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ABSTRACT

Many of the findings from ergonomics research on visual display workstations are relevant to the design of interactive learning stations. This 1993 paper briefly reviews ergonomics research on visual display workstations; specifically, (1) potential health hazards from electromagnetic radiation; (2) musculoskeletal disorders; (3)vision complaints; and (4) psychosocial stresses. Guidelines are provided on how to design an ergonomically correct workstation and learning environment that seek to balance human performance with learner satisfaction and well being. (Contains 64 references.) (GR)

Ergonomic Guidelines for Designing Effective and Healthy Learning Environments for Interactive Technologies

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Abstract

Many of the findings from ergonomics research on visual display workstations are relevant to the design of interactive learning stations. This paper briefly reviews ergonomics research on visual display workstations; specifically, (1) potential health hazards from electromagnetic radiation; (2) musculoskeletal disorders; (3) vision complaints; and (4) psychosocial stresses. Based on this review, guidelines on how to design an ergonomically correct workstation and learning environment are presented. These guidelines seek to balance human performance with learner satisfaction and well-being.

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INTRODUCTION

Technological advances in recent years have led to the prevalence of computer and other electronic technologies in the everyday lives of people-at play, at work, in the home and in school (Forester, 1989; Fox, 1989; Postman, 1992). Recent technology innovations include the "Personal Digital Assistant" (Linderholm, 1992) and the inchoate fields of cyberspace (Gibson, 1984; Benedikt, 1992) and virtual reality (Rhiengold, 1991). As technologies insinuate themselves into work, entertainment and learning environments, the interests of broadcasting, publishing, and computer industries intersect and become the focal point for a variety of interactive systems (Brand, 1988). These systems may include visual display monitors, microcomputers, laser discs, various optical disk formats and a plethora of peripherals (Frenkel, 1989). As these technologies become more widely used certain problems are emerging. These problems range from the slightly humorous (the images of frustrated consumers attempting to program a video cassette player to record their favorite television program) to the very serious, e.g., (potential health hazards from electromagnetic fields emitted by visual display devices, and the physical and psychological stress of spending long hours working or studying at computer workstations).

Much research addressing the potential and real problems associated with the design and use of visual display workstations has been conducted. The majority of research has focused on the productivity and health of workers who use visual display workstations: (NIOSH, 1991; Sauter, 1991; EPA, 1990; Klemmmer, 1989; Kilbom, 1988; Zenz, 1975). Numerous guidelines for the design of effective and safe workstations have emerged from this research:IEEE, Spectrum: Special Workstations Guide (1991); NIOSH Publication on Video Display Terminals (1991); Computer Workplace Ergonomics (Gross and Hassel 1991); Herman Miller Research and Design (1991); American National Standard for Human Factors Engineering of Visual Terminal Workstations (1988); Boeing Aerospace Company (1984);Human Factors of Workstations with Visual Displays, (IBM, 1984); and Design of Visual Display Products-Workstation Ergonomics, (IBM, 1988). A somewhat lesser, although substantial, amount has been written about the real or potential problems associated with the design and use of technology in the home (Miles, 1988; Norman, 1988; Bass, 1991). Very little, however, has been written about problems, either potential or real, associated with using visual display technologies designed for use in learning environments (Spangenberg, 1975; Yeaman, 1983, 1984, 1986).

Learning environments, of course, differ from the workplace environment. In the learnplace environment, the measure of productivity is not a unit of work but rather the accomplishment of an educational objective, usually demonstrable in knowledge or performance. The design and implementation of the learning environment is an important factor in achieving educational objectives. Interactive technologies are an important segment of the learning environment; they include the full range of optical formats (laser videodiscs, CD-ROM, CD-ROM XA, CD-I, CD-TV, and DVI) and microcomputers and peripherals that are currently available. Also included are those technologies that are on the horizon and those that can be reasonably anticipated for the near future, such as multimedia systems.

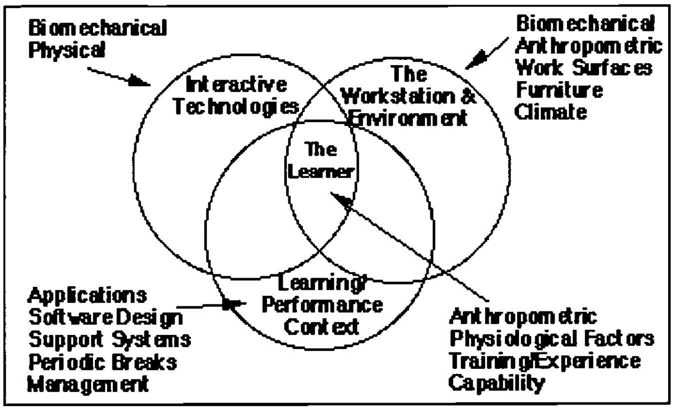
The learnplace environment for interactive technologies has many similarities with the workplace environment for visual display workstations. Among these similarities are such dynamics as: (1) viewing a visual display monitor; (2) using a mechanical device (keyboard, mouse, trackball) or a touch screen monitor; (3) sitting for long periods in awkward positions while interacting with devices and furniture configurations; and (4) performing under stress. Many of the findings from ergonomics research on visual display workstations are relevant to the design of interactive learning stations.

The paradigm and hypotheses guiding research on the effective design and use of visual display workstation technologies were derived from the principles of ergonomics. Ergonomics is an interdisciplinary science that addresses human performance and well-being in relation to the job (task), the equipment, and the environment (Gross and Hassel, 1991). Ergonomics embraces three major concerns: (1) safety and health; (2) comfort and well-being; and (3) productivity and efficiency (Berns and Claridge, 1990). The scientific disciplines involved in ergonomics fall under three general headings: (a) engineering and physical sciences; (b) biological sciences; and (c) behavioral sciences, including psychology (Zenz, 1975). These disciplines define the domain for research on ergonomics.

AN ERGONOMIC MODEL

A useful conceptual framework for operationalizing this domain is found in Human Factors, Ergonomics and Usability, (Baker, 1989). Baker describes a "model of work" proposed by IBM (1982) and Baker (1984) that explores the work environment by delineating the relationships among: (a) the individual user; (b) the tools; (c) the workstation; and (d) the job to be performed. With the substitution of "learner" for "user" and "learning/performance" for "job to be performed", this model is easily adaptable to the learnplace.

Figure 1. illustrates the model with the proposed substitutions.



VISUAL DISPLAY TERMINAL HAZARDS

A dichotomy of opinion exists today on the subject of potential health hazards from video display terminals (VDTs). One set of opinions, represented by the public, is informed by popular literature. The other, represented by the scientific community, is informed by epidemiological studies. This makes for an interesting dilemma--the public is worried although the preponderance of scientific evidence indicates no conclusive evidence of harmful health effects from VDTs.

Public concern over the potential health hazards of electromagnetic radiation emitted by visual display terminals was aroused by the publication of several articles in popular magazines and newspapers: (Brodeur, 1990; Borrell, 1990; Infoworld, 1990; San Jose Mercury, 1990; Washington Post, 1990). Some of these articles had very provocative titles:Is Your Computer Killing You, (Borrell) and The Magnetic Field Menace, (Brodeur). These articles drew attention to possible health hazards from very low-frequency (VLF) and extremely low-frequency (ELF) electromagnetic fields emitted by visual display terminals. Magnetic fields, or more specifically, magnetic flux densities historically have been measured with a unit called the milligauss (1 milligauss(mg)= .001Gauss(g) (Feero, 1991). Electrical engineers and physicists use the Tesla as a unit of international standard (Feero, 1991). One Tesla is equivalent to 10,000 Gauss or 10,000,000 milligauss. The Tesla is used in technical journals and the milligauss unit is used in information for the general public.

Public articles also focused on the concern of European countries, particularly Sweden, with the development of guidelines for radiation emissions from VDTs. It was noted that in 1986 Sweden developed guidelines for VLF magnetic emissions (defined as frequencies between 2kHz and 400kHz, in cycles per second, and that these had been amended in 1990 to include guidelines for ELF magnetic fields (defined as 5Hz to 2kHz to an intensity of no more than 2.5mg at one-half a meter from the monitor)(O'Connor, 1991). This vigilance in Sweden spurred concern in the United States.

Scientific research indicates that video display terminals cause four types of electrical and magnetic fields:

(1) an electrostatic field associated with high voltage applied to the internal surface of the cathode screen; (2) a magnetic field of extremely low- frequency generated by the vertical scanning coil; (3) a low-frequency magnetic field generated by the horizontal scanning coil; and (4) a low-frequency electrical field generated by the high voltage flyback transformer (Laliberte, 1987; Marha, 1986). This results in VLF and ELF emissions from the back and sides of monitors. These emissions, therefore, have been the focal point of concern and research.

The National Institute for Occupational Safety and Health (Murray, 1991) reports three specific health problems that are generally attributed to operators' exposure to radiation emitted from VDTs: (1) cataracts; (2) reproductive problems; and (3) facial skin rashes. Both animal and human studies demonstrate that the aforementioned health problems can result from exposure to a high level of radiation similar to the type emitted by VDTs (NIOSH 1991). However, dozens of radiation surveys conducted by NIOSH and independent groups such as Bell Laboratories, Duke University School of Medicine and the University of Washington have not shown any scientific evidence that the occurrence of cataracts, birth defects, miscarriages, or skin rashes is related to radiation exposure from VDTs (NIOSH,1991). In the final report of An Investigation of Electrical and Magnetic Field and Operator Exposure Produced by VDTs: NIOSH VDT Epidemiology Study by Robert Tell and Associates, it was reported that typical personnel exposures to electric and magnetic fields are: (1) relatively low; (2) within a relatively confined range of magnitudes; (3) not highly dissimilar to exposures commonly encountered from radios and other devices routinely found in the home or workplace; and (4) generally substantially less than any electromagnetic field exposure limits developed for radiation protection purposes by organizations within the United States and many other countries.

NIOSH (Murray, 1991) also addressed the issues of whether malfunctioning VDTs, aging VDTs and the presence of multiple terminals cause increased radiation and therefore poses more danger. It was found that: (1) malfunctions would make a VDT unusable; (2) exposure does not seem to increase as terminals become older; and (3) multiple terminals do not increase exposure.

Charles Reis (1991) tried to put the issue in perspective in an article entitled, Video Display Terminal Hazards: The Other Side of the Controversy. His article was a balanced attempt to review both popular press articles and epidemiological studies conducted by industry, academia, and government agencies. Reis concludes that it is an almost impossible task to draw a sound conclusion on the VDT hazard issue and suggests more research on the long term effects of exposure to VDTs. This is both sensible and prudent. Further research is necessary to determine the long term effects on users from exposure to visual display monitors. Long term studies make sense since children and people of all ages are being introduced to technology and are certain to be exposed to visual display monitors over the long term. This is not to say that liquid crystal displays and other display technologies, which emit no radiation, could not at some future time replace standard cathode-ray tube type monitors and end the dilemma.

The scientific community also supports research on the long term effects of exposure to VDTs. NIOSH supports long term research predicated on the need to accurately measure the levels of radiation exposure for users and to compare these levels to existing occupational exposure standards and to the threshold for biological effects available from epidemiological studies (Murray, 1991).

The question becomes, what should users do until there is definitive scientific evidence that visual display terminals do not pose a long term health hazard. Preventive measures offer a logical solution. The Swedish guidelines, which are also recommended by the Institute of Electrical and Electronics Engineers, Inc., are a good general reference point. Recent studies of some commercial monitors found that field strength diminishes with distance and that it is generally below 1 milligauss at 76 cm from the monitors front and 122 cm from its sides and back (Spectrum, 1991). This finding is consistent with information reported in the Brodour (1990) article appearing in MACWORLD. Taken together, these findings suggest that the user is exposed to ELF levels of less than 1 milligauss when sitting 29 inches from the front of the display and 4 feet from the sides or back of the display. And since an office partition will not shield users from ELF emissions, workspaces should be designed so that no one in an adjoining area is within 4 feet of the sides or back of a monitor in someone else's work area (Spectrum, 1991).

It should be noted that there have been some false claims that anti-glare screens reduce low level magnetic fields. When properly grounded, anti-glare screens reduce electrical emissions but they do not significantly reduce low-level magnetic fields (Branscum, 1990). Magnetic field elimination or reduction through shielding requires use of high permeability materials (Laliberte, 1987). According to Laliberte, shielding against magnetic fields has been obtained by adding a semi-transparent, high permeability filter to the screen. Some monitor manufacturers have resorted to various shielding or cancellation techniques for reducing magnetic emissions. Although these efforts are represented by only a few large companies (IBM and SuperMac), an after market appears to be developing (O'Conner, 1991) and a recent advertisement in Monitor Radiation News (Vol. 1., 1991). This development has the ironic effect of perpetuating concern about radiation while simultaneously providing preventive measures.

MUSCULOSKELETAL DISORDERS IN A VISUAL DISPLAY ENVIRONMENT

Musculoskeletal disorders represent a complex phenomenon. Within the context of computer work environments, the individual disorders themselves are complex and represent a wide array of conditions that are commonly referred to as cumulative trauma disorders (CTDs) or repetitive strain injuries (RSIs). Research shows that computer work and the design of the workstation can interact to amplify the risks of musculoskeletal disorders such as carpal tunnel syndrome and other cumulative trauma disorders. Statistics on organizations where computers and keyboards are essential for productivity illustrate increasing numbers of carpal tunnel syndrome and repetitive stress injuries in both the United States and the United Kingdom (Mallory and Bradford, 1989; Hill, 1989). This reportedly has led some companies to spend millions of dollars on medical treatment, ergonomically correct equipment, training and legal expenses (Minter, 1989).

Because of the complexity of these disorders, however, and the methodological limitations of the studies investigating them, their etiology cannot be attributed solely to the visual display workstation environment (Sauter, et. al., 1991). Herman Miller Research and Design (1991) corroborate the complex nature of CTDs by organizing risk factors into three general groups:(1) ergonomic stresses; (2) psychosocial stresses; and (3) physiological predispositions. The dynamic interrelationships among these factors is brought home again by a recent report by NIOSH (Swaboda, 1992) showing that psychological factors such as job insecurity, work demands and electronic monitoring contribute to musculoskeletal disorders among VDT users even when preventive ergonomic measures are implemented. Etiology is further complicated by chronic pain syndromes (Kusack, 1990). Therefore, caution must be used in attributing the causes of such injuries. Nevertheless, adequate research evidence exists to justify a systematic examination of the ergonomic aspects of work environments in which mechanical input devices, such as keyboards (QWERTY), mice and trackballs are in use. Each of these devices forces users to make repetitive, small movements that over time can cause RSIs (Hurty, 1992).

A major comprehensive study of workstation design and musculoskeletal discomfort within the context of a visual display terminal data entry task was conducted by Sauter and others (1991). The primary objective of this study was to clarify the contribution of workplace ergonomic factors to musculoskeletal problems among VDT users. The study objective had special significance given statistical evidence pointing to the increased incidence of musculoskeletal disabilities among VDT workers in the United States (Eisen and LeGrande, 1989; Pasternak, 1989; NIOSH, 1990). Study methodology attempted to overcome limitations of previous studies which led to discrepant findings of the association of ergonomic factors and musculoskeletal problems. Emphasis was placed on: (1) objective assessment of work postures; (2)

reclassification of continuous data on working conditions and discomfort into categorical variables for analysis; (3) use of multivariate statistical techniques; and (4) adjusting for biodemographic factors.

The study findings provide support for the emerging data on outbreaks of musculoskeletal disorders among VDT users that point to the vulnerability of upper extremities--the hand and the wrist in particular. The authors concluded that the study findings: (1) served to reduce the uncertainty regarding the contribution of ergonomic factors to the etiology of musculoskeletal problems; (2) suggested workstation configurations that will minimize these problems; and (3) improved the definition of the regional pattern of musculoskeletal problems among VDT users. Among the suggestions for environment and workstation design were: (1) low placement of the keyboard; (2) avoidance of low compressible seats to prevent leg discomfort; (3) preference for an erect sitting posture and backrest height adjustments; and (4) physical exercise during work and frequent rest breaks.

Most of the general information articles citing musculoskeletal disorders in VDT workstation environments focus on carpal tunnel; however, other musculoskeletal problems are also associated with VDT workstations. A comprehensive list would include such disorders as tendinitis, tenosynovitis, trigger finger, gamekeeper's thumb, Guyon's canal syndrome, epicondylitis, cubital tunnel syndrome, low back pain, and others (Herman Miller, Inc.1991). What these disorders appear to have in common is a work environment characterized by: (1) awkward positions; (2) localized pressure; (3) holding a static position without movement; (4) excessive use of force or strength; and (5) repetition without rest breaks (Herman Miller Research and Design, 1991).

Several studies cited in Herman Miller (1991), associate awkward wrist positions with CTDs. Users of keyboards, computer mice and trackballs are susceptible to awkward wrist positions. Keyboard computing-related CTDs are the result of pressure changes in the carpal tunnel caused by many repetitive movements made while the wrist is vertically deviated outside of neutral range-either in a position of flexion (bent such that the palm is lower than the wrist joint), or extension (bent such that the palm is higher than the wrist joint) (Marras and Schoenmarken, 1991). In this case the major postural risk factors are wrist extension/flexion and the acceleration of extension/ flexion hand movements (Proformix-Research Update #002, 1991).

To minimize this risk and practice safe keyboarding, it is universally recommended that wrists be properly supported in a neutral position with minimal flexion and extension. Alternatives to the flat keyboard might also provide a solution. Several alternative keyboards split the keys into left-hand and right-hand groups, aiming them inward to reduce bent wrists. Others crack the keyboard in half, creating a tent shape eliminating the forearm rotation required for standard keyboards. Unfortunately, these alternatives are presently prototypes and are not available (Buesen, 1984; Hobday, 1988; Zipp, 1981).

Mice and trackball devices are beginning to attract the attention of ergonomists. Since these devices involve small, repetitive movements that have a cumulative effect, they also are looked upon as a source of repetitive strain injuries. Given their recent introduction compared to the computer keyboard, however, there is scant ergonomic information (Whitefield, 1989; Herman Miller, 1991; Hurty, 1991). Because many mouse users rest their forearms on their work surface and move the mouse around through wrist movements they create a side-to-side bending of the wrists which can potentially cause CTDs. In the case of the trackball, the role of the thumb is an important consideration. The thumb's limited freedom of movement is well suited for side-to-side grasping actions but makes it a poor choice for controlling up-and-down or circular motions (Hurty, 1991). Touch screens also deserve attention. Touch screens are appealing input devices for a number of reasons: (1) users point directly at an object; (2) they require little or no training; (3) they are faster than other pointing devices; and (4) no extra work surface is required. The down side to touch screens involves arm fatigue, callouses on fingers with heavy use, smudges, optical interference and increased glare.

With all these devices, as well as with the keyboard, it is important to address the broader issue of overall workstation design to ensure prevention of musculoskeletal injuries. In as much as musculoskeletal injuries are influenced by workstation design and the inter-relationships among psychosocial stresses and physiological predispositions, it is crucial that studies on etiology be implemented as controlled experiments. These studies should have valid experimental methodologies and should be followed-up by case control and prospective studies performed on ergonomic interventions in actual work settings (Sauter, 1991).

Lab and field studies should also be developed to provide practical data on specific ways in which preferred individual adjustments of workstations differ from the recommended standards. Some recent studies have shown that individuals prefer adjustments that differ from the standards (Jaschinski, 1988; Sauter, 1991). Standards are not meant to be monolithic. Professional ergonomists and users should work together towards the goal of developing equipment and workstations that allow the user maximum flexibility to customize the configuration.

VISUAL DISPLAY TERMINALS AND VISION COMPLAINTS

In a recent survey conducted by the American Optometric Association, eyestrain, headaches, and blurred vision were ranked as the top three vision complaints associated with the use of VDTs (Sheedy, 1992). Visual fatigue and double vision have been reported by other surveys. Studies are divided, however, on the issue of whether VDT use directly causes increased visual problems.

Research distinguishes between visual causative factors (specific diagnosable visual disorders that an individual has) and environmental causative factors (specific factors in the design of the VDT, the workstation and the environment) (Sheedy and Parsons, 1990). It must be noted also, that an individual's visual problems may be due to a single cause or a combination of causes. Since it is duly noted that: (a) individual predispositions have an effect on visual problems; (b) problems can have one or more causes; and (c) separating out predispositions from environmental factors is a daunting prospect, it will suffice to simply delineate some of the environmental factors that are amenable to change and that may influence vision complaints.

The major environmental problem involves lighting. Florescent overhead lighting is the norm in most offices. This results in 100-150 ft. candles of illumination on desk surfaces. This level greatly exceeds the 18-46 ft. candles recommended by the ANSI Standard (1988). Because desk and reference documents are significantly brighter than the VDT screen, adaptation problems may occur as the result of the users having to move their eyes back and forth from brightly lit documents to the screen. Another source of eye discomfort is glare off the screen caused by bright lights in peripheral vision (either from florescent lights or bright outside light). These problems can be alleviated by turning off some overhead lights, drawing blinds or shades or moving the VDT, perhaps recessing it so that it is lower than the desk surface. Reflections on the screen can also interfere with resolution and contrast. Glass anti-reflection screens are a good solution and are preferred over mesh screens. VDTs with dark characters on white background provide better resolution. A screen refresh rate of at least 60 Hz (German health regulations require 70 Hz) is preferred. A lower refresh rate creates screen flicker which may cause eyestrain and headaches. For optimal viewing of the screen, the screen height should be adjusted to 10-200 below the user's eyes. This range appears to alleviate neck and back ache as well as dry irritated eyes and contact lens difficulties because of decreased blinking (Sheedy, 1992).

Adult learners working with VDTs are faced with a special problem. The loss of eye focusing that invariably accompanies advancing age (presbyopia) requires special prescription lenses for the adult population (Sheedy, 1992). In the Sheedy (1992) survey, thirty percent of all VDT patients received prescriptions for bifocals and nineteen percent for trifocals. Bifocal and trifocal users may experience neck and back problems in addition to vision complaints as they attempt to accommodate two or three visual focal points. The author can attest to this special difficulty, having word processed this paper while wearing trifocals.

The American Optometric Association estimates that among the seventy million eye exams a year, ten million patients obtain eye exams because of problems with VDTs (Sheedy 1992). Thirty-seven percent of these complaints are attributed to environmental visual factors such as lighting, poor screen resolution and glare. Neck and back ache are also reported with these vision complaints due to high VDT placement.

VISUAL DISPLAY TERMINALS AND PSYCHOSOCIAL STRESSES

The recent NIOSH study (Swoboda, 1992) linking job stress to VDT physical injuries reinforces the ergonomic perspective of the dynamic interplay among the worker, the job, the workstation, and the environment. As reported in the Washington Post (July 21, 1992) the NIOSH study was conducted at the request of US West, Inc. and the Communications Workers of America Union. The study reported that musculoskeletal disorders occurred among VDT workers even in situations where ergonomic precautions where implemented by employers to protect them. Even when preventive workstation designs were implemented, psychosocial factors apparently influenced the development of musculoskeletal injuries. This finding has caused leaders at US West to view management's treatment of workers as equally important to an injury free environment as the equipment and the workstation.

Earlier studies (Sauter, 1981; Smith, 1983; Arndt, 1984; Sauter, 1984) reported on the general stress levels caused by the introduction of automated technology in the office; specifically, the visual display terminal. These studies did not look for the effect of psychosocial (organizational or social environment) stresses on physical complaints of VDT users. Like the previous subjects discussed, it is difficult to demonstrate a cause and effect relationship from the research. However, it is informative to review the results of a major ergonomic intervention study conducted at Federal Express Company.

A report of this ergonomic intervention was presented as a case study by Allen Westin in Promoting Health and Productivity in the Computerized Office: Models of Successful Ergonomic Interventions (1990). By 1983, Federal Express had 8000 VDTs in use throughout the organization. Federal Express's Director of Human Resources Analysis established the proactive view that the issue of VDT use was not a narrow ergonomics issue involving only equipment and workstations. He expanded ergonomics to include job design, work-group relations, employee education and manager training. Through surveys and interviews, management staff discovered that employees perceived a direct relationship between job stress, VDT work, and their health. With this information, Federal Express developed a "corporate ergonomic standard" to ensure the health and well-being of those whose work environment involved video display terminal use. In 1990, Federal Express had 52,300 VDTs and an additional 3000-4000 stand-alone PCs.

The pay off from this forward-looking approach has been no reported cases of repetitive strain injury at Federal Express despite their intensive and extensive VDT use. There have been fewer than six stress related claims by VDT users filed under worker compensation in the past five years. The model implemented at Federal Express should be reviewed by other companies or groups as a potential approach for preventing psychosocial stresses from contributing to the development of musculoskeletal disorders among VDT users.

Other ergonomic interventions have reported similar positive results (Sauter, et al. 1990). Ergonomics in these interventions was broadly defined, as in the Federal Express case, to include: (1) equipment and workstation design; (2) job design; (3) work-group relations; and (4) education of employees and training of staff. The interventions reported show a matrix of effects suggesting significant health and productivity gains from the effective application of ergonomics in the VDT workplace. These studies also demonstrate dramatic productivity increases in the range of twenty percent resulting from ergonomic improvements in the design of job, and the workplace. A concomitant increase in worker satisfaction and a decrease in somatic complaints were also reported. Absenteeism, turnover, sick leave and compensation claims were also in decline.

CONCLUSION AND RECOMMENDATIONS

New interactive technologies present a challenge and an opportunity for designers of learning environments. This paper has touched upon several of the major variables that influence the design of safe and effective visual display learning environments. An ergonomic model was presented as an organizing concept for defining the domain of ergonomic variables relevant to the study of learning environments. Research on ergonomics in the workplace was reviewed with the goal of deriving relevant guidelines for designing learning environments for interactive technologies. Based on this review, and the perusal of major documents from science and industry on ergonomic standards and specifications, a set of guidelines was presented. It is hoped that these guidelines will be useful to health science educators and administrators.

The application of ergonomics is a complex process that requires careful management. To ensure that standards and guidelines drawn from human factors and anthropometric data are safe and effective for individuals, they must be validated through prospective demonstrations and case studies in "real life" learning environments.

General Workstation Specifications

- Worksurface depth and width--a minimum depth of 30 inches and width of 48 inches--surface space must allow for efficient organization of documents, papers and other materials relevant to the learning task
- Worksurface height--if adjustable, between 25.5 and 29.5 inches for effective use of keyboard and mouse--if not adjustable, 28.3 inches as a compromise--option of the keyboard tray below the work surface which places hands and wrists in a wrist neutral position
- Surfaces should have bullnose edges to avoid sharp corners
- The keying surface between 23 inches and 28.5 inches from the floor with detachable keyboard--top surface of the "home row" of keys no higher than 2-2.5 inches above worksurface--to allow elbows at 900 and arms and hands parallel to the floor--keyboard where thumb joints are located--wrist rests are helpful
- A mouse and writing platform that are positioned within the primary reach zone and will give hand/wrist support during use
- Research findings on carpal tunnel suggest options of- an adjustable keyboard tray below the work surface which places hands and wrists in a "wrist neutral" position or the Tony Keyboard that is hinged in the middle reducing pressure on the median nerve
- Interactive and multimedia equipment requires additional space for peripherals such as modems; CD-ROM drives; laser videodiscs; second monitor; and printers--a plan for how equipment will be used will determine space requirements--options include stacking on surface or additional adjacent, above or below moveable surfaces

Visual Display

- Distance between learner's eyes and visual display should be between 18-28 inches to provide preventive measures against the potential hazards from extremely low frequency electromagnetic

emissions (ELF)--Swedish National Board for Measurement and Testing guidelines (MPR-2) and IEEE recommendations--restrict ELF magnetic fields (5Hz-2kHz) to an intensity of no more than 2.5mg (milligauss) at half a meter (19.7 inches) from the monitor
- Acceptable viewing angles range from 0-60 degrees from the top of the screen to the home row of the keyboard--preferred viewing angle is somewhere between 10-20 degrees below the horizontal--display should be located so that the individual's normal line of vision falls in the upper half of the display
- Monitor should have independent height and angle tilt and swivel adjustments--Glass anti-glare screens are preferred over mesh screens-- special glare control screen filters are available to reduce static electricity
- Monitors should be placed at 90 degree angle to windows and never directly in front of windows
- Display should be "flicker free"--refresh rate of at least 60Hz and higher are preferred (German standard is 72Hz)
- Non-interlaced monitors are preferred over interlaced
- Keep monitors clean

Seating (Cited primarily from ANSI/HSF 100-1988)

- Seat height--consensus not available on optimal seat height--ANSI/HSF 100-1988 calls for seat height adjustment of 16 to 20.5 inches--Herman Miller et. al., show that 40% of subjects set their chairs at 20.25 inches or higher--difference points up need for adjustable chair
- Seat depth should be between 15 and 17 inches--it is recommended that seats have a "waterfall" contour just behind the user's knee and underside of the thigh to avoid excessive pressure in this area
- Seat width minimum is set at 18.2 inches
- Seat pan angle when user has feet flat on floor must ensure angle between upper and lower leg of between 60 and 100 degrees
- Seat pan and pan angle should range from 90 to 105 degrees
- A seat back rest and lumbar support should be provided--no specific guidelines given

Acoustics, Lighting and General Environment

- Acoustic panels are required for workstations in addition to acoustically treated ceilings--goal is to balance sound from background and adjacent sources
- Ambient or background noise (white noise) is desirable at a level that does not interfere with task performance (between 40-55dba)
- Illuminance sources should be designed and located to minimize glare-- illuminance measured in the range of 200 lux to 500 lux on the work area is sufficient
- Task or local lighting may be needed for reading documents or passive light-absorbing displays with inadequate luminance-task lights with batwing lenses provide sufficient light and minimize glare
- A combination of indirect -overhead, natural and task lighting is preferable
- For close-up work light should be directed sideways onto documents to avoid producing glare on monitor--helps prevent eye fatigue and headaches
- Florescent glare can be reduced by replacing plastic prism coverings with grids that break up the light pattern
- Color scheme should be neutral and pleasing to the eye
- Proper ventilation requires about two air exchanges per hour-temperature and humidity should be kept constant with temperature range from 68 to 750F

Multiple Group Learning Workstations

- Learning stations should be configured so that no individual comes within 48 inches of the side or back of a monitor--corner arrangement prevents extremely low-frequency (ELF) problems--when users face each other, check distance from back of monitor to opposite user
- Power supply under a raised floor with 4-plex grounded outlets every five feet
- Information on electrical requirements (watts) per computer and peripheral type should be calculated based on required configurations-- information is available in technical specifications from manufacturers
- Cables, wires, and electrical cords should be channeled with a wire management system built into the workstation panels
- Separate air conditioning for workstation area with circuits separate from other areas and no mechanical devices
- For small group work-- a viewing area adjacent to workstations equipped with wall screen and multiscan video projection system for accommodating different monitor scanning rates
- Small group area convertible into break area with tables and comfortable chairs for relaxation, stretching and change of activities

Psychosocial Harmony Through Training and Exercise

- Teachers should receive orientation and training with regard to their perceptions of how the technology will be used and their expectations of the learners' behaviors--these expectations should be clearly communicated to the learners and the learners should have an opportunity to acknowledge them
- Learners should receive proper orientation and training with regard to what behaviors are expected of them in this environment and in addition, they must receive specific instructions on how to operate all equipment and on how to effectively customize the adjustable features of their environment
- Adequate opportunities should be given for rest breaks and exercise--in addition to brief exercises for flexibility, stretching and strength development, vision aerobics software is available for depth perception, focusing skills, frequent blinking and relaxation exercises

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