INDUSTRIAL PSYCHOLGY

UNIT-IV

ENGINEERING PSYCHOLOGY

History of Engineering Psychology

At end of the nineteenth century that the first systematic investigations were conducted on man's capacity to work as it is influenced by his job and his tools.

Frederick W. Taylor (1898) made empirical studies of the best design of shovels and of the optimum weight of material per shovelful for handling different products, such as sand, slag, rice coal, and iron ore. He focused primarily in **rates of doing work** and in the **effects of incentives and worker motivation on rates of working**.

Frank B. Gilbreth to set a firm foundation for this field with his **classic study of bricklaying (1909).** Gilbreth invented scaffolding which could be quickly adjusted so that the bricklayer could work at the most convenient level at all times. Gilbreth was able to increase the number of bricks laid from 120 to 350 per man per hour.

This innovative work of **Taylor and Gilbreth** was the beginning of that branch of industrial engineering now known as **time and motion study**.

The primary emphasis in time and motion engineering has been on **man as a worke**r, as a source of mechanical power.

During the **two world wars** there appeared a new class of machines —machines that made demands upon the operator not in terms of his muscular power but rather in terms of his sensory, perceptual, judgmental, and decision-making abilities.

For illustration, the job of a SONAR Operator requires virtually no muscular energy, but it makes severe demands on his sensory capacity, his attentiveness, and his decision-making ability.

During World War I a group of psychologists under **Robert M. Yerkes** was organized as the Psychology Committee of the National Research Council. Largely the psychologists in World War I were concerned about the selection, classification, and training of recruits, and with morale, military discipline, recreation, and problems of emotional stability in soldiers and sailors.

During World War II Psychologist were more concern about Radar, sonar, high altitude and high speed aircraft, naval combat information centers, and air traffic control centers placed demands upon their human operators that were often far beyond the capabilities of human senses, brains, and muscles.

Operators sometimes had to look for targets which were all but invisible, recognize speech against backgrounds of deafening noise, track targets simultaneously in the three dimensions of space with both hands, and absorb large amounts of information to reach life-and-death decisions within seconds.

Scope of Engineering Psychology

Engineering Psychology is also called **as Ergonomics (UK and Europe**), Human factor Psychology or **Human factor engineering (in USA)** or psycho technology or applied exp**erimental psychology,**

The discipline study how people interact with machines and technology.

They use psychological science to guide the design of products, systems and devices we use daily.

They often focus on performance and safety.

Human factors and engineering psychologists strive to make Man & Machine interactions easier, more comfortable, less frustrating and, safer.

Engineering psychology is a branch of applied psychology. Engineering psychology specifically concerned with the innovation and application of information about human behavior to the machines, tools, and jobs so that their design may best match the capabilities and boundaries of their human users.

Engineering psychology is a part of industrial psychology. It includes additional topics as personnel procurement, selection, training, classification, and promotion; labor relations; morale and human relations; organizational management; and consumer behavior.

The field of **human factors engineering** includes portions of human sciences as anatomy, anthropometry, applied physiology, environmental medicine, and toxicology.

These distinctions between engineering psychology, industrial psychology, and human factors engineering are more academic than real. In his practical work, the engineering psychologist needs to know enough about all of these disciplines so that he can make use of them in arriving at sensible and informed design decisions.

TIME AND MOTION STUDY

A **time and motion study** (or **time-motion study**) is a business efficiency technique combining the Time Study work of Frederick Winslow Taylor with the Motion Study work of Frank and Lillian Gilbreth (the same couple as is best known through the biographical 1950 film and book *Cheaper by the Dozen*). It is a major part of scientific management (Taylorism). After its first introduction, time study developed in the direction of establishing standard times, while motion study evolved into a technique for improving work methods. The two techniques became integrated and refined into a widely accepted method applicable to the improvement and upgrading of work systems. This integrated approach to work system improvement is known as methods engineering and it is applied today to industrial as well as service organizations, including banks, schools and hospitals.

Time studies

Time study is a direct and continuous observation of a task, using a timekeeping device (e.g., decimal minute stopwatch, computer-assisted electronic stopwatch, and videotape camera) to record the time taken to accomplish a task and it is often used when:

- there are repetitive work cycles of short to long duration,
- wide variety of dissimilar work is performed, or
- Process control elements constitute a part of the cycle.

The Industrial Engineering Terminology Standard defines time study as "a work measurement technique consisting of careful time measurement of the task with a time measuring instrument, adjusted for any observed variance from normal effort or pace and to allow adequate time for such items as foreign elements, unavoidable or machine delays, rest to overcome fatigue, and personal needs.

The systems of **time and motion studies** are frequently assumed to be interchangeable terms, descriptive of equivalent theories. However, the underlying principles and the rationale for the establishment of each respective method are dissimilar, despite originating within the same school of thought.

The application of science to business problems, and the use of **time-study methods** in standard setting and the planning of work, was pioneered by Frederick Winslow Taylor. Taylor liaised with factory managers and from the success of these discussions wrote several papers proposing the use of wage-contingent performance standards based on scientific time study. At its most basic level time studies involved breaking down each job into component parts, timing each part and rearranging the parts into the most efficient method of working. By counting and calculating, Taylor wanted to transform management, which was essentially an oral tradition, into a set of calculated and written techniques·

Taylor and his colleagues placed emphasis on the content of a **fair day's work**, and sought to maximize productivity irrespective of the physiological cost to the worker. For example, Taylor thought unproductive time usage (soldiering) to be the deliberate attempt of workers to promote their best interests and to keep employers ignorant of how fast work could be carried out. This instrumental view of human behavior by Taylor prepared the path for human relations to supersede scientific management in terms of literary success and managerial application.

Direct time study procedure

Following is the procedure developed by Mikell Groover for a direct time study:

1. Define and document the standard method.
2. Divide the task into work elements.

   These first two steps are conducted prior to the actual timing. They familiarize the analyst with the task and allow the analyst to attempt to improve the work procedure before defining the standard time.

3. Time the work elements to obtain the observed time for the task.

4. Evaluate the worker's pace relative to standard performance (performance rating), to determine the normal time.

   Note that steps 3 and 4 are accomplished simultaneously. During these steps, several different work cycles are timed, and each cycle performance is rated independently. Finally, the values collected at these steps are averaged to get the normalized time.

5. Apply an allowance to the normal time to compute the standard time. The allowance factors that are needed in the work are then added to compute the standard time for the task.

Conducting time studies

According to good practice guidelines for production studies a comprehensive time study consists of:

1. Study goal setting;
2. Experimental design;
3. Time data collection;
4. Data analysis;
5. Reporting.

Easy analysis of working areas

The collection of time data can be done in several ways, depending on study goal and environmental conditions. Time and motion data can be captured with a common stopwatch, a handheld computer or a video recorder. There is a number of dedicated software packages used to turn a palmtop or a handheld PC into a time study device. As an alternative, time and motion data can be collected automatically from the memory of computer-control machines (i.e. automated time studies).

Criticisms

In response to Taylor's time studies and view of human nature, many strong criticisms and reactions were recorded. Unions, for example, regarded time study as a disguised tool of management designed to standardize and intensify the pace of production. Similarly, individuals such as Gilbreth (1909), Cadbury and Marshall heavily criticized Taylor and pervaded his work with subjectivity. For example, Cadbury in reply to Thompson stated that under scientific management employee skills and initiatives are passed from the individual to management, a view reiterated by Nyland. In addition, Taylor's critics condemned the lack of scientific substance in his time studies, in the sense that they relied heavily on individual interpretations of what workers actually do. However, the value in rationalizing production is indisputable and supported by academics such as Gantt, Ford and Munsterberg, and Taylor society members Mr C.G. Renold, Mr W.H. Jackson and Mr C.B. Thompson. Proper time studies are based on repeated observation, so that motions performed on the same part differently by one or many workers can be recorded, to determine those values that are truly repetitive and measurable.

Motion studies

In contrast to, and motivated by, Taylor's time study methods, the Gilbreths proposed a technical language, allowing for the analysis of the labor process in a scientific context. The Gilbreths made use of scientific insights to develop a study method based upon the analysis of "work motions", consisting in part of filming the details of a worker's activities and their body posture while recording the time. The films served two main purposes. One was the visual record of how work had been done, emphasizing areas for improvement. Secondly, the films also served the purpose of training workers about the best way to perform their work. This method allowed the Gilbreths to build on the best elements of these work flows and to create a standardized best practice.

Although for Taylor, motion studies remained subordinate to time studies, the attention he paid to the motion study technique demonstrated the seriousness with which he considered the Gilbreths’ method. The split with Taylor in 1914, on the basis of attitudes to workers, meant the Gilbreths had to argue contrary to the trade unionists, government commissions and Robert Hoxie who believed scientific management was unstoppable. The Gilbreths were charged with the task of proving that motion study particularly, and scientific management generally, increased industrial output in ways which improved and did not detract from workers' mental and physical strength. This was no simple task given the propaganda fuelling the Hoxie report and the consequent union opposition to scientific management. In addition, the Gilbreths credibility and academic success continued to be hampered by Taylor who held the view that motion studies were nothing more than a continuation of his work.

While both Taylor and the Gilbreths continue to be criticized for their respective work, it should be remembered that they were writing at a time of industrial reorganization and the emergence of large, complex organizations with new forms of technology. Furthermore, to equate scientific management merely with time and motion study and consequently labor control not only misconceives the scope of scientific management, but also misinterprets Taylor's incentives for proposing a different style of managerial thought.

Health care time and motion study

A **Health care time and motion study** is used to research and track the efficiency and quality of health care workers. In the case of nurses, numerous programs have been initiated to increase the percent of a shift nurses spend providing direct care to patients. Prior to interventions nurses were found to spend ~20% of their time doing direct care. After focused intervention, some hospitals doubled that number, with some even exceeding 70% of shift time with patients, resulting in reduced errors, codes, and falls.

Methods

- External observer: Someone visually follows the person being observed, either contemporaneously or via video recording. This method presents additional expense as it usually requires a 1 to 1 ratio of research time to subject time. An advantage is the data can be more consistent, complete, and accurate than with self-reporting.
- Self-reporting: Self-reported studies require the target to record time and activity data. This can be done contemporaneously by having subjects stop and start a timer when completing a task, through work sampling where the subject records what they are doing at determined or random intervals, or by having the subject journal activities at the end of the day. Self-

reporting introduces errors that may not be present through other methods, including errors in temporal perception and memory, as well as the motivation to manipulate the data.

- Automation: Motion can be tracked with GPS. Documentation activities can be tracked through monitoring software embedded in the applications used to create documentation. Badge scans can also create a log of activity.

MAN-MACHINE SYSTEM

Asystem consisting of a human operator or group of operators and a machine, by means of which the operator performs a task involving, for example, the production of material goods, the management of some type of operation, or the processing of information. Human labor in a manmachine system is based on interaction according to received information with both the object of labor or control and the machine through the mediation of control elements.

Interest in man-machine systems arose in the mid-20th century, when systems of various kinds became with increasing frequency the objects of technical planning and design. The effectiveness of these systems, which included those for the control of production, transportation, communications, and space flights, was largely determined by the activity of the human operators. The combination of human abilities and capabilities of a machine or complex of technological devices significantly increases the effectiveness of control. Although there is a joint performance of control functions by the human operator and machine, each of the two components of the system is governed in its work by its own unique rules. The effectiveness of the system as a whole is determined by the extent to which characteristic features of the operator and machine, both limitations and potentials, are identified and taken into account when building the system. These features are most fully identified in the process of coordinating the external, that is, technological, means of action and the internal means of action, that is, means inherent to the operator. Coordination includes the construction of information and conceptual models.

The information model is a representation, organized according to a definite system of rules, of the states of the object of labor or control, the man-machine system itself, the environment, and the procedures for acting upon these states. Physically speaking, information models are built using data display equipment. With an information model at hand, the operator uses his own knowledge and experience to formulate a conceptual model—the aggregate of his own ideas about the goals and objectives of the labor activity and about the states of the object of labor, the man-machine system itself, the environment, and the procedures for acting upon the states.

One of the key problems in constructing man-machine systems is the optimal distribution of functions between the operator and technological devices, that is, determining which operations must be performed by the operator and which by the machine to ensure the required effectiveness. There are two basic variations in the distribution of functions. In the first, the operator merely monitors the machine performing the task and confirms the result; in the second, the operator and machine must perform certain motions jointly. Here, a result cannot be obtained without joint operation. The first variation is a type of parallel organization of interaction between the operator and machine, while the second reflects a sequential, or stepwise, organization. In choosing one variation or the other, consideration must be given to methodological factors relating to the social function of man as the doer of labor and to the practical recommendations of management science, including recommendations on the organization of control at the higher levels of the system. Assessments from engineering psychology and results from studies on the psychophysiological functions of man should have an important place in these considerations. According to current ideas, an efficient, and even an optimal, distribution of functions should be based on quantitative evaluations of the quality of task performance by the operator and by the machine and on evaluations of the effect of this quality on the overall effectiveness of the system.

No uniform classification of man machine systems has yet been made. Human functions in such systems that reflect a fundamental change in the technological method of linking man and machine may serve as the distinguishing criterion. “Labor,” wrote Marx in describing automated production “is now not so much part of the process of production as it is a role whereby man assumes the attitude of controller and regulator in relation to the process of production. Instead of being the main agent of the production process, the worker assumes a place alongside the process” (K. Marx and F. Engels, *Soch*, 2nd ed., vol. 46, part 2, p. 213).

There are five basic classes of man-Machine systems. In the first, the human operator is included in the technological process, to which he must constantly attend. He is guided in his work by instructions, which cover virtually all possible situations and solutions. Operators at transfer lines and operators who receive and transfer information are part of this type of manmachine system. In systems of the second class, operators monitor and control a process. Operators in radar systems and traffic controllers in transportation systems are part of these systems. The third class of man-machine systems requires the operator to issue commands to robots, manipulators, and machines that amplify human muscular energy. In systems of the fourth class, the operator acts as an investigator. Decipher clerks and computer operators are examples of operators in this class. In systems of the fifth class, the operator is called upon to make management decisions. Organizers, planners, and executives work with systems in this class. In the second, fourth, and fifth classes of systems, the operator can set up a dialogue with the machine. Here, the operator and machine alternate in performance of the task.

Study of man-Machine systems can and must be carried out as an investigation of the functional whole. Treating the human being as a special component in a technical system makes it possible to increase the effectiveness of the system. This approach, however, is not without limitations; by treating man as a “black box,” both the social nature of labor and the role of man as the doer of labor are overlooked. The relation between man and machine is above all a relation between the doer of labor and the implement of labor.

- The basic difficulty in studying manmachine systems lies in the need to combine research from such different branches of science as physiology, engineering, psychology, human-factors engineering, and cybernetics, each of which has its own methodology and terminology.

Human–machine choreography

The area of human–machine choreography is yet to be extensively explored. How body-structure can be extended through machine mechanisms points to how the body can perform beyond its biological form and functions as well as beyond the local space it inhabits. How human movement is transduced into machine motion and then can be both expressed and extended into virtual performance on the web promises new possibilities in both conceptual approach and aesthetic application. For example, incorporating virtual camera views of the performing human–machine system enriches the choreography and intensifies the artistic result.

The Muscle Machine

The Muscle Machine is a hybrid human–robot walking machine. Designed by artist James Stelarc (who has also created other such systems), it is an exoskeleton with six robotic legs that are controlled by the leg and hand movements of its pilot.

Mechanism

The rubber muscles contract when inflated and extend when exhausted. This results in a more reliable and robust engineering design. The body stands on the ground within the chassis of the machine, which incorporates a lower body exoskeleton connecting it to the robot. Encoders on the hip joints provide the data that will allow the human controller to move and direct the machine as well as vary the speed at which it will travel. The action of the human operator lifting a leg lifts the three alternate machine legs and swings them forward. By turning its torso, the body makes the machine walk in the direction it is facing. Thus the interface and interaction is more direct, allowing intuitive human-machine choreography. The walking system, with attached accelerometer sensors generates data that is converted to sounds that augment the acoustical pneumatics and machine mechanism operation. Once the machine is in motion, it is no longer applicable to ask whether the human or machine is in control as they become fully integrated and move as one. The six-legged robot both extends the body and transforms its bipedal gait into a 6-legged insect-like movement. The appearance and movement of the machine legs are both limb-like and wing-like motion.

WORKPLACE DESIGN :-

Workplace design refers to the process of **designing** and organizing a **workplace** to optimize worker performance and safety. It is an important health and safety issue for workers in both high-risk environments (such as construction sites) and low-risk workplaces (such as offices).

Human factors psychology (or ergonomics, a term that is favored in Europe) is the third subject area within industrial and organizational psychology. This field is concerned with the integration of the human-machine interface in the workplace, through design, and specifically with researching and designing machines that fit human requirements. The integration may be physical or cognitive, or a combination of both. Anyone who needs to be convinced that the field is necessary need only try to operate an unfamiliar television remote control or use a new piece of software for the first time. Whereas the two other areas of I-O psychology focus on the interface between the worker and team, group, or organization, human factors psychology focuses on the individual worker’s interaction with a machine, work station, information displays, and the local environment, such as lighting. In the United States, human factors psychology has origins in both psychology and engineering; this is reflected in the early contributions of Lillian Gilbreth (psychologist and engineer) and her husband Frank Gilbreth (engineer).

Human factor professionals are involved in design from the beginning of a project, as is more common in software design projects, or toward the end in testing and evaluation, as is more common in traditional industries (Howell, 2003). Another important role of human factor professionals is in the development of regulations and principles of best design. These regulations and principles are often related to work safety. For example, the Three Mile Island nuclear accident lead to Nuclear Regulatory Commission (NRC) requirements for additional instrumentation in nuclear facilities to provide operators with more critical information and increased operator training (United States Nuclear Regulatory Commission, 2013). The American National Standards Institute (ANSI, 2000), an independent developer of industrial standards, develops many standards related to ergonomic design, such as the design of control-center workstations that are used for transportation control or industrial process control.

Many of the concerns of human factors psychology are related to workplace safety. These concerns can be studied to help prevent work-related injuries of individual workers or those around them. Safety protocols may also be related to activities, such as commercial driving or flying, medical procedures, and law enforcement, that have the potential to impact the public.

One of the methods used to reduce accidents in the workplace is a checklist. The airline industry is one industry that uses checklists. Pilots are required to go through a detailed checklist of the different parts of the aircraft before takeoff to ensure that all essential equipment is working correctly. Astronauts also go through checklists before takeoff. The surgical safety checklist shown in developed by the World Health Organization (WHO) and serves as the basis for many checklists at medical facilities.

As an example of research in human factors psychology Bruno & Abrahão (2012) examined the impact of the volume of operator decisions on the accuracy of decisions made within an information security center at a banking institution in Brazil. The study examined a total of about 45,000 decisions made by 35 operators and 4 managers over a period of 60 days. Their study found that as the number of decisions made per day by the operators climbed, that is, as their cognitive effort increased, the operators made more mistakes in falsely identifying incidents as real security breaches (when, in reality, they were not). Interestingly, the opposite mistake of identifying real intrusions as false alarms did not increase with increased cognitive demand. This appears to be good news for the bank, since false alarms are not as costly as incorrectly rejecting a genuine threat. These kinds of studies combine research on attention, perception, teamwork, and human–computer interactions in a field of considerable societal and business significance. This is exactly the context of the events that led to the massive data breach for Target in the fall of 2013. Indications are that security personnel received signals of a security breach but did not interpret them correctly, thus allowing the breach to continue for two weeks until an outside agency, the FBI, informed the company (Riley, Elgin, Lawrence, & Matlack, 2014).

In what follows, three of the most important concerns of ergonomic design will be examined: first, that of *controls*, devices to transfer energy or signals from the operator to a piece of machinery; second, *indicators* or displays, which provide visual information to the operator about the status of the machinery; and third, the combination of controls and displays in a panel or console.

Designing for the Sitting Operator

Sitting is a more stable and less energy-consuming posture than standing, but it restricts the working space, particularly of the feet, more than standing. However, it is much easier to operate foot controls when sitting, as compared to standing, because little body weight must be transferred by the feet to the ground. Furthermore, if the direction of the force exerted by the foot is partly or largely forward, provision of a seat with a backrest allows the exertion of rather large forces. (A typical example of this arrangement is the location of pedals in an automobile, which are located in front of the driver, more or less below seat height.) Figure 1 shows schematically the locations in which pedals may be located for a seated operator. Note that the specific dimensions of that space depend on the anthropometry of the actual operators.

The space for displays and for controls that must be looked at is bounded by the periphery of a partial sphere in front of the eyes and centred at the eyes. Thus, the reference height for such displays and controls depends on the eye height of the seated operator and on his or her trunk and neck postures. The preferred location for visual targets closer than about one metre is distinctly below the height of the eye, and depends on the closeness of the target and on the posture of the head. The closer the target, the lower it should be located, and it should be in or near the medial (mid-sagittal) plane of the operator.

It is convenient to describe the posture of the head by using the “ear-eye line” (Kroemer 1994a) which, in the side view, runs through the right ear hole and the juncture of the lids of the right eye, while the head is not tilted to either side (the pupils are at the same horizontal level in the frontal view). One usually calls the head position “erect” or “upright” when the pitch angle *P* between the ear-eye line and the horizon is about 15°, with the eyes above the height of the ear. The preferred location for visual targets is 25°–65° below the ear-eye line , with the lower values preferred by most people for close targets that must be kept in focus. Even though there are large variations in the preferred angles of the line of sight, most subjects, particularly as they become older, prefer to focus on close targets with large *LOSEE* angles.

Designing for the Standing Operator

Pedal operation by a standing operator should be seldom required, because otherwise the person must spend too much time standing on one foot while the other foot operates the control. Obviously, simultaneous operation of two pedals by a standing operator is practically impossible. While the operator is standing still, the room for the location of foot controls is limited to a small area below the trunk and slightly in front of it. Walking about would provide more room to place pedals, but that is highly impractical in most cases because of the walking distances involved.

The location for hand-operated controls of a standing operator includes about the same area as for a seated operator, roughly a half sphere in front of the body, with its centre near the shoulders of the operator. For repeated control operations, the preferred part of that half sphere would be its lower section. The area for the location of displays is also similar to the one suited to a seated operator, again roughly a half sphere centered near the operator’s eyes, with the preferred locations in the lower section of that half sphere. The exact location for displays, and also for controls that must be seen, depends on the posture of the head, as discussed above.

The height of controls is appropriately referenced to the height of the elbow of the operator while the upper arm is hanging from the shoulder. The height of displays and controls that must be looked at is referred to the eye height of the operator. Both depend on the operator’s anthropometry, which may be rather different for short and tall persons, for men and women, and for people of different ethnic origins.

CONTROLS

Foot-operated Controls

Two kinds of controls should be distinguished: one is used to transfer large energy or forces to a piece of machinery. Examples of this are the pedals on a bicycle or the brake pedal in a heavier vehicle that does not have a power-assist feature. A foot-operated control, such as an on-off switch, in which a control signal is conveyed to the machinery, usually requires only a small quantity of force or energy. While it is convenient to consider these two extremes of pedals, there are various intermediate forms, and it is the task of the designer to determine which of the following design recommendations apply best among them.

As mentioned above, repeated or continual pedal operation should be required only from a seated operator. For controls meant to transmit large energies and forces, the following rules apply:

- Locate pedals underneath the body, slightly in front, so that they can be operated with the leg in a comfortable position. The total horizontal displacement of a reciprocating pedal should normally not exceed about 0.15 m. For rotating pedals, the radius should also be about 0.15 m. The linear displacement of a switch-type pedal may be minimal and should not exceed about 0.15 m.
- Pedals should be so designed that the direction of travel and the foot force are approximately in the line extending from the hip through the ankle joint of the operator.
- Pedals that are operated by flexion and extension of the foot in the ankle joint should be so arranged that in the normal position the angle between the lower leg and the foot is approximately 90°; during operation, that angle may be increased to about 120°.
- Foot-operated controls that simply provide signals to the machinery should normally have two discrete positions, such as ON or OFF. Note, however, that tactile distinction between the two positions may be difficult with the foot.

Selection of Controls

Selection among different sorts of controls must be made according to the following needs or conditions:

- Operation by hand or foot
- Amounts of energies and forces transmitted
- Applying “continuous” inputs, such as steering an automobile
- Performing “discrete actions,” for example, (a) activating or shutting down equipment, (b) selecting one of several distinct adjustments, such as switching from one TV or radio channel to another, or (c) carrying out data entry, as with a keyboard.

The functional usefulness of controls also determines selection procedures. The main criteria are as follows:

- The control type shall be compatible with stereotypical or common expectations (for instance, using a push-button or toggle switch to turn on an electric light, not a rotary knob).
- Size and motion characteristics of the control shall be compatible with stereotypical experience and past practice (for instance, providing a large steering wheel for the two-handed operation of an automobile, not a lever).
- The direction of operation of a control shall be compatible with stereotypical or common expectations (for instance, an ON control is pushed or pulled, not turned to the left).
- Hand operation is used for controls that require small force and fine adjustment, while foot operation is suitable for gross adjustments and large forces (however, consider the common use of pedals, particularly accelerator pedals, in automobiles, which does not comply with this principle).
- The control shall be “safe” in that it cannot be operated inadvertently nor in ways that are excessive or inconsistent with its intended purpose.

“detent” controls, characterized by discrete detents or stops in which the control comes to rest. It also depicts typical “continuous” controls where the control operation may take place anywhere within the adjustment range, without the need to be set in any given position.

The sizing of controls is largely a matter of past experiences with various control types, often guided by the desire to minimize the needed space in a control panel, and either to allow simultaneous operations of adjacent controls or to avoid inadvertent concurrent activation. Furthermore, the choice of design characteristics will be influenced by such considerations as whether the controls are to be located outdoors or in sheltered environments, in stationary equipment or moving vehicles, or may involve the use of bare hands or of gloves and mittens. For these conditions, consult readings at the end of the chapter.

Several operational rules govern the arrangement and grouping of controls. These are listed in table 3. For more details, check the references listed at the end of this section and Kroemer, Kroemer and Kroemer-Elbert (1994).

Preventing Accidental Operation

The following are the most important means to guard against inadvertent activation of controls, some of which may be combined:

- Locate and orient the control so that the operator is unlikely to strike it or move it accidentally in the normal sequence of control operations.
- Recess, shield or surround the control by physical barriers.
- Cover the control or guard it by providing a pin, a lock or other means that must be removed or broken before the control can be operated.
- Provide extra resistance (by viscous or coulomb friction, by spring-loading or by inertia) so that an unusual effort is required for actuation.
- Provide a "delaying" means so that the control must pass through a critical position with an unusual movement (such as in the gear shift mechanism of an automobile).
- Provide interlocking between controls so that prior operation of a related control is required before the critical control can be activated.

Note that these designs usually slow the operation of controls, which may be detrimental in case of an emergency.

Data Entry Devices

Nearly all controls can be used to enter data on a computer or other data storage device. However, we are most used to the practice of using a keyboard with push-buttons. On the original typewriter keyboard, which has become the standard even for computer keyboards, the keys were arranged in a basically alphabetic sequence, which has been modified for various, often obscure, reasons. In some cases, letters which frequently follow each other in common text were spaced apart so that the original mechanical type bars might not entangle if struck in rapid sequence. "Columns" of keys run in roughly straight lines, as do the "rows" of keys. However, the fingertips are not aligned in such manners, and do not move in this way when digits of the hand are flexed or extended, or moved sideways.

Many attempts have been made over the last hundred years to improve keying performance by changing the keyboard layout. These include relocating keys within the standard layout, or changing the keyboard layout altogether. The keyboard has been divided into separate sections, and sets of keys (such as numerical pads) have been added. Arrangements of adjacent keys may be changed by altering spacing, offset from each other or from reference lines. The keyboard may be divided into sections for the left and right hand, and those sections may be laterally tilted and sloped and slanted.

The dynamics of the operation of push-button keys are important for the user, but are difficult to measure in operation. Thus, the force-displacement characteristics of keys are commonly described for static testing, which is not indicative of actual operation. By current practise, keys on computer keyboards have fairly little displacement (about 2 mm) and display a “snap-back” resistance, that is, a decrease in operation force at the point when actuation of the key has been achieved. Instead of separate single keys, some keyboards consist of a membrane with switches underneath which, when pressed in the correct location, generate the desired input with little or no displacement felt. The major advantage of the membrane is that dust or fluids cannot penetrate it; however, many users dislike it.

There are alternatives to the “one key-one character” principle; instead, one can generate inputs by various combinatory means. One is “chording”, meaning that two or more controls are operated simultaneously to generate one character. This poses demands on the memory capabilities of the operator, but requires the use of only very few keys. Other developments utilize controls other than the binary tapped push button, replacing it by levers, toggles or special sensors (such as an instrumented glove) which respond to movements of the digits of the hand.

By tradition, typing and computer entry have been made by mechanical interaction between the operator’s fingers and such devices as keyboard, mouse, track ball or light pen. Yet there are many other means to generate inputs. Voice recognition appears one promising technique, but other methods can be employed. They might utilize, for example, pointing, gestures, facial expressions, body movements, looking (directing one’s gaze), movements of the tongue, breathing or sign language to transmit information and to generate inputs to a computer. Technical development in this area is very much in flux, and as the many nontraditional input devices used for computer games indicate, acceptance of devices other than the traditional binary tap-down keyboard is entirely feasible within the near future. Discussions of current keyboard devices have been provided, for example, by Kroemer (1994b) and McIntosh (1994).

DISPLAYS

Displays provide information about the status of equipment. Displays may apply to the operator’s visual sense (lights, scales, counters, cathode-ray tubes, flat panel electronics, etc.), to the auditory sense (bells, horns, recorded voice messages, electronically generated sounds, etc.) or to the sense of touch (shaped controls, Braille, etc.). Labels, written instructions, warnings or symbols (“icons”) may be considered special kinds of displays.

The four “cardinal rules” for displays are:

1. Display only that information which is essential for adequate job performance.
2. Display information only as accurately as is required for the operator’s decisions and actions.
3. Present information in the most direct, simple, understandable and usable form.
4. Present information in such a way that failure or malfunction of the display itself will be immediately obvious.

The selection of either an auditory or visual display depends on the prevailing conditions and purposes. The objective of the display may be to provide:

- historical information about the past state of the system, such as the course run by a ship
- status information about the current state of the system, such as the text already input into a word processor or the current position of an airplane
- predictive information, such as on the future position of a ship, given certain steering settings
- instructions or commands telling the operator what to do, and possibly how to do it.

A visual display is most appropriate if the environment is noisy, the operator stays in place, the message is long and complex, and especially if it deals with the spatial location of an object. An auditory display is appropriate if the workplace must be kept dark, the operator moves around, and the message is short and simple, requires immediate attention, and deals with events and time.

Visual Displays

There are three basic types of visual displays: (1)The *check* display indicates whether or not a given condition exists (for example a green light indicates normal function). (2)The *qualitative* display indicates the status of a changing variable or its approximate value, or its trend of change (for example, a pointer moves within a “normal” range). (3) The *quantitative* display shows exact information that must be ascertained (for example, to find a location on a map, to read text or to draw on a computer monitor), or it may indicate an exact numerical value that must be read by the operator (for example, a time or a temperature).

Design guidelines for visual displays are:

- Arrange displays so that the operator can locate and identify them easily without unnecessary searching. (This usually means that the displays should be in or near the medial plane of the operator, and below or at eye height.)
- Group displays functionally or sequentially so that the operator can use them easily.
- Make sure that all displays are properly illuminated or illuminant, coded and labelled according to their function.
- Use lights, often coloured, to indicate the status of a system (such as ON or OFF) or to alert the operator that the system, or a subsystem, is inoperative and that special action must be taken. Common meanings of light colours are listed in figure 5. Flashing red indicates an emergency condition that requires immediate action. An emergency signal is most effective when it combines sounds with a flashing red light.

Figure 5. Colour coding of indicator lights

For more complex and detailed information, especially quantitative information, one of four different kinds of displays are traditionally used: (1) a moving pointer (with fixed scale), (2) a moving scale (with fixed pointer), (3) counters or (4) “pictorial” displays, especially computer-generated on a display monitor. Figure 6 lists the major characteristics of these display types.

It is usually preferable to use a moving pointer rather than a moving scale, with the scale either straight (horizontally or vertically arranged), curved or circular. Scales should be simple and uncluttered, with graduation and numbering so designed that correct readings can be taken quickly. Numerals should be located outside the scale markings so that they are not obscured by the pointer. The pointer should end with its tip directly at the marking. The scale should mark divisions only so finely as the operator must read. All major marks should be numbered. Progressions are best marked with intervals of one, five or ten units between major marks. Numbers should increase left to right, bottom to top or clockwise. For details of dimensions of scales refer to standards such as those listed by Cushman and Rosenberg 1991 or Kroemer 1994a.

Starting in the 1980s, mechanical displays with pointers and printed scales were increasingly replaced by “electronic” displays with computer-generated images, or solid-state devices using light-emitting diodes (see Snyder 1985a). The displayed information may be coded by the following means:

- shapes, such as straight or circular
- alphanumeric, that is, letters, numbers, words, abbreviations
- figures, pictures, pictorials, icons, symbols, in various levels of abstraction, such as the outline of an airplane against the horizon
- shades of black, white or gray
- colours

Unfortunately, many electronically generated displays have been fuzzy, often overly complex and colourfull, hard to read, and required exact focusing and close attention, which may distract from the main task, for example, driving a car. In these cases the first three of the four “cardinal rules” listed above were often violated. Furthermore, many electronically generated pointers, markings and alphanumerics did not comply with established ergonomic design guidelines, especially when generated by line segments, scan lines or dot matrices. Although some of these defective designs were tolerated by the users, rapid innovation and improving display techniques allows many better solutions. However, the same rapid development leads to the fact that printed statements (even if current and comprehensive when they appear) are becoming obsolete quickly. Therefore, none are given in this text. Compilations have been published by Cushman and Rosenberg (1991), Kinney and Huey (1990), and Woodson, Tillman and Tillman (1991).

The overall quality of electronic displays is often wanting. One measure used to assess the image quality is the modulation transfer function (MTF) (Snyder 1985b). It describes the resolution of the display using a special sine-wave test signal; yet, readers have many criteria regarding the preference of displays (Dillon 1992).

Monochrome displays have only one colour, usually green, yellow, amber, orange or white (achromatic). If several colours appear on the same chromatic display, they should be easily discriminated. It is best to display not more than three or four colours simultaneously (with preference being given to red, green, yellow or orange, and cyan or purple). All should strongly contrast with the background. In fact, a suitable rule is to design first by contrast, that is, in terms of black and white, and then to add colours sparingly.

In spite of the many variables that, singly and interacting with each other, affect the use of complex colour display, Cushman and Rosenberg (1991) compiled guidelines for use of colour in displays; these are listed in figure 7.

Other suggestions are as follows:

- Blue (preferably desaturated) is a good colour for backgrounds and large shapes. However, blue should not be used for text, thin lines or small shapes.
- The colour of alphanumeric characters should contrast with that of the background.
- When using colour, use shape as a redundant cue (e.g., all yellow symbols are triangles, all green symbols are circles, all red symbols are squares). Redundant coding makes the display much more acceptable for users who have colour-vision deficiencies.
- As the number of colours is increased, the sizes of the colour-coded objects should also be increased.
- Red and green should not be used for small symbols and small shapes in peripheral areas of large displays.
- Using opponent colours (red and green, yellow and blue) adjacent to one another or in an object/background relationship is sometimes beneficial and sometimes detrimental. No general guidelines can be given; a solution should be determined for each case.
- Avoid displaying several highly saturated, spectrally extreme colours at the same time.

Panels of Controls and Displays

Displays as well as controls should be arranged in panels so they are in front of the operator, that is, close to the person’s medial plane. As discussed earlier, controls should be near elbow height, and displays below or at eye height, whether the operator is sitting or standing. Infrequently operated controls, or less important displays, can be located further to the sides, or higher.

Often, information on the result of control operation is displayed on an instrument. In this case, the display should be located close to the control so that the control setting can be done without error, quickly and conveniently. The assignment is usually clearest when the control is directly below or to the right of the display. Care must be taken that the hand does not cover the display when operating the control.

Popular expectancies of control-display relations exist, but they are often learned, they may depend on the user's cultural background and experience, and these relationships are often not strong. Expected movement relationships are influenced by the type of control and display. When both are either linear or rotary, the stereotypical expectation is that they move in corresponding directions, such as both up or both clockwise. When the movements are incongruent, in general the following rules apply:

- *Clockwise for increase*. Turning the control clockwise causes an increase in the displayed value.
- *Warrick's gear-slide rule*. A display (pointer) is expected to move in the same direction as does the side of the control close to (i.e., geared with) the display.

The ratio of control and display displacement (C/D ratio or D/C gain) describes how much a control must be moved to adjust a display. If much control movement produces only a small display motion, once speaks of a high C/D ratio, and of the control as having low sensitivity. Often, two distinct movements are involved in making a setting: first a fast primary ("slewing") motion to an approximate location, then a fine adjustment to the exact setting. In some cases, one takes as the optimal C/D ratio that which minimizes the sum of these two movements. However, the most suitable ratio depends on the given circumstances; it must be determined for each application.

Labels and Warnings

Labels

Ideally, no label should be required on equipment or on a control to explain its use. Often, however, it is necessary to use labels so that one may locate, identify, read or manipulate controls, displays or other equipment items. Labelling must be done so that the information is provided accurately and rapidly. For this, the guidelines in table 4 apply.

Font (typeface) should be simple, bold and vertical, such as Futura, Helvetica, Namel, Tempo and Vega. Note that most electronically generated fonts (formed by LED, LCD or dot matrix) are generally inferior to printed fonts; thus, special attention must be paid to making these as legible as possible.

- The *height* of characters depends on the viewing distance:
  viewing distance 35 cm, suggested height 22 mm

  viewing distance 70 cm, suggested height 50 mm

  viewing distance 1 m, suggested height 70 mm

  viewing distance 1.5 m, suggested height at least 1 cm.

- The *ratio of strokewidth to character height* should be between 1:8 to 1:6 for black letters on white background, and 1:10 to 1:8 for white letters on black background.
- The *ratio of character width to character height* should be about 3:5.
- The *space between letters* should be at least one stroke width.
- The *space between words* should be at least one character width.
- For *continuous text*, mix upper- and lower-case letters; for *labels*, use upper-case letters only.

Warnings

Ideally, all devices should be safe to use. In reality, often this cannot be achieved through design. In this case, one must warn users of the dangers associated with product use and provide instructions for safe use to prevent injury or damage.

It is preferable to have an “active” warning, usually consisting of a sensor that notices inappropriate use, combined with an alerting device that warns the human of an impending danger. Yet, in most cases, “passive” warnings are used, usually consisting of a label attached to the product and of instructions for safe use in the user manual. Such passive warnings rely completely on the human user to recognize an existing or potential dangerous situation, to remember the warning, and to behave prudently.

Labels and signs for passive warnings must be carefully designed by following the most recent government laws and regulations, national and international standards, and the best applicable human engineering information. Warning labels and placards may contain text, graphics, and pictures—often graphics with redundant text. Graphics, particularly pictures and pictograms, can be used by persons with different cultural and language backgrounds, if these depictions are selected carefully. However, users with different ages, experiences, and ethnic and educational backgrounds, may have rather different perceptions of dangers and warnings. Therefore, design of a *safe* product is much preferable to applying warnings to an inferior product.

COMPUTER WORKSTATIONS & ERGONOMICS

Individuals who use computers for extended periods of time may experience discomfort or pain as a result of poor posture, improper adjustment or use of workstation components or other factors. In most cases, there are relatively simple and inexpensive corrective measures which can be employed to reduce the likelihood of discomfort or injury.

EHS staff are available to train computer users on how to adjust their computer workstations in order to work safely.

For more information on how to adjust your computer workstation, please follow the links below:

Setting Up Your Workstation

Here are some general guidelines to adjusting your workstation in order to achieve a neutral posture while working. Of course, no two bodies are identical and different styles, models, and sizes of furniture and accessories may be needed. The best results are achieved when the individual is involved in the selection and adjustment process.

Chair

Desired features for computer task chairs include:

- pneumatic seat height adjustability
- 360 degree swivel
- back height/lumbar support adjustability
- seat depth adjustability (either by moving the back of the chair or by moving the seat pan).
- Tilt is not necessarily recommended, and, if a chair has tilt, it should also be equipped with tilt lock.
- Armrests are not recommended for computer use. If a chair is equipped with arms, they should be adjusted to their lowest point.

Users should be able to sit such that their feet are flat on the floor (or a footstool, if necessary), knees are approximately 90 degrees and the back of the chair is in use.

Keyboard/Mouse

- Users should be able to place their hands on the keyboard or mouse with their neck and shoulders relaxed, their upper arms at their sides, their elbows at or slightly larger than 90 degrees and wrists straight.
- If a keyboard or mouse is too high when placed on the desk surface, users can employ a height- and tilt-adjustable keyboard tray. Keyboard trays should be large enough to accommodate the keyboard and mouse on the same level. If a keyboard tray is not practical or desired, users may be able to raise the height of the chair and use a footstool.

- In order to keep wrists in a neutral posture, keyboard legs should be folded up and keyboard trays can be adjusted to a slightly negative angle (away from the user).

Monitor

- Monitors should be placed at a distance such that the user can focus on the screen while still using the back of the chair and keep their arms parallel to their upper body. This may be anywhere between 18 and 30 inches.

- Monitor height should be adjusted such that the user's eyes are level with the top of the screen. This may need to be adjusted with the use of corrective glasses, as multi-lens glasses can impact how a user holds their neck posture.
- Computer users who use two monitor screens must assess how both monitors are used:
    - If both monitors are used equally, the monitors should be placed together, directly in front of the user.
    - If one monitor is used primarily and another is used only occasionally, the primary monitor should be placed directly in front of the user with the secondary monitor immediately to the side. In either situation, both monitors should be adjusted to the same height.

Laptop Computers

Laptop computers and tablets do not have the adjustability of a desktop computer when adjusting keyboard, mouse and monitor. For long term use of laptops, a docking station, port replicator or external keyboard and monitor are recommended.

Accessries

- Telephone headsets: If your job requires you to frequently use the telephone and the computer at the same time, a telephone headset may be recommended. Contact the University Telephone Office to find telephone headsets compatible with University telephones
- Input devices: There are a number of alternatives to the standard mouse input device. Since there are many varied work types, work spaces and operator issues, there is no single alternative device which is recommended. Contact EHS with questions about specific input devices.
- "Ergonomic" or "Natural" keyboards: There are a variety of keyboard types available for use. However, research shows that standard keyboards allow most users to keep their arms and wrists in a neutral posture.
- Keyboard or mouse palm/wrist rests: Palm/wrist rests may be used to keep a user's wrists in a neutral posture and prevent leaning wrists on the edge of a desk, creating contact stress.

Tips for Reducing Computer Discomfort

Evaluating Your Work

- How much time is spent on the computer each day?
- What are your non-computer-related job tasks? Can these be scheduled throughout the day?
- Is your computer work mouse-intensive, keyboard-intensive or a combination?
- Does your work require you to work on the computer and the telephone at the same time?

Other Considerations

- Do you wear corrective lenses? Should you consider lenses specifically for computer use?
- Do you have poor posture habits, such as crossing legs, leaning to one side or the other, slouching, etc.?
- Do you participate in home activities which might use similar motions or muscle groups as computer work (i.e., gardening, playing an instrument, home computer use, etc.)?

General Tips and Work Practices

Even the perfect posture is not perfect for 8 hours per day. Computers users should devote at least five minutes of every hour of computer use to a non-computer-related task.

- Stand up while on the phone to force a break from computer work and focus on a distant object
- Print to a remote printer to force yourself to stand up and move around
- Schedule non-computer-related tasks throughout the day
- Blink your eyes multiple times during computer breaks to avoid eyestrain.
- Each time you sit, take the opportunity to “reset” your posture. Sit back in the chair, relax your neck and shoulders, move the chair in, etc.

Sit-Stand Workstations

Standing desks or sit-stand workstations are rapidly gaining in popularity. While research suggests that prolonged sedentary behavior has emerged as a risk factor for various negative health outcomes, there is little agreement on the best intervention strategies to reduce sedentary behavior.

The following information outlines the EHS guidance regarding these emerging intervention strategies:

Departmental Purchases

As with chairs, desks or other office furniture, sit-stand desks are purchases made at the discretion of the department. EHS does **NOT** make recommendations in regards to the need for or the type of sit-stand workstations.

Medical Accommodation

Requests for a medical accommodation, including those for a sit-stand or standing desk, should be referred to the Office of Human Resources (for staff), the Office of the Dean of Faculty (for DOF employees), or the Office of Disability Services (for undergraduate and graduate students).

Standing Desks vs. Sit-Stand Desks

Some workstations are designed for the user to stand exclusively and some are designed to vary posture between sitting and standing. Research suggests that variability is key and users benefit from the ability to change postures between sitting and standing.

Types of Sit-Stand Workstations

There is a wide range of sit-stand workstations commercially available, from free-standing electrically controlled to manual setups that can be placed on an existing desk surface. Each type has benefits and limitations. Departments and users should consider the following when evaluating products:

- Ease of use
- Cost
- Desk space footprint
- Distance to monitor
- Space for mouse or other input device

Alternative Strategies

There are several alternative strategies to reducing sedentary behavior, both at work and outside of work. All computer users should be encouraged to devote at least five minutes of every hour of computer use to non-computer-related tasks.

Work-related strategies can include:

- Standing while speaking on the telephone builds in a natural break throughout the day and avoids the temptation to pinch the telephone headset between your shoulder and chin
- Print to a remote printer to force yourself to stand and retrieve documents
- Schedule non-computer-related tasks throughout the day
- Set a timer that reminds you to stand up and move throughout the day. Certain commercially available fitness trackers (Fitbit, Garmin, etc.) will remind you to move throughout the day
- Use these University Health Services Desk Stretch videos to increase movement throughout the day

Strategies outside of work can include:

- Join a walking group in the neighborhood or at the local shopping mall.
- Recruit a partner for support and encouragement.
- Get the whole family involved — enjoy an afternoon walk or bike ride with your kids. Play with your kids — tumble in the leaves, build a snowman, splash in a puddle, or dance to favorite music.
- Walk up and down the soccer or softball field sidelines while watching the kids play.
- Walk the dog frequently

- Clean the house or wash the car.
- Drive less: walk, bike or take public transportation
- Do stretches, exercises, or pedal a stationary bike while watching television.
- Mow the lawn with a push mower.
- Plant and care for a vegetable or flower garden.

Training on Adjusting Your Computer Workstation

EHS staffs are available to train computer users on how to adjust their computer workstations and work safely. Contact the individuals listed to the right to arrange a training session.

Reporting a Work-Related Computer Injury

For employees, all work-related injuries must be reported to Employee Health at University Health Services at 609-258-5035.

If you believe you are experiencing an injury due to the setup or use of your computer workstation, contact Employee Health at 609-258-5035 (for employees) or Student Health at 609-258-3141 (for undergraduate and graduate students).

For more information on reporting work related injuries, go to the Injury & Incident Reporting page.