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Ergonomic requirements for the design of displays and control actuators —

Part 1:
Human interactions with displays and control actuators

Spécifications ergonomiques pour la conception des dispositifs de signalisation et des organes de service —

Partie 1: Interactions entre l'homme et les dispositifs de signalisation et organes de service

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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 9355-1 was prepared by the European Committee for Standardization (as European Standard EN 894-1:1997) and was adopted, under a special “fast-track procedure” by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 4, *Ergonomics of human-system interaction*, in parallel with its approval by the ISO member bodies.

ISO 9355 consists of the following parts, under the general title *Ergonomic requirements for the design of displays and control actuators*:

— *Part 1: Human interactions with displays and control actuators*

— *Part 2: Displays*

— *Part 3: Control actuators*

— *Part 4: Location and arrangement of displays and control actuators*

Annex A of this part of ISO 9355 is for information only.

Ergonomic requirements for the design of displays and control actuators —

Part 1:
Human interactions with displays and control actuators

1 Scope

This part of ISO 9355 applies to the design of displays and control actuators on machinery. It specifies general principles for human interaction with displays and control actuators, to minimize operator errors and to ensure an efficient interaction between the operator and the equipment. It is particularly important to observe these principles when an operator error may lead to injury or damage to health.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 9355. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 9355 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

EN 418, *Safety of machinery — Emergency stop equipment, functional aspects — Principles for design*

EN 614-1, *Safety of machinery — Ergonomic design principles — Part 1: Terminology and general principles*

ISO 9355-2, *Ergonomic requirements for the design of displays and control actuators — Part 2: Displays*

ISO 9355-3, *Ergonomic requirements for the design of displays and control actuators — Part 3: Control actuators*

ISO 9241-10, *Ergonomic requirements for office work with visual display terminals (VDTs) — Part 10: Dialogue principles*

3 Definitions

For the purposes of this part of ISO 9355, the following definitions apply:

3.1
control actuator
The part of the control actuating system that is directly actuated by the operator, e.g. by applying pressure.

3.2
display
Device for presenting information that can change with the aim of making things visible, audible or discriminable by touch (tactile).

3.3
operator
The person or persons given the task of installing, operating, adjusting, maintaining, cleaning, repairing or transporting machinery [EN 292-1[1)]].

4 Design principles for operator-task relationships

Human-machine systems are considered here as closed loops: the machine displays information to the operator who uses control actuators to affect the machine, which in turn provides feedback to the operator, etc.

Human-machine systems can comprise any number of man-machine units or subsystems, in which a single operator interacts with a machine or process. Several subsystems may act independently or interact with each other. When considering the requirements for a particular human-machine subsystem it is important to assess how it interacts with the system as a whole.

Moreover, human-machine systems are part of more complex systems. For example, the physical environment (noise, lighting, etc.) as well as the social and organisational environment can affect the efficient operation of human-machine systems.

Knowledge of ergonomics principles is the basis for a successful implementation of a human-machine system. In particular, it is important to ensure that systems are designed as an iterative process between the designer and the users. EN 614-1 provides a framework for incorporating ergonomics principles in the design process that shall be taken into account when designing machines. This framework can help designers to take account of the principles in this standard.

An important factor to consider is the degree to which the human operator is needed in the system in order to accomplish the given task. The informative Annex A summarizes information on the capabilities of humans when interacting with machines. The designer shall consider if the planned allocation of a particular function in a man-machine system is in accordance with human capabilities. If this is not the case, the designer shall redesign the system. A result of the redesign may be a (sub) system without the involvement of an operator.

The overall principle which concerns human-machine systems is that the machine and its associated elements (displays, controls, instructions, etc.) shall be suitable for the operator and the given task. In order to realise this general principle, the machine system shall be so designed that human characteristics with respect to physical, psychological and social aspects are considered. The following clauses present ergonomics principles that shall be considered when designing a human-machine system. Some guidance on methods which can be used to achieve the principles is also given. It should be noted that this list is not exhaustive but provides a good indication of practical measures which should be considered. ISO 9241-10 gives further information on these principles when applied to software.

When trying to comply with these requirements it is important that the selected solutions shall be tested under realistic conditions (see EN 614-1).

4.1 Suitability for the task

A human-machine system is suitable for the task if it supports the operator in the safe, effective and efficient completion of the task.

4.1.1 Principle of function allocation

The most suitable allocation of functions between the operator and the machine should be decided after considering the requirements of the task and the strengths and limitations of the human operator.

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1) EN 292-1, *Safety of machinery — Basic concepts, general principles for design — Part 1: Basic terminology, methodology.*

Application:

Ensure the machine does not place unacceptable demands on the operator in terms of, for example, speed and accuracy of response, forces required to operate control actuators, vigilance for small changes in display status.

4.1.2 Principle of complexity

As far as consistent with the task requirements, possibilities shall be offered to reduce complexity. Special consideration shall be given to the complexity of the task structure and the type and amount of the information to be processed by the operator.

Application:

When designing human-machine interaction then speed and accuracy are important variables to consider. Those factors which influence these variables need to be determined.

For example, in check reading, the operator makes a qualitative assessment that the system is within acceptable boundaries. The accuracy of such readings may be enhanced if the pointers of the displays are arranged into a pattern so that it is easy to determine if one or several of the pointers deviate from the normal pattern (see ISO 9355-2).

4.1.3 Principle of grouping

Arrange displays and control actuators so that they are easy to use in combination by following procedures for grouping items.

Application:

Where control actuators and displays are operated in a certain fixed sequence, they shall be arranged in that sequence. This arrangement helps the operator to remember the sequence and it decreases response time and leads to fewer errors.

Where control actuators and displays are not operated in a fixed sequence then the grouping should be determined using the following aspects:

a) The importance for the safe use of the machine;

b) The frequency of use in regular machine operation;

c) The use of elements in a sub-sequence (for example, start up controls like the ignition, choke and starter on a car);

d) The functional relationship between elements (for example, the wiper and wash controls on a car).

The above aspects are not mutually exclusive and several elements may appear in more than one category.

Consequently the location of displays and control actuators should be arranged so that:

a) The important and frequently used items are in the most accessible positions;

b) Items in sub-sequences are then placed together;

c) Functionally related items are placed in groups with visual and spatial separation from other items.

Important displays and control actuators, such as those used for emergencies shall be designed and positioned so that they can be used quickly and accurately. Guidance on emergency stop devices is given in EN 418.

4.1.4 Principle of identification

Control actuators and displays should be readily identifiable.

Application:

Labels, signs and other informative texts or symbols should be located on or adjacent to their associated control actuators and displays in such a position that they are visible when the control actuators are operated. It is generally preferable to place such means of identification either above or on the control actuator or display.

4.1.5 Principle of operational relationship

Associated control actuators and displays should be arranged to reflect their operational relationships.

Application:

Control actuators should be located adjacent to associated displays so as to make their relationship obvious to the operator.

The direction of control actuator operation shall be consistent with the direction of associated system responses and/or display movements (see ISO 9355-2 and ISO 9355-3).

If a system failure occurs, it shall be identified to the operator as quickly as possible.

4.2 Self-descriptiveness

The human-machine interface should be designed so as to be self-descriptive, this means that the operator can easily recognise the displays and controls and understand the underlying process.

4.2.1 Principle of information availability

Information about the status of the system shall be readily available at the request of the operator without the need to interfere with other activities.

Application:

Verification that an operator action has been accepted by the system shall be presented to the operator without unnecessary delay. If the execution is prolonged, the operator should be informed. When appropriate the system shall respond instantly and simultaneously to an operator's actuation of the associated control actuator. With delays greater than 1 s, the perceived association is reduced and preliminary feedback becomes necessary.

4.3 Controllability

The operator shall dominate the system. This means that the system and its components shall guide the operator throughout the task during periods when the system is under direct operator control. The operator shall not be dominated by the workcycle rhythm inherent in the system.

4.3.1 Principle of redundancy

Provision should be made for additional displays and controls where such redundancy may benefit overall system safety.

Application:

In certain situations the efficiency and safety of a system depends upon the system's ability to present redundant information to the operator. Important information should be available from different sources. With respect to control actuators, some system requirements may demand that a given function can be operated from different locations in order to maintain speed, accuracy, health and safety.

4.3.2 Principle of accessibility

Information should be readily accessible.

Application:

Ensure the layout places the displays within the operator's field of vision. The important information in terms of safety and frequently consulted information shall be located in the central areas most frequently scanned by the eye (see ISO 9355-2).

In addition to this general requirement consider that the information may be obscured because of the positioning of the operator's arms.

4.3.3 Principle of movement space

The body movements that are required to operate control actuators should not cause discomfort for the operator.

Application:

The space between individual control actuators shall be optimal in order to ensure efficient operation, since too much space may demand unnecessary movements, while too little space may cause accidental operation. In order to determine the optimal space it is essential to consider the specific characteristics of each individual control actuator as well as the overall context in which the control actuators are to be operated, e.g. some systems are operated by persons wearing gloves.

4.4 Conformity with user expectations

Population stereotypes and other user expectations of how the human-machine interface operates are powerful influences in determining how an operator will use a particular control actuator or display. Under stress operators can be expected to revert to population stereotypes even if they have been trained to act in a contrary manner.

4.4.1 Principle of compatibility with learning

The function, movement, and position of control actuator and display elements shall correspond to what the operator expects from previous work experience or training.

Application:

What is expected from conventions is important when applying this principle. For example, there is a sterotype to rotate a dial clockwise to increase a value on a display and to move a control actuator upwards or to the right to increase the value.

4.4.2 Principle of compatibility with practice

The function, movement, and position of control actuator and display elements shall correspond to expectancies based on practical experience in using the system and the relevant manual.

Application:

After some time the operator becomes accustomed to the particular response times exhibited by the system and develops expectations regarding them. Similar operations shall thus exhibit the same general pattern with respect to response times. The operator shall be informed if the response time of the system deviates from what would normally be expected.

4.4.3 Principle of consistency

Similar parts of the human-machine system should operate in a consistent manner.

Application:

The arrangement, function and movement of control actuators, displays, and other devices of the system shall be consistent and not interchanged throughout the system or systems, e.g. related control actuators and displays shall be arranged in the same order.

A consistent set of codes and symbols shall be used.

4.5 Error tolerance

A system is said to be error tolerant if, despite evident errors in operation, the intended result is achieved with either no or minimal corrective action.

4.5.1 Principle of error correction

Systems should be able to perform error checking and provide the operator with the means for handling such errors.

Application:

If the system can correct an operator error in several ways, the operator shall have the chance to select from these possibilities. However, it could be important to inform the operator about the correct procedure to be followed.

Enough information shall be provided in critical situations to ensure optimal error handling. If a system failure occurs it shall be identified to the operator as quickly as possible. Error messages shall be easily understood. The operator shall be able to execute the necessary actions without extensive information processing and help from manuals etc. The operator should be able to choose between brief and detailed error information.

4.5.2 Principle of error handling time

The system should provide sufficient time for an operator to reliably recover from any errors.

Application:

Ensure that the operator has sufficient opportunity to identify any errors and make appropriate corrective actions before the consequences of the errors become critical.

Guidance on how to minimize the likelihood of inadvertent operation of control actuators is presented in ISO 9355-3.

4.6 Suitability for individualization and learning

A system is suitable for individualization and learning if it can be adjusted to individual needs.

4.6.1 Principle of flexibility

The system shall be flexible enough to be adapted to differences in personal needs, general physiological and psychological abilities, learning abilities and cultural differences.

Application:

Where possible, the operator shall be able to influence the speed of interaction.

The experienced operator shall be able to structure the feedback so that it conforms to their level of expertise. By the same token the inexperienced operator should be able to set the level of feedback at an appropriate level.

In a complex system, the system should provide the operator with the choice of brief or detailed information about the system.

Regarding operation, most control actuators can be operated equally well with both hands. However, control actuators that demand accurate, and/or fast, operation should either be capable of being operated by either hand or be so designed to allow accurate and/or fast operation by the non-preferred hand.

Annex A
(informative)

Human information processing

Human information processing

A.0 Introduction

Many criteria and principles of ergonomics are derived from knowledge acquired in the fields of human-machine systems and general psychology. This Annex presents some of this basic knowledge in terms of an overview of some principles of human information processing. However, it is to be noted that due to the rapid theoretical and empirical development in the field, there are many diverging opinions regarding these matters. The following presentation should thus be regarded as a set of tentative suggestions based on some current ideas about these issues.

The following approach considers the human mind as an information processing system. In this system three interacting subsystems are distinguished, namely:

a) The perceptual system;

b) The cognitive system;

c) The motor system.

Although, as mentioned above, it is practice to distinguish among different systems of information processing, it is important to realize that some of these distinctions often become blurred in the observation of an operator in a real situation. It is therefore essential to realize that human performance always reflects the interaction and combinations of many different information processing subsystems and that these interactions may produce unpredictable results.

A.1 Overview

The presentation below is arranged under the following main sections; attention, perception, cognition, motor performance and performance shaping factors. Due to the close interrelationship among the systems discussed under each section, the order of presentation is somewhat arbitrary and is mainly adopted for heuristic reasons. For example, the issue of memory is discussed under the cognitive section, but, as mentioned above, the characteristics of memory are involved in many of the systems discussed, such as attention, expectation etc.

A.2 Attention

In many situations, e.g. those involving a human operator in a human-machine system, the person can be viewed as a single channel processor with capacity to process information from no more than a few sources at a time.

Attention is normally confined to two main sources, the internal world i.e. thoughts and sensations from the body, and the external world. Since attention can be described as a limited resource, there may be competition among attentional resources. For example, an operator who is occupied with thoughts or decision making may suffer attentional deficits regarding events happening in the outside world. A consequence for the design of human-machine systems is that it is essential not to overload the attentional resources of the operator.

A.2.1 Deliberate and forced attention

It is useful to distinguish between deliberate, or controlled, attention and attention which is forced by stimuli, either external or internal to the operator. In many human-machine situations the operator controls attentional resources by deliberate selection of where attention is to be focused. In other situations, however, if a strong or expected signal from outside occurs, then the operator interrupts ongoing attentional control and directs attention towards the source of the signal. Such events may have a disturbing effect on the operator's performance, and thus it is essential that emergency alarms etc. are not triggered to an unnecessary extent and that signals do not distract persons for whom the signals are not intended. Attention may also be automatically directed towards the operator's own physiological sensations, such as painful stimuli or physiological sensations associated with stress. Such sensations may have an interfering effect on deliberate task-related attention.

A.2.2 Simultaneous attention toward several sources

Under certain conditions man is also capable of performing several operations simultaneously. The following characteristics of a human-machine system may help to optimize such activities:

a) Narrow spatial location between displays may help parallel processing. However, in the case of auditory displays, this arrangement is not recommended;

b) Integral displays may also enhance the possibilities for parallel processing;

c) If the system demands parallel processing, the designer should consider the use of displays made for different senses, since different senses are assumed to draw on different attentional resources;

d) The designer should also consider that attentional resources are needed to a larger extent if the operator is unfamiliar with a system.

A.3 The perceptual system

The perceptual system translates information from the external world into mental representations. The process of recognizing an object may be viewed as "pattern recognition" where features of stimuli are processed and compared with information stored in long term memory. An experienced operator has the ability to recognize complex spatial and temporal patterns. Shortly after a stimulus is presented, a representation of the visual stimulus appears in a visual image store and in an auditory image store for auditory presented information. These sensory memories hold information coded physiologically as an analogue to external stimuli.

Similar signals occurring within a single processing cycle, may combine into a single perception. There is thus a critical period when signals are not detectable as individual stimuli.

A.3.1 Decay times

The decay times (half-life) for information held in the perceptual memories are roughly about 0,1 to 1 s for the visual store and about 0,9 to 3,5 s for the auditory store.

A.3.2 Attention and expectancy

A person's expectation regarding a stimulus or a configuration of stimuli will influence the accuracy of identification. For example, a strong expectation that stimuli of a specific kind will appear, may result in the stimulus recognition being based on fewer features than would otherwise be the case for a stimulus with lower expectation. This characteristic of expectation in relation to perception is very important for the design of control actuators and displays. For example, control actuators that share many shape attributes may be confused because the experienced user may only use some of the attributes for identification.

A.3.3 Perceptual organization

Some principles, known as "Gestalt principles of perceptual organization", strongly determine how visual information is processed mentally. These principles may be viewed as natural and largely inherited tendencies which serve the purpose of structuring the external world into coherent perceptions (Gestalts).

a) The principle of "proximity" states that elements appearing very close together are perceived as a unit;

b) The principle of "similarity" states that similar features or objects may be perceived as a unit;

c) The principle of "good continuation" states that elements are easily organized into characteristic patterns. Elements consistent with these patterns are easily detected even in the presence of disturbances;

d) The principle of "closure" states that there is a tendency to continue to fill out a pattern so that it corresponds to a "good form", in terms of a simple and closed figure;

e) The principle of "common fate" states that if two or more features share a common fate (i.e. a movement direction, synchronous flashing etc.) they will be perceived as a unit.

The above principles may serve as guidelines in the layout of control actuators and displays and are largely those that serve as the background for various ergonomics principles of display and control actuator layout.

A.4 The cognitive system

The cognitive system involves two important and related memories: the long term memory which stores information more permanently, and the short term memory which holds temporarily activated information, which is easily accessible to the operator.

A.4.1 Short term memory

The most important characteristic of short term (or working) memory is its limited capacity, both with respect to the amount of information that can be held, and to the decay rate of the information held.

The decay rate of short term memory is determined by numerous factors such as the use of various cognitive strategies, the senses involved (visual, acoustic or tactile), the number and character of the activated information units etc. However, in practice the following characteristics are the most essential:

a) The more units held in short term memory the faster the decay;

b) The capacity of short term memory is restricted to a few information units (i.e. letters, words, numbers, etc.). The exact figure for the capacity is difficult to estimate. A tentative suggestion is that about 5 to 9 information units are the upper limit of the amount of information easily held in short term memory;

c) The more similar the information units are, the more errors can be expected.

The designer of a human-machine system, should consider the limits of the short term memory. The following suggestions should be observed:

a) Do not present more information than is needed;

b) Make sure the information is sufficiently discrete to minimize the risk of errors;

c) Remember that it is difficult to make decisions when the operator is required to hold too many units of information in short term memory.

A.4.2 Long term memory

For both theoretical and practical reasons, it is fruitful to distinguish between two related long term memory structures. First, the declarative memory contains information about factual knowledge, for example, the identity of a machine part, the meaning of a symbol, safety rules etc. Declarative memory also contains memory of specific experiences of a person. The other main type of memory is known as the procedural memory, or the memory which stores skills of various kinds.

A.4.2.1 Declarative memory

The specific features of declarative memory which can be assumed to be especially important for the designer of human-machine systems are the following:

Retrieval from declarative memory occurs either as (a) recognition or as (b) free recall. The human has been found to have a rather good capacity for recognition while free recall is comparatively less efficient. An implication of this characteristic of memory is that the designer should, as far as possible, present information so that it can be recognized instead of trusting the operators' free recall of information. For example, when presenting information on VDTs, it is sometimes better to have a menu system where the individual features can be recognized, instead of relying upon the operators' free recall of certain commands.

It should also be mentioned that recall from memory is strongly dependent on the context. If some specific features have been learned in a certain context it is easier to remember those features when the original context is present. This may have implications, for example, in the design of manuals and instructions, which to be efficient, should include sufficient information (pictures, diagrams etc.) similar or identical to the real operating situation.

A.4.2.2 Procedural memory

A very important aspect of procedural memory is that well practised skills tend to function almost automatically with a minimum of deliberate control and attention. However, the fact that a minimum amount of control and attention has to be invested in a well-practised task, makes these tasks especially vulnerable to errors. For example, an operator who performs a well learned sequence of acts may suffer errors because some circumstances may deviate from the normal pattern or circumstances, and there might be little attention invested in the task to recognize those circumstances. For example, a driver who is used to a certain route may forget a new intention to deviate from the route at a certain location.

A.4.2.3 Expectations

As indicated above the expectations of the individual are important in order to understand recall from memory. In general, people assume certain default values associated with various types of information. These default values help in structuring information and create a preparation for action. However, default values may also, in certain situations, lead to the person assuming knowledge which was not in the original situation. It is thus wise always to analyze what kind of default values the operator may hold in relation to machine systems. Default values are, as previously stated in this standard, also of much more general importance than in the context of retrieving information from memory. In particular, the conventions associated with control actuators and display movement are of crucial importance.

A.4.2.4 Learning skills

When a person is acquiring a new skill, this process normally proceeds from demanding attention, towards automation. In general, it takes a relatively long time to learn a skill so that it can be performed at the automatic level. In contrast, certain declarative "facts" about how the task shall be performed, can, "in principle," take a short time to learn. However, these declarative facts, even if they are well-known at the declarative level, may not be efficiently performed at the skill level. Knowledge may not be accessed efficiently if the skill is not well practised.

A.4.2.5 Problem solving

Problem solving can be defined as behaviour directed towards achieving one or several goals. In order to analyze problem solving situations it is practical to distinguish between (a) the initial state i.e. the conditions, rules and restrictions given in the beginning of the problem solving process, (b) the intermediate states i.e. the states that the problem solver passes on the way towards the goal, and (c) the characteristics of the goal states. The initial state may be crucial for problem solving performance. With respect to problem solving in the context of human-machine systems, it is important that the operator is given sufficient knowledge in order to solve problems. For instance, the optimal design of a system seen from the point of normal operation may be very different from the optimal design seen from the point of an emergency situation, a start up or a shut down. The lesson to learn for the designer is to consider the system not only from the point of normal operation mode but also from other system modes. For example, in order to optimize the information of the initial state in an accident scenario the designer may consider separate control panels for such possible events.

During the intermediate states of problem solving different actions may be tested and their results evaluated. From a human-machine perspective, an important factor during this stage is feed-back, which should be fast and accurate. Slow feed-back from the system may result in the operator taking actions that later prove to be inefficient.

Under stress problem solving tends to degrade so that the operator may function on a more "primitive" level. Several kinds of "mental trap" may be observed in problem solving, such as:

a) The operator restricts attention to details and misses relevant information;

b) The operator fixes on an idea and fails to test alternative ideas;

c) The operator blindly follows an instruction in spite of the circumstances no longer being relevant to that specific instruction;

d) The operator hesitates to act without waiting for relevant feed-back from the system.

The following strategies can be used to minimise this type of problem:

a) emphasise relevant information corresponding to the current system status;

b) provide support for the operator in devising alternative problem solving strategies;

c) provide support for the operator to build up comprehensive knowledge of the system;

d) provide feedback to the operator in the form of further instructions where possible.

A.5 Reaction times of the motor system

Reaction time is used as a measure for the time taken from the instant a sense is stimulated until a reaction of the motor system occurs. A simple reflex arc, takes about 0,04 s, while the fastest reaction time which involves the brain is about 0,15 s. The normal range of reaction times for expected signals is between 0,2 to 0,3 s. When the signal is unexpected the reaction time increases to over 0,5 s.

A.6 Performance shaping factors

Human-machine systems impose demands on the operator in terms of stress, fatigue, boredom and other states of the operator. Performance and the probability for errors may be a function of such states of the operator. Consequently, the designer must consider some of the external circumstances in which the system shall be operated and consider if these circumstances are likely to affect the performance of the operator.

A.6.1 Increased stress

Examples of factors that may increase the operator's stress level are (a) high performance demands, (b) time induced stress (c) severe negative consequences of failure (d) environmental factors such as noise and heat.

The performance effects associated with increased stress levels in general:

a) Narrow the operator's attention during multiple component tasks; less attention is available for the non-dominant tasks under stress;

b) Reduced working memory capacity;

c) Decreased accuracy in tasks which demand rapid decision making.

A.6.2 States of reduced activation

Tasks which may reduce the operator's level of activity are, for example: (a) simple and monotonous tasks, (b) tasks that demand continuous attention, (c) tasks which provide little or no feedback, and (d) tasks that stretch over a long period of time.

Such states as described above may cause performance effects in terms of slower reaction times and missed information.

A.7 Suitability of humans and machines for different tasks

The allocation of functions and tasks to operators and machines is essential for the efficient and safe design of a human-machine system. Table A.1 presents the basic advantages and disadvantages of the human operator.

The capabilities of machines are changing due to the development of technology. Furthermore the attributes of machines are different depending on the type of the machine (computer, power tool etc.). The user of the table is expected to adapt the column "machine" of the table to the specific application.

Table A.1 — Suitability of humans and machines for different tasks

Performance attributes	Capability	
	Human	**Machine**
General		
Flexibility	Well suited for a great range of tasks	Specialized, less flexibility
Adaptation to changing task requirements	In general, good adaptation to unexpected demands, may work for a restricted time under transient overload	Poor adaptability to new situations. Will fail in situations it is not designed for.
Learning and Training	Easily trained, learning is normal behaviour	Restricted learning capabilities
Unstructured tasks, with uncertainty	Well suited	Poorly suited
Predictability of system behaviour	Human behaviour not strictly determined and predictable	Follows rules strictly, well determined behaviour, in general predictable
Input		
Perception and recognition performance	Limited number of senses with high sensitivity available, high speed and accuracy in combining inputs and recognizing patterns, perception may be influenced by expectations	Sensing system can be designed according to requirements, high performance requires high expense
Monitoring	Poorly suited for prolonged routine monitoring due to vigilance limitation	Well suited for routine monitoring
Incomplete information input and disturbances	Can handle noisy and incomplete information input	Poorly suited for handling noisy and incomplete information input
Processing of information		
Channel and processing capacity	Limited number of sensor and effector channels, restricted parallel processing capability	Channel and processing capacity can be designed according to requirements
Strategic and tactical planning, organization, decision making	Well suited, errors may occur due to incorrect internal models of reality and in stress situations	Poorly suited

Table A.1 — Suitability of humans and machines for different tasks (*concluded*)

Performance attributes	Capability	
	Human	Machine
Induction and generalization	Can make inductive decisions in novel situations, can generalize	Little or poor capability for induction and generalization
Memory	Poor short term memory, good long term memory, no overflow, selective storing behaviour, information loss may occur, information in memory may change	Good short term and long term memory, in general no information loss, no change of information
Performance consistency	Performance varies as a function of stress, fatigue, boredom etc.	Good performance consistency achievable
Repetitive and monotonous tasks	Not suited due to vigilance limitation and impairment by monotonous and repetitive stress and strain	Well suited
Output		
Physical capacity	Biologically restricted physical capacity	Physical capacity can be designed according to requirements
Speed	Biologically restricted speed, few output channels	In general high speed possible
Accuracy	High motor skill but limited accuracy achievable	Accuracy can be designed according to requirements, high expense for high accuracy
Environment		
Environmental conditions	Works well in a range of normal conditions but requires high expense for protective measures under extreme conditions	Can be designed for operation under specific environmental conditions
Maintenance and supply	Low supply expense under normal environmental conditions, but facilities for human needs required, no technical maintenance required, self-recovering	Energy and material supply, maintenance required

ICS 13.180

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