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Ergonomic principles related to mental workload —

Part 2: Design principles

Principes ergonomiques relatifs à la charge de travail mental —

Partie 2: Principes de conception

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Foreword

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This document was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 1, *General ergonomics principles*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 122, *Ergonomics*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 10075-2:1996), which has been technically revised.

The main change is as follows:

— The structure is now based on working conditions and no longer on strain consequences. All design principles are formulated positively and are divided into three parts, namely justification, guidelines and examples.

A list of all parts in the ISO 10075 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document represents an extension of ISO 6385, providing design principles for work systems with special reference to mental workload as defined in ISO 10075-1.

Mental workload is the effect of a complex interaction of individual, technical, organisational and social factors. Thus, personnel, technical, organisational and social factors and the effects of their interactions are relevant for the design of work systems.

Ergonomic principles related to mental workload —

Part 2:
Design principles

1 Scope

This document gives guidance on design principles and on design of work systems, including task and equipment design (comprising robotics and intelligent autonomous systems) and design of the workplace, as well as working conditions with the inclusion of social and organisational factors, emphasising mental workload and its effects as specified in ISO 10075-1.

It applies to the design of work and use of human capacities, with the intention of providing optimal working conditions with respect to health and safety, well-being, performance and effectiveness, preventing overload as well as underload, in order to avoid impairing effects and fostering the facilitating effects described in ISO 10075-1.

This document includes the design of technical, organisational and social factors only and does not apply to problems of selection or training.

This document does not address problems of measurement of mental workload or its effects.

This document refers to all kinds of human work activities (see ISO 10075-1), not only to those which can be described as cognitive or mental tasks in a restricted sense but also to those with a primarily physical workload.

This document is applicable to all those engaged in the design and use of work systems, for example system and equipment designers, employers and workers and their representatives, where they exist.

This document 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 documents are referred to in the text in such a way that some or all of their content constitutes requirements 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, *Ergonomics principles in the design of work systems*

ISO 10075-1, *Ergonomic principles related to mental workload — Part 1: General issues and concepts, terms and definitions*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 6385 and ISO 10075-1 apply.

ISO and IEC maintain terminology databases for use in standardisation at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

4 Design principles

4.1 General principles

In order to avoid impairing effects and to foster facilitating effects of work system design on users, the work system must fit the user. The guidelines given in this document are recommendations concerning human-factors or ergonomics-related work design. Designing or redesigning work systems entails taking into account: people, technology, organisational and social conditions and their interactions right from the beginning, for example when planning work systems. This means that ergonomists should be integrated into the design process as early as possible. Where appropriate, stakeholders should be involved in the design process.

If there are already users, as in system redesign, their experiences and competencies should be integrated into the design or redesign 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 and needs, with respect to design quality, can be incorporated into the design process. This enables user-oriented results and better acceptance on the side of the user, which contributes to the efficiency of the work system as a whole.

Furthermore, feedback mechanisms are useful to enable workers to help the designer to continuously improve the design, taking into account new situations or problems.

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

The user population must be considered from the beginning of the design process when system functions are specified. Defining system functions and subfunctions as well as function allocation between workers and technical systems and between different workers warrants 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, in a particular organisational and social 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 either the task or job level, or both;

— at the level of technical equipment;

— at the environmental level;

— at the organisational and social level;

b) the duration of the exposure to the workload:

— at the level of the temporal organisation of work.

Table A.1 in Annex A shows a matrix of the guidelines and their relation to the impairing consequences of mental strain.

Personnel factors, such as abilities, performance capacities and motivation (on an inter-individual as well as on an intra-individual differences basis) influence the resulting workload. Thus, selection and training should be taken into account in the design of work systems.

Work system design starts with a function analysis of the system, followed by function allocation among worker and technical system and task analysis, and results in task design and allocation to the worker. It is proven that human factor experts are integrated into this process from the beginning in order to be able to perform these steps with a view to the resulting design 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 be noted that environmental requirements, system demands, challenges and people themselves change over time. People, for example, can develop skills, abilities and expectations. This means that systems design should take into account such changes, enabling the system to adapt to these evolving needs. This can be done, for example, by dynamic task allocation, allowing the worker to allocate tasks to the technical system or to the worker, depending on the actual state of the worker.

Mental workload has different qualitative aspects leading to different qualitative effects (see ISO 10075-1). It is thus not sufficient to 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, although the effects are different. Monotony and mental satiation occur in repetitive monotonous activities. However, monotony is characterized by reduced activation and mental satiation by increased activation. The presentation of the following guidelines has thus been organized according to the components in work system design in ISO 6385 and with reference to impairing and fostering effects as described in ISO 10075-1. This should help the designer to take appropriate measures to avoid impairing effects and to foster facilitating effects of mental workload. Some of the guidelines are related to several consequences of mental strain. Accordingly, there are different possibilities to avoid the impairing consequences of mental strain.

4.2 Design principles in relation to work organisation

4.2.1 Perform system design reviews and include prospective risk assessment

4.2.1.1 Justification

The evaluation of work processes at various stages of development allows for adjustments. The focus should always be human-centred, since latent or occasional impairments due to working conditions can result in reasonably foreseeable misuse, mental fatigue and stress responses during worker task performance.

4.2.1.2 Guidelines

The designer should:

— perform system design reviews;

— assess dynamics and the variability of health and safety risks during system design;

— include, in design reviews, the system life cycle, potential system states, system performance, contexts of use, risks by system wear and tear, and reasonably foreseeable misuses.

4.2.1.3 Example

A building originally designed as a production site is planned to be used as an office or coworking space. Offices and production sites have different illumination requirements. Illumination for office use is suboptimal with regard to natural illumination and artificial illumination design.

4.2.2 Individuals' and team work-related objectives

4.2.2.1 Justification

Objectives should be attainable within regular working hours, otherwise the worker can experience mental fatigue, stress response or burnout.

4.2.2.2 Guidelines

The designer should:

— define individuals' and team work-related objectives consistently and attainably;

— enable worker participation in setting objectives and giving support for achieving these if necessary.

NOTE A commonly used criteria is SMARTE (specific-measurable-achievable-reasonable-timely-ethical).

4.2.2.3 Examples

A nursing goal following the SMARTE criteria can be that a particular patient consumes at least 1,5 litres of fluid every day starting on a certain date, and that this goal is reviewed daily.

At a financial bank, the workers task is to finish a fixed number of financial transactions (e.g. funds) monthly. Every month, the attainability of this objective is reviewed by the worker and employer.

4.2.3 Extended reachability

4.2.3.1 Justification

If workers are available outside working hours, mental fatigue and burnout can occur.

4.2.3.2 Guideline

The designer should provide rules for extended reachability which are agreed upon and clearly communicated and documented.

4.2.3.3 Examples

Rules can include the definition of time of non-availability, the ignoring of certain calls, the separation of mail accounts into private and professional, the automation of mail sorting or the switch-off of notification functions.

4.2.4 Flexibility in time allocation

4.2.4.1 Justification

In interaction work, working conditions should allow the worker to satisfy the needs of the interaction partner (e.g. patients, and clients) in the given situation; otherwise, mental fatigue or burnout can occur.

4.2.4.2 Guideline

The designer should ensure that work systems allow flexibility in the time allocated to any task, especially those requiring social interaction.

4.2.4.3 Example

A certain proportion of the daily working time can be set aside for disposable, as well as demand-oriented interaction times.

4.2.5 Definition of work-related services

4.2.5.1 Justification

If there are no definitions and clear descriptions of roles, the expectations between workers, clients and management can differ and result in unnecessary work for the persons involved, leading to stress response and mental satiation.

4.2.5.2 Guideline

The designer should define and document the scope and character of work or services and inherent tasks as well as the roles and responsibilities.

4.2.5.3 Example

The description of a service can include, for example, information on the service objective, the period of service provision and quality assurance measures.

4.2.6 Duration of working hours

4.2.6.1 Justification

The duration of working time influences the mental fatigue of workers. Mental fatigue can affect health, safety and performance. The duration of working time should therefore be designed to prevent mental fatigue.

4.2.6.2 Guidelines

The designer should:

— ensure that the duration of daily working time does not exceed 8 hours; however, an increase in the duration of daily working time to 10 hours is acceptable if the average daily working time does not exceed 8 hours within a defined period;

— ensure that the duration of weekly working time does not exceed 48 hours; however, an increase in the duration of weekly working time to 60 hours is acceptable if the average weekly working time does not exceed 48 hours within a defined period;

— ensure that the duration of working time is reliable for the worker;

— involve workers in the planning of working time.

These are recommendations which the designer can apply in arranging working hours, taking the applicable legal and regulatory requirements into consideration.

4.2.6.3 Examples

The designer can consider the introduction of working time accounts with time limits.

The designer can also consider compensation for overtime and extra work done in free time (rest time) in the course of an agreed time period.

4.2.7 Time off between successive work days or shifts

4.2.7.1 Justification

The purpose of the time off between successive workdays or shifts (rest periods) is to allow workers to recover. The rest period between successive shifts should be sufficient to allow full recovery from the mental fatigue of the previous shift. This is to ensure health, safety and performance and to prevent accidents caused by exhaustion or lack of concentration.

4.2.7.2 Guidelines

The designer should:

— provide a rest period of at least 11 h between two shifts;

— design shift sequences to exclude the shortening, interruption and division of rest periods;

— allow an exceptional shortening of the rest period if there is a possibility of compensation within a fixed period of time (e.g. within 4 weeks);

— keep the number of on-call duties during the workers' rest period as low as possible;

— limit the availability of workers during rest periods;

— consider monitoring adherence to rest periods (e.g. digital logbooks, time-recording systems);

— take account of secondary activities, such as travel time during business trips, when planning rest periods.

4.2.7.3 Examples

The designer can consider reliable and comprehensible deployment planning with substitute regulations and binding rest periods, developed with the participation of workers.

If not possible otherwise, the rest period can be shortened by a maximum of 1 h (e.g. in hospitals or care facilities).

4.2.8 Time of day

4.2.8.1 Justification

Human bodily functions are subject to a natural 24 h day-night rhythm. The worker's performance fluctuates during the working day. It is lower during the night than during the day. Activities during periods of low performance are subject to higher risks to safety and health.

4.2.8.2 Guidelines

The designer should:

— consider circadian variations when planning working hours;

— reduce performance requirements during night hours compared with those during daytime work (more breaks, fewer pieces, appropriate staff ratios in relation to task requirements).

4.2.8.3 Example

If atypical working hours are necessary, they should be:

— mutually agreed upon by the worker and the employer;

— made voluntary if possible;

— performed by a sufficient number of workers.

4.2.9 Shift work

4.2.9.1 Justification

Shift work, especially night work, necessitates workers to perform work at a time when the organism or body needs rest and time to recover due to natural circadian fluctuations. Such work can affect well-being, present a risk to safety and health and have adverse social implications.

4.2.9.2 Guidelines

The designer should:

— rotate shifts forward on a rolling basis (early shift, late shift, night shift);

— adopt a short cycle (maximum 2 to 3 days) in planning shifts;

— keep the number of consecutive night shifts as low as possible (maximum three, but preferably only two in a row);

— avoid permanent night shifts;

— involve workers in the planning of shift schedules.

4.2.9.3 Example

The early shift in the three-shift system should start at a time which allows workers in this shift sufficient night sleep (e.g. later than 6 a.m.).

4.2.10 Breaks and rest pauses

4.2.10.1 Justification

Depending on the intensity, duration and temporal pattern of mental strain, mental fatigue (which is an adverse and impairing effect) can occur.

4.2.10.2 Guideline

The designer should introduce planned breaks to provide opportunities for recuperation and maintain efficiency and effectiveness.

4.2.10.3 Examples

Due to the exponential relation between the duration of uninterrupted work, mental fatigue and recovery, short breaks after short periods of work are preferable to longer breaks after long periods of work. For example, six short breaks of 5 min each after 55 min of work are preferable to one break of 30 min after 6 h of work. Work or rest schedules for night work should feature shorter working periods than those of day work.

4.3 Design principles in relation to working tasks

4.3.1 Operating strategies

4.3.1.1 Justification

In complex situations, strategies, rules or operation procedures can facilitate decision-making and reduce the likelihood of a stress response among workers.

4.3.1.2 Guidelines

The designer should:

— provide a clear strategy for answering multiple requests in work systems where they need to be answered;

— ensure the strategy to be used and the rules for following that strategy are clearly defined, for example first-in-first-out, hierarchical or conditional;

— prefer a simple strategy, such as first-in-first-out to more complex strategies;

— ensure that the conditions for following conditional serving strategies are clearly understandable.

4.3.1.3 Examples

When providing first aid, there are specific rules concerning the order of medical measures.

Call-centre agents, too, can be given a strategy regarding which customer to take next. A first-in-first-out strategy is often followed, although more complex strategies are sometimes adopted.

4.3.2 Continuous time constraints

4.3.2.1 Justification

Continuous time constraints can lead to shortcuts in task performance and, thus, to errors. If performance is critical regarding its consequences, continuous time constraints can lead to mental fatigue, stress responses or consequences in safety or the quality and quantity of work performance.

4.3.2.2 Guidelines

The designer should:

— minimize continuous time constraints;

— provide autonomy at work and ensure role clarity, including clarity of task objectives, to help to reduce the impact of time constraints;

— consider the interplay of the different levels (such as organisation, team, task and worker) and support from the management;

— consider the timing of tasks with time demands in relation to the available resources;

— prioritize tasks and reduce interruptions;

— provide resources for unforeseen events, where strict deadlines are necessary.

4.3.2.3 Examples

Successful project management necessitates the planning of work packages, taking into account responsibility and time, in order to avoid time constraints.

4.3.3 Flexibility of decision-making

4.3.3.1 Justification

If there is no leeway in decision-making, it is possible that the goals of a work system will not be achieved. Furthermore, the worker can experience a stress response, mental satiation or burnout as a long-term consequence.

4.3.3.2 Guideline

The designer should:

— provide flexibility in decision-making (decision latitude), where it is necessary to reach the objectives of the work system;

— allocate additional resources for task performance within the scope of the decision-making process.

4.3.3.3 Example

A worker must repair a machine. There are several ways to repair the damage. Depending on the level of knowledge, the worker can use any of these methods.

4.3.4 Ambiguity of task goals

4.3.4.1 Justification

If task goals are ambiguous, workers can decide the priority of goals for themselves. This can lead to a stress response and inadequate task fulfilment, due to excessive demands or uncertainty about appropriate task performance.

4.3.4.2 Guidelines

The designer should:

— define clear task goals;

— define the priority of different task goals when there are two or more goals;

— define task allocation between workers when there is more than one worker involved;

— provide social support in cases where ambiguous tasks cannot be avoided.

4.3.4.3 Examples

Agreements regarding the number of final quality inspections of a product without definition of the motivating conditions (e.g. systematically low quality of individual components, failures in preceding assembly or production slowdowns) can lead to ambiguity of task goals.

Ambiguity arises when there is a lack of clarity about the priority of tasks in relation to the objectives or a lack of clarity regarding improving the quality over the quantity of the product.

4.3.5 Complexity of task requirements

4.3.5.1 Justification

If tasks are too complex, workers will possibly need to make too many decisions or decisions that are too complicated, within a specific time interval, potentially resulting in a stress response. On the other hand, tasks with a low level of complexity can lead to monotony or mental satiation.

4.3.5.2 Guidelines

The designer should:

— ensure that task complexity is at an optimal level, i.e. neither too low or too high;

— provide decision support systems where task complexity is too high;

— define clear task goals, including any task sub-goals.

4.3.5.3 Example

In a control or emergency room environment, monitoring and responding to changes within a number of parameters simultaneously can be challenging and can necessitate the prioritisation of requirements or the provision of support.

4.3.6 Time sharing

4.3.6.1 Justification

If two or more tasks requiring attention are performed simultaneously, the limits of human processing capacity can be exceeded. Important information can either be overlooked or the worker can become mentally fatigued, or both.

4.3.6.2 Guidelines

The designer should:

— provide for a sequential task execution;

— prioritize tasks concerning their execution urgency;

— ensure that there are no interruptions during task execution.

4.3.6.3 Examples

Training with a simple and consistent stimulus-reaction assignment can be used for reducing attentional demands. This only applies if the consequences of failures concerning erroneous information processing have low relevance.

Follow-up alarms in the monitoring of flour bag filling quantities are identified as such in the control room of a mill and marked for the worker. This makes it clear that the number of problems is not increasing.

In the control rooms of emergency call centres, there are priorities for accepting incoming call numbers (e.g. emergency calls or workstation calls).

4.3.7 Dimensionality of motor performance

4.3.7.1 Justification

Combining a number of task-related activities calls for the coordination of movements in two or more planes can place high demands on a worker, resulting in either a stress response or mental fatigue, or both.

4.3.7.2 Guideline

The designer should keep the dimensionality of movements as low as possible as well as practical.

4.3.7.3 Examples

When operating an overhead crane, the worker coordinates movements in three planes: vertical for the hook, forwards-backwards for the boom and sideways for the crane assembly.

When reversing with an excavator or forklift, it is difficult to perform other control movements at the same time.

4.3.8 Mental models

4.3.8.1 Justification

Workers need a clear understanding of the work system, its functions and the work process in which they are directly involved. This mental model (mental representation) should be sufficiently complete and consistent to enable them to fulfil their task effectively and efficiently. A lack of understanding can lead to a stress response or mental satiation.

4.3.8.2 Guidelines

The designer should:

— design work systems in such a way that the worker can create a mental model of the system;

— design tasks, interactions and information for the workers to support mental modelling of the system.

4.3.8.3 Examples

Active visualization of information on the interrelationships between subsystems support the building and development of mental models, for example through flowcharts, recording of time-related system responses or mapping techniques.

4.3.9 Parallel versus serial processing

4.3.9.1 Justification

Serial processing allows only one process at a time and effectively means that a process must be completed before the next starts. Parallel processing assumes some or all processes involved in a cognitive task(s), such as visual search or object recognition, occur at the same time. In the context of performance optimisation in multi-tasking, parallel processing is faster but results in a higher cognitive load, resulting in either a stress response or mental fatigue, or both.

4.3.9.2 Guidelines

The designer should:

— select serial processing over parallel processing in general due to demands on processing resources;

— present information in a parallel manner where comparisons are made among different objects or sources of information.

4.3.9.3 Example

Displays exist that allow presentation of critical information in parallel with a reference standard, to make comparisons easy.

4.3.10 Decision support

4.3.10.1 Justification

Decision supports are used to assist workers in complex decision-making processes. This can enhance decision-making in the workflow, reducing the risk of mental fatigue.

4.3.10.2 Guidelines

The designer should:

— provide decision support with prompts and reminders to assist workers' decision-making if results cannot be fully anticipated;

— provide decision support by supervisors, experts or colleagues in critical situations.

4.3.10.3 Examples

Clinical decision support systems deliver information regarding various vital parameters on demand, giving guidance on care and handling of patients.

Bow-tie diagrams can be used to visualize decision components to support decision-making.

4.3.11 Sustained attention

4.3.11.1 Justification

Tasks with low and high signal or event rates, low probability of critical event rates or low signal discriminability can lead to reduced vigilance and degradation of performance.

4.3.11.2 Guidelines

The designer should:

— minimize the number of tasks which necessitate high sustained attention;

— limit the duration of tasks with sustained attention;

— provide organizational means (e.g. rest pauses, job rotation) when tasks with sustained attention cannot be avoided;

— inform the worker using different sensory modalities regarding possibly occurring critical events during monitoring tasks.

4.3.11.3 Examples

Workers monitor and control water levels in a control room. To avoid sustained attention, an acoustic signal alerts the worker before the level is critical. After performing monitoring and control tasks for a limited time duration, workers perform tasks with different demands or rest pauses are introduced.

4.4 Design principles in relation to job

4.4.1 Social interaction

4.4.1.1 Justification

Opportunities for social interaction can provide social support in establishing and maintaining sustainable relationships with colleagues, clients and patients with the potential for reducing stress responses and, in specific situations, avoiding monotony.

4.4.1.2 Guidelines

The designer should:

— ensure task and equipment design give opportunities for adequate or appropriate social interaction;

— provide support systems for emotionally demanding work;

— ensure that workers are given rules and means to enable them to safely address inappropriate behaviours from others;

— ensure that systems allow flexibility in the time allocated to tasks;

— enable emotional authenticity by providing an appropriate form of management.

4.4.1.3 Examples

Structures for protecting workers from inappropriate behaviour from others can include technical aids, such as partition or dividing walls, or trained counselling personnel.

Support for workers can be given through (group) supervision, coaching and by allocating tasks with reduced customer contact.

4.4.2 Dependencies on others' task performance

4.4.2.1 Justification

Direct dependency on co-workers' task performance can increase stress response or mental fatigue.

4.4.2.2 Guideline

The designer should ensure workers' independence from co-workers' task performance as far as the task allows.

4.4.2.3 Examples

Independence can be achieved by decoupling task performance by means of either time or material buffers, or both.

Another way to achieve independence can be to have workers assembling different parts or a whole unit of a product.

Communication or continuous improvement meetings are set up to resolve problems arising from dependency on a co-worker's task performance.

4.4.3 Identical task requirements

4.4.3.1 Justification

Identical task requirements over a long period within one job can increase workload and reduce learning or development.

4.4.3.2 Guideline

The designer should change task requirements to involve different information-processing resources.

4.4.3.3 Examples

Changes in task requirements can be achieved by a systematic rotation among different positions with specific requirements (job rotation) or by combining task elements or different operational levels, for example combining assembly with inspection (job enrichment).

Changes in tasks with different demands in mental workload can include changes from monitoring to manual control, or from performing logical analysis to routine operations.

4.4.4 Confidential communication

4.4.4.1 Justification

If feedback about the contributions of a worker to the work result is not trustworthy, stress response and burnout can occur.

4.4.4.2 Guideline

The designer should communicate the extent of attainment of a system's objectives and the contribution of a worker to that attainment confidentially.

4.4.4.3 Example

Trust can be achieved by confidentiality and conveying to interaction partners that personal statements have not been and will not be passed on without their consent.

4.4.5 Changes in task-related activities with different demands or types of mental workload

4.4.5.1 Justification

Changes in task-related activities can have effects comparable to breaks or rest pauses, and thus should be provided in order to prevent mental fatigue.

4.4.5.2 Guideline

The designer should provide changes in task-related activities with different demands in mental workload.

4.4.5.3 Example

Workers can change from monitoring to manual control or from performing logical analyses to routine operations to prevent mental fatigue.

4.5 Design principles in relation to work equipment and interfaces

4.5.1 Design the socio-technical system transparent for the user

4.5.1.1 Justification

System transparency extends beyond predictability of system functioning and mental modelling in that it covers alternative system use, challenging functional limits and contexts of use, risk mitigation and avoiding reasonably foreseeable misuse.

4.5.1.2 Guidelines

The designer should:

— design the socio-technical system transparent for the worker;

— design the system and instruct the involved workforce in such a way that the worker is informed about its actual position in the total system, about the system state, how the state evolved, what functions are available at the moment to what effect and how to proceed in order to perform the tasks as planned;

— design the system to enable the worker to provide feedback regarding the actual and target states of the system.

4.5.1.3 Example

Advanced production plants have a high degree of opacity and of system-specific complexity. The interrelationships and system states can be communicated to the worker at the plant by means of appropriate audio-visual displays.

4.5.2 Re-evaluate after adopting an assistance system to an existing system

4.5.2.1 Justification

System re-evaluation is needed after changing system components, in order to avoid the impairing consequences of work strain, such as human error, stress response and mental fatigue, and to allow the detection of new risks.

4.5.2.2 Guideline

The designer should evaluate the revised system after adopting an assistance system to an existing system.

4.5.2.3 Example

Assistance systems are often implemented to support human-system interaction or to compensate for the requirements of already existing systems (e.g. camera-monitor systems to compensate for monitoring hazard areas that are out of direct human view). The integration of assistance systems to support specified tasks necessitates re-evaluation of the system, including assistance systems against human factors and ergonomics requirements in work system design (e.g. the arrangement of an assistance system in the centre of the field of view below the front windscreen to avoid occlusion of the windscreen and glare).

4.5.3 Time lag

4.5.3.1 Justification

If there is a lag between an action taken and the response of the system, a worker is forced to anticipate the response of the system in order to correctly carry out the necessary actions.

4.5.3.2 Guideline

The designer should consider the use of predictive displays.

4.5.3.3 Example

With large sea-going vessels, there can be a considerable time lag between a control action and the response of the vessel. The use of predictive displays assists the worker in anticipating the correct control movement.

4.5.4 Adequacy of information

4.5.4.1 Justification

Missing or unnecessary information contributes to mental workload because the worker ends up making decisions on the basis of insufficient information or filtering the relevant information from the total information supplied, both of which can lead to mental fatigue.

4.5.4.2 Guideline

The designer should provide all of the information necessary for task accomplishment.

4.5.4.3 Examples

The provision of proper instructions, for example in assembly lines in the workplace, quality inspection tasks or the usage of issue-tracking systems to manage customer requests, can prevent mental fatigue.

The provision of proper instructions or specific rules regarding the distribution and usability of task-related information, can prevent mental fatigue.

Sending emails in a well-structured manner, with a relevant subject line, and only using "cc" when necessary for task completion, can also offer adequate information.

4.5.5 Ambiguity of information

4.5.5.1 Justification

Ambiguous information requires workers to interpret information and can lead to higher mental workload.

4.5.5.2 Guideline

The designer should provide distinctive information to the worker.

4.5.5.3 Examples

Range information (acceptable, not acceptable) in displaying system states can reduce mental workload.

Increasing the visibility of the necessary information, by optically highlighting it or by hiding irrelevant information, can also reduce mental workload.

4.5.6 Signal discriminability

4.5.6.1 Justification

Low discriminability of information-carrying signals against a background of irrelevant information necessitates that the worker expends effort to filter for relevant information.

4.5.6.2 Guideline

The designer should ensure that the signals relevant for processes and incident preparedness are easily detectable and discriminable.

4.5.6.3 Examples

Signal discriminability can be improved by:

— manipulating the intensity of signals;

— coding signals differently by using shape, colour, duration or time characteristics;

— reducing background (noise) intensity;

— masking and filtering by technical systems.

4.5.7 Redundancy

4.5.7.1 Justification

Redundancy means the duplication of critical information displays, with the intention of increasing system reliability and reducing mental load on the worker.

Redundant presentation of information, often in different sensory channels, can help the worker to cross-check information, especially critical information requiring action.

In certain situations, the efficiency and safety of a system depends upon the system's ability to present redundant information.

4.5.7.2 Guidelines

The designer should:

— provide additional displays and controls where such redundancy can benefit overall system safety;

— optimize the degree of redundancy according to operational requirements;

— enable workers to select the degree of redundancy appropriate for task accomplishment.

NOTE With respect to control actuators or displays, some system requirements can demand that a given function be operated or monitored from different locations, in order to maintain speed, accuracy, health and safety.

4.5.7.3 Examples

A flight or train announcement (e.g. change of gate or platform) can be communicated by public address system as well as shown on the departure information screen.

A pop-up box on a control panel screen alerts the worker that a situation needs attention, while the details of the situation (and perhaps suggested action) are displayed in the status line at the bottom of the screen.

4.5.8 Compatibility

4.5.8.1 Justification

Information displays, control movements or system responses which are incompatible with common user expectations produce conflicting information and force the worker to expend extra effort to accomplish the required performance.

NOTE Usage of incompatible controls or displays results in longer response time, greater error (especially in stress or emergency situations), longer training time and higher mental fatigue rate.

Controls, displays, control-displays or control-response relationships which are expected by the anticipated user population are referred to as stereotypes. Controls, displays, control-display relationships or control system responses which conform to the stereotypes are called compatible; those which do not conform to the stereotypes are called incompatible.

Stereotypes and other user expectations of how the human–machine interface operates influence how a worker will use a particular control actuator or display. Under critical situations, workers can be expected to revert to stereotypes, even if they have been trained to act in a contrary manner.

4.5.8.2 Guideline

The designer should ensure that controls, displays, control-display or control-response relationships match the expectation of the anticipated user population.

4.5.8.3 Examples

Stereotypes and user expectations are sometimes culturally sensitive or location specific. For instance, moving a toggle switch downwards is expected to activate (switch on) in some countries and to deactivate (switch off) in others.

Stereotypes and user expectations are sometimes also dependent on context. Turning a control actuator to the right is usually coupled with an increase in system response or display movements.

4.5.9 Accuracy of information processing

4.5.9.1 Justification

Information processing is frequently a function of speed versus accuracy. A worker can trade accuracy for speed in perceptual as well as cognitive tasks.

4.5.9.2 Guideline

The designer should provide appropriate automated or computerized aids for information presentation (for information displays) or control dynamics (for input devices).

4.5.9.3 Example

Trend displays and predictor displays help the worker to take proactive control actions, thereby optimising the mental processing load.

4.5.10 Controllability

4.5.10.1 Justification

Dynamic systems should be controllable by the worker. Controllability depends on the order of control, dimensionality of control movements, time delays in system response and information display as feedback to user control actions, and display-control compatibility. High-order dynamics increase mental workload.

4.5.10.2 Guidelines

The designer should:

— provide control dynamics of the second order or lower;

— ensure display-control compatibility;

— minimize time delays in system response and information presentation.

4.5.10.3 Examples

Mouse control should be appropriate for the control of positions on a screen. Joystick control can be used for controlling the velocity of vehicles, such as trains, trams or aircraft.

4.5.11 Control dynamics

4.5.11.1 Justification

High-order control dynamics make it difficult for workers to control systems due to increased mental workload.

4.5.11.2 Guideline

The designer should provide supportive technical systems (e.g. integrators, differentiators and amplifiers), where high-order control dynamics are necessary.

4.5.11.3 Example

A worker interacting with a high-order technical system (e.g. ship, chemical plant) needs decision-making information about the past and future states of the systems presented by trend and predictive displays.

4.5.12 Tracking requirements

4.5.12.1 Justification

Real-time and low-latency tracking behaviour facilitates responses by workers to avoid higher demands on the worker.

4.5.12.2 Guideline

The designer should provide pursuit tracking if the worker is required to immediately evaluate and react to current events.

4.5.12.3 Examples

It is necessary for surgical support systems to realize real-time and high-accuracy tracking to ensure worker and patient safety.

In aircraft and maritime navigation systems, the desired vertical and horizontal path to the destination is tracked by the pilot or helmsman. This can be done by correcting the real position of the plane or ship by compensatory changes in direction and speed. A system providing a speed and direction solution in advance (pursuit tracking) reduces the mental load of the pilot or helmsman.

4.5.13 Error tolerance

4.5.13.1 Justification

Error-tolerant systems can reduce fatal consequences of unintended operations by no or minimal corrective action by the worker and therefore support system safety and protect workers' health and well-being.

4.5.13.2 Guidelines

The designer should:

— provide systems that require confirmation of critical actions with an indication of their possible consequences before they are executed;

— provide systems where workers' last actions can be reversed.

4.5.13.3 Example

Error tolerance systems provide explanations to workers in order to facilitate the correction of errors (e.g. wrong input and typing error).

4.5.14 Adjust system design

4.5.14.1 Justification

System design is not a one-shot process and should be adjusted to changes over time (e.g. technical and human system life cycle), as well as to dynamics built in the technical and the human sub-system (e.g. machine and human learning). Static design and the level of assistance of technical systems can result in a misfit between human behaviour and technical system design, with the consequence of skill degradation, monotony and mental fatigue.