oriented results and better acceptance on the side of the user, which will contribute to the efficiency of the work system as a whole.

If the design is made for an entirely new system, the designer should take due account of the abilities, skills, experiences and expectations of the prospective user population. It should be kept in mind that training should be regarded as supporting work system design, not as a replacement for system design omissions leading to sub-optimal design.

This concern for the user is necessary from the beginning of the design process when system functions are specified. Defining system functions and subfunctions as well as function allocation between operators and machines and between different operators requires consideration of the characteristics of the people involved.

In designing work systems it should be kept in mind that work consists of a combination of tasks, which are executed with particular technical equipment in a particular work environment and in a particular organizational structure. Therefore each of these components offers opportunities to influence the design of the work system with regard to mental workload.

Design principles can thus be related to different levels of the design process and the design solution in order to influence:

a) the intensity of the workload:

– at the task and/or job level,

– at the level of technical equipment,

– at the environmental level,

– at the organizational level, and

b) the duration of the exposure to the workload:

– at the level of the temporal organization of work.

Table A.1 in annex A shows a matrix of the levels of the design process and their relation to the consequences of mental strain, together with examples of applicable design solutions.

Personal factors, like abilities, performance capacities, motivation - on an inter-individual as well as on an intra-individual differences basis - will influence the resulting workload. Thus selection and training, as mentioned above, have to be taken into account appropriately in the design of work systems.

Work system design starts with a function analysis of the system, followed by function allocation among operators and machines, task analysis, and results in task design and allocation to the operator. It is essential that human factors experts are integrated into this process from the beginning in order to be able to perform these steps with a view to the resulting operator requirements, in particular with respect to mental workload. Such a procedure will reveal the appropriate requirements to be taken into account at each level of system design.

In designing work systems, it should further be kept in mind that environmental requirements, system demands, challenges and people themselves change over time by developing skills, abilities and expectations. This means that systems design should provide for such changes, enabling the system to adapt to these requirements. This can be done for example by dynamic task allocation, allowing the operator to allocate tasks to the technical system or to the operator, depending on the actual state of the operator.

Mental workload is not a one-dimensional concept, but has different qualitative aspects leading to different qualitative effects (see ISO 10075). It is thus not sufficient to simplistically consider workload ranging on a unitary dimension (quantitatively) from underload to optimal load to overload. Some of the impairing effects of mental workload share common causes, but this must not be misinterpreted as identity of these effects. The presentation of the following guidelines has thus been organized according to the impairing effects as described in ISO 10075. This should help the designer to take appropriate measures to avoid impairing effects of mental workload. Since some of the principles apply to more than one of these effects, repetition cannot be avoided.

4.2 Guidelines concerning fatigue

4.2.1 General

Mental workload can be described in terms of intensity, duration, and the temporal distribution of the intensity in which the operator is exposed to the workload. Besides quantitative aspects, qualitative differences in mental workload have to be considered, e.g. perceptual-motor tasks vs task with high memory load. Thus one of the major approaches to designing work systems with respect to reducing fatigue within the operator is to reduce or optimize the intensity of workload, limit the duration of the exposure, or change the distribution by introducing rest pauses. It is necessary to keep in mind that reducing mental workload is not always the best strategy to provide for unimpaired performance. Reducing mental workload beyond an optimal level may lead to impairments as described in 4.3 to 4.5.

4.2.2 Intensity of mental workload

The intensity of mental workload is affected by the following characteristics, with the order of presentation starting at the task level and moving from perception to action to the environmental and organizational levels, as shown in figure 1.

4.2.2.1 Ambiguity of the task goal

If the task goal is ambiguous, the operator is required to interpret the task and to make decisions about which goals with which priorities should be pursued. During system design, clear task goals shall be provided and the priorities of different goals should be specified, e.g. keeping the safety system functioning has priority over production efficiency. If more than one operator is concerned, task allocation among operators shall be made clear.

4.2.2.2 Complexity of task requirements

A task of too high complexity could mean that the operator has to make too many decisions in a given unit of time. If task complexity is too high for the envisaged operator population, decision support systems should be used. Too low complexity should be avoided, because it may lead to monotony or satiation.

4.2.2.3 Serving strategies

In systems where multiple requests have to be answered, a clear strategy for answering them shall be provided (e.g. first-in-first-out vs. a hierarchical strategy). First-in-first-out strategies are rather simple. Hierarchical serving strategies are more complex. If conditional strategies are employed, the conditions for following those strategies should always be clearly understandable.

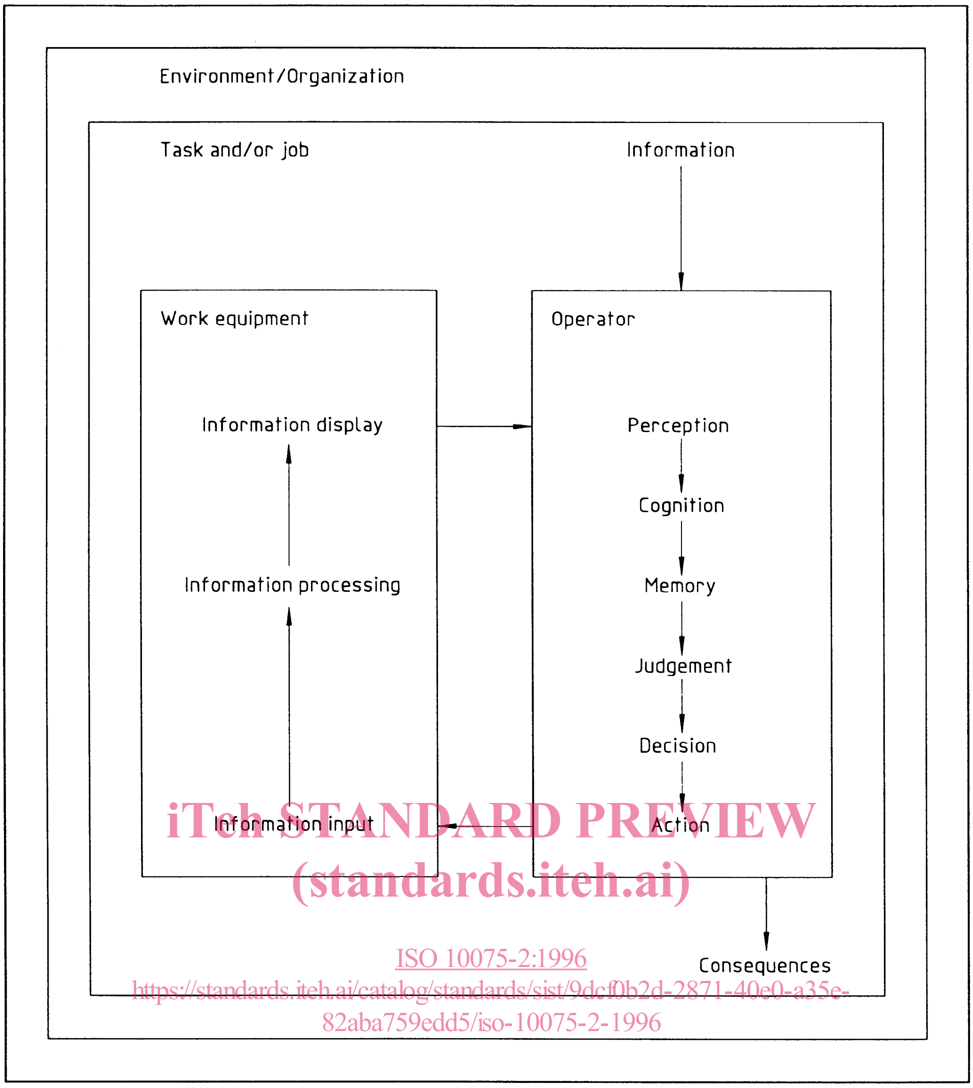

Figure 1 — Relation between mental workload and different levels of design

4.2.2.4 Adequacy of information

Missing as well as unnecessary information contributes to mental workload because the operator has to make decisions on the basis of insufficient information or to filter the relevant information from the total information supplied. Thus, information which is necessary for task accomplishment shall be supplied.

4.2.2.5 Ambiguity of information

This requires the operator to interpret information. Information should thus be presented in an unambiguous way, e.g. by providing range information (acceptable, not acceptable) in displaying system states.

4.2.2.6 Signal discriminability

Low discriminability of information-carrying signals against a background of irrelevant information requires the operator to expend effort to filter signals. Signal discriminability can be improved, e.g. by manipulating the intensity of signals, coding signals differently by using shape, colour, duration or time characteristics, reducing background (noise) intensity, and masking and filtering by technical systems.

4.2.2.7 Redundancy

Redundant information display can help the operator to cross-check displayed information. On the other hand, too much redundancy of displayed information can distract the operator and thus increase mental workload. Redundancy thus should be planned according to operational requirements. Where possible, operators should be enabled to select the degree of redundancy which they feel appropriate for task accomplishment.

4.2.2.8 Compatibility

Information displays, control movements or system responses which are incompatible with common user expectations will produce conflicting information and force the operator to expend extra effort to accomplish the required performance, e.g. turning a control actuator to the right should be coupled with an increase in system response or display movements, not with a decrease or system shutdown. Special attention should be paid to compatibility of control and system dynamics, e.g. using zero-order control actuators for zero-order control systems.

4.2.2.9 Accuracy of information processing

Increased mental workload due to necessary accuracy requirements (e.g. beyond human capabilities) can be reduced to adequate levels by providing technical aids with appropriate resolution of information presentation (for information displays) or control dynamics (for input devices).

4.2.2.10 Parallel vs. serial processing

Serial processing in general is preferable to parallel processing due to demands on processing resources. On the other hand, if comparisons have to be made among different sources of information, it is preferable to present this information in a parallel manner. If orientation is required, parallel information presentation is preferable to serial information presentation.

4.2.2.11 Time sharing

If two or more tasks requiring attentional control have to be performed simultaneously, the limits of processing capacities are soon reached. It is thus preferable to provide for sequential task performance. Consistently-mapped practice for some of the tasks may be used to reduce workload by reducing attentional control if consequences due to errors by erroneous automatic information processing are of minor importance.

4.2.2.12 Time delays

A time-delayed response of the system requires the operator to mentally anticipate the system response in order to perform the required control movement correctly. Time delays should thus be avoided. If this is not possible, quickening or prediction displays should be used.

4.2.2.13 Mental models

Inconsistent, incomplete or missing mental representation of the process or system functions requires the operator to expend extra effort to be able to control the system. System design and layout should be done in a way that enables the operator to understand the process at the level appropriate to the operator's function in that process. Information should be provided and supplied in a manner that shows interrelations among subsystems, e.g. by flowcharts, recording time-related system responses, providing opportunities for collecting experiences of system reactions to operator control actions.

4.2.2.14 Absolute vs. relative judgement

Absolute judgements require reference standards to be kept in memory, whereas relative judgements require decisions with regard to a simultaneously given reference standard, which is easier to perform. Relative judgements are therefore preferable to absolute judgements. This can be accomplished by providing displays that allow for the presentation of reference standards to which critical information can be compared.