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Learning from Office Automation: Ergonomics and Human Impact

Introduction

I am by no means an expert on library systems. My primary connection with such systems is that of the typical university professor—i.e., I am a patron. However, I do know something about office automation. In particular I know some things about some of the problems involved in implementing office automation systems, particularly regarding the interaction between human beings and computer systems. Therefore, from my perspective, the issues surrounding automated library systems are a particular instance of general issues of office automation.

It is, by now, somewhat less than startling to make the statement that the advent of inexpensive computing power has produced a radical transformation of those daily work activities that have come to be labeled the "information handling" professions. Information handlers (formerly "white collar workers") tend to spend their workdays in something like an office, and, since at least 1980, they have constituted the majority of the U.S. workforce.[1] Furthermore, information handlers are increasingly more likely to be processing information in electronic form, by communicating with some sort of computerized system via a video display terminal (VDT). Predictions are that by 1990 from one-third to one-half of all U.S. workers will be using some sort of terminal for all or part of their workday.[2] What this means is that an increasingly larger proportion of the working population will perform an increasingly larger proportion of their daily work activities by interacting with a VDT. Most of what we have come to mean by "work"—whether we are senior professionals or entry-level clerks—will involve sitting in a relatively fixed posture while manipulating a keyboard and peering at a display screen.

However, we have now already had some ten to fifteen years' experience with VDT use on a relatively wide scale, and there seems to be evidence that this experience has not been without its cost. Complaints regarding health problems among operators of VDTs began to appear in the mid-1970s and reached a point such that, even in 1977, a trade magazine could describe them as "epidemic" in nature.[3] These health complaints have tended to fall into three areas:

1. physical strain—primarily in the visual and musculoskeletal areas;
2. concern over the levels of electromagnetic radiation emission; and
3. psychological strain.

Since my own experience has been primarily in dealing with the first category, I will concentrate there. With regard to the other areas, I think it is fair to say that most radiation experts have been fairly well convinced that VDTs do not emit sufficient levels of radiation to present any kind of health hazard.[4] Discussion of psychological issues deserves its own separate treatment, perhaps at another time.[5]

The main argument will be that primary causes of visual and muscular problems among VDT operators are likely to be ergonomic in nature. Explored in some detail will be the causes and potential solutions for many of these problems and it will be argued that their solution will lead to an "everybody wins" situation in which productivity increases while operator complaints decrease.

The Ergonomic Argument

First, ergonomics should be defined. *Ergonomics* is an applied science concerned with the fit between people and the things (tools, equipment, environments) that people use. Ergonomists study the characteristics of people—both physical and psychological—as these characteristics interact with the physical design of objects, in order that the use of such objects may be made as effective, healthy, and safe as possible. (Synonyms for ergonomics in the U.S. are *human engineering, human factors,* and *engineering psychology.*)

A fairly comprehensive literature[6] suggests that a likely cause of at least a portion of the high levels of eye and muscle complaints of VDT operators are likely to be the results of ergonomic design deficiencies in existing workstations and VDT equipment, particularly among operators required to maintain fixed postures for relatively long periods of time.

During a two-year visiting appointment at the National Institute for Occupational Safety and Health, I attempted to verify this argument in the laboratory. My colleagues and I[7] conducted a series of laboratory simulations of VDT data-entry work in which operators, working three hours per day without breaks over four days, alternated between workstations which were either well designed or poorly designed from an ergonomic perspective.

The results of these ergonomic simulations supported the original argument. The same individuals doing the same kinds of work were seen to produce higher levels of output (keystrokes per minute) while showing fewer muscle complaints in the well-designed workstation as compared with the poorly designed workstation. These results were repeated in two similar studies. A field study by Springer reports similar findings.[8]

These reports, along with a number of unpublished, less controlled investigations from the field (including my own workstation at home!) lead to a fairly convincing justification for taking ergonomic design seriously. Of course, an increase in productivity will grab everyone's attention, but what about the health complaints? How seriously should these be taken?

The fact that "almost everyone" suffers from back pain and a bit of eye strain occasionally may act to trivialize these problems, but in fact their very widespread nature increases their economic importance as a health issue. Studies from Sweden where health records related to occupations are carefully collected[9] indicate that the single largest category of occupational disease (over 50 percent of total cases) is described as ergonomic in nature. That is, these disorders are associated with strain resulting from static postures in which the worker is required to maintain a fixed position for long periods of time. Working at a video display terminal is not the only such category of occupation, but certainly it is becoming a major one.

Posture

Postural Strain

This discussion of postural strain will be restricted primarily to those situations where a worker is sitting for prolonged periods of time. From a fundamental, analytic point of view, sitting is a very interesting and complex form of behavior. The fact that it is so common, familiar, and so overlearned does not minimize its ergonomic importance.

Sitting at a workstation embodies at least two functional requirements that are often contradictory. The first requirement is to support the mass of the body against the force of gravity. Under normal conditions, of course, the body cannot maintain itself upright on its own but requires specific action by sets of so-called antigravity muscles that keep the body in an upright posture by acting against the force of gravity. When one faints, he or she loses consciousness, the antigravity system no longer functions, and the individual collapses. In the case of seated posture, the muscles are helped out by the various horizontal and vertical surfaces of the chair. These surfaces allow the weight of various portions of the body to be supported.

The degree to which this support is required depends initially on the nature of the work that is being done. As an example, a friend of mine is an ophthalmologist who does microsurgery involving corneal implants. His workstation, which costs thousands of dollars, is a chair with a microscope built into it. For the ophthalmologist to work effectively, he is required to have his body absolutely rigid in order for his hands and eyes to be completely supported. The information-handling tasks we are all concerned with are not quite as demanding, but still require that the primary interface points—the VDT, the fingers, and the eyes—be in proper orientation with respect to the keyboard and screen. The first requirement of a workstation is to provide sufficient support and stability so as to allow these crucial body components to interact properly with the physical characteristics of the workstation—namely the keyboard and screen.

However, the first criterion is inevitably in conflict with a second demand which has to do with the biochemical nature of fatigue. At a simple muscular level, fatigue results from a build-up of lactic acid. Lactic acid is a by-product of the conversion of blood sugar to ATP (adenosine triphosphate), which is required to give energy to muscles. This is a normal process that goes on continuously with all muscles. However, what we know and experience as muscle fatigue occurs when this lactic acid by-product is not removed quickly enough by the blood. It is interesting that the removal of lactic acid is enhanced by the increased blood flow which results from motion. Under ideal conditions, muscle contractions can go on almost indefinitely if the removal of lactic acid occurs at the same rate as its build-up. A good example of this would be the simple case of someone walking who is in even moderately good shape. One can walk for fairly long periods of time without stopping to rest. This is because the muscular activity involved in moving forward is at the same time generating sufficient blood flow to remove lactic acid.

Sufficient blood flow to remove lactic acid is not generated by the seated worker. Since there is little or no movement, the blood supply is minimal. In fact, most seated postures hamper the flow of blood. This is because the primary veins of the body, located on the back surface of the legs and thighs, are compressed while seated at a chair, therefore, the normal return flow of blood to the heart while slowed down by the lack of activity is even further hampered by the blockage of these veins. Thus lactic acid builds up and causes fatigue. In order to counteract this, there is the tendency for the body to move homeostatically, that is to want to shift and squirm in order to move to allow the blood flow to occur. A well-designed workstation will simultaneously allow for both of these functions. That is, it must provide adequate support while at the same time allowing for adequate movement so as to enhance blood flow.

Requirements for Workstation Design

Having defined the problem of static load as a major contributor to fatigue and having described other possible problems of muscle functions, there are some relatively simple requirements that can operate at least to minimize fatigue thus allowing energy resources to be used for more effective performance.

Standard recommendations. Current understanding of the biomechanics of the muscle function has led to proposed recommendations for VDT workstation design that would require minimum levels of muscle activity in order to maintain the operator in proper orientation with respect to keyboard and screen.[10]

These recommend that the workstation be designed in such a way as to allow feet to rest solidly on the floor or on a footrest in order to anchor the lower limbs of the body. The angle between the thigh and lower leg should be approximately 90 degrees. The angle between the thigh and trunk should likewise be 90 degrees. The lower or lumbar region of the back should be supported by a backrest. The elbows should be approximately at the level or perhaps a little below the level of the home row of the keyboard and the wrists should be flat. The head and neck angle should be such that the line of view between the eyes and the screen or copy should be about 15 degrees below the horizontal. However, this is only one dimension of the problem. In addition, the operator should be allowed sufficient flexibility to be able to move around and shift position.

Flexibility and adjustability. It is fairly obvious that people differ in size and shape. However, in the past, workstations have been designed with reference to a set of "average" human dimensions. A simple demonstration can point out the mythological nature of this "average" human. Take any relatively large group and ask how many people are average with regard to weight. Probably a fairly large number of individuals would be within a few percent of the U.S. average—166 pounds for males, 137 for females. Now, of those individuals who are average in weight, how many are also average in height (68 inches for males; 63 inches for females)? I would suspect the number would decrease drastically. Moving to other body dimensions that are crucial for workplace design, such as seated elbow height (the height of the elbow above the floor), seated eye height (the height of the eyes above the floor), and so forth, we find very rapidly that the concept of average is completely misleading. Virtually nobody is average. Traditional practice has been to take an average set of dimensions and expect all individuals to fit them. But no one fits them precisely. We would not tolerate the clothing industry having only one set of clothes to fit everyone; however, we are willing to accept this with regard to furniture.

What are the consequences of not taking these differences in body measurements into account? Most people are aware of these consequences: your chair is too short, your chair is too tall, the work surface is too high, the work surface is too low. All of this puts added strain on the body increasing the likelihood of fatigue discussed earlier. Therefore, a major ergonomic principle has to do with the ability to adjust the components of the workstation. That is, the office furniture must be of sufficient flexibility so that an operator can get himself or herself into the optimal posture already described. To accomplish this requires being able simultaneously to adjust the keyboard height independently of the screen height and tilt and independent adjustment of the chair height. Furthermore, adjustments must be possible for individuals of different sizes and shapes.

On ergonomic chairs. Let's concentrate on the chair in more detail. The standard recommendations just described assume that the operator is sitting upright with the chair providing a sort of bulge in the lumbar or lower region of the back. The reason for the lumbar bulge relates to the difference between the posture of the spine while sitting and standing. In standing position, the normal curvature of the spine takes on the form of an "S." In the lumbar (lower back) region, the spinal curve has a forward bend. The spine segments are flexible, and in seated posture, the pelvis rotates backward and this bend tends to reverse. The result is that the disks that are located between the spinal segments are compressed and tend to be displaced backward against the ligament, causing pain.[11] It has been demonstrated that the pressure on these disks can be exceptionally large when leaning forward in a chair with no support—a situation many office workers find themselves in daily. Although not demonstrated clinically, this is a likely source of back pain.[12]

If one sits upright in a chair with a lumbar bulge or support, lower back pain can be minimized. The lumbar bulge, which is part of the backrest, works against the reversal of the S-curve. Thus, chairs that are labeled "ergonomic" should have some sort of lumbar support.

Additional features of an ergonomic chair are concerned with the ability to give good support to the back while at the same time adjusting the seat height to a sufficient range so that a relatively large number of people can get into an optimal position. Further, these adjustments should be able to be carried out easily from a seated position. The old system of having to get down on hands and knees and spin the little collar on the chair around simply never worked. No one ever took the trouble to do it.

A new piece of technology called the gas cylinder has allowed a whole new range of flexibilities. The gas cylinder is the same hydraulic device used in a car with a hatchback to keep the hatchback up. These cylinders have been incorporated into chairs and allow for push-button control. However, fixing posture into one optimal orientation solves one problem but exacerbates a second: the homeostatic component. That is, even a chair with a proper lumbar support which puts the worker into an anatomically correct posture will still not be the complete answer because of the necessity for the body to move about.[13] In fact, although ergonomists have recommended the upright seating posture for years, field observations confirm that very few people, if given a choice, will actually remain in this position for long periods of time.[14] The preferred posture appears to be backward leaning. Thus we now need to incorporate into the current ergonomic chairs a back tilt option, a second set of buttons allowing the seated worker to move the chair to a backward-tilt position.

Focusing now on the complete workstation as a total system—involving the *interaction* of desk, chair, and terminal—there is a further problem. As you lean backward, the angle between upper and lower arm will no longer be the optimal 90 degrees; and presumably, the result will be an increased fatigue tendency in these limbs. If the keyboard support surface happens to be adjustable, it could be raised sufficiently high to preserve the 90-degree arm angle; however, this introduces yet another problem in that there is now an acute angle at the wrist. Since the wrists are particularly sensitive to pressure, particularly in situations where people are working for prolonged periods of time, it is necessary to flatten the angle between the hand and the arm. To accomplish this, the desk or workstation needs a device called a palm or wrist rest. This is a padded structure that goes in front of the keyboard and allows the wrists to flatten out.

Now the operator is comfortably leaning backward, his/her arms at a 90-degree angle, the hands accurately in place against a raised keyboard, and the wrists flattened by a palm/wrist rest. However, can he/she still see the screen or copy? An additional concern which is inherent to the backward tilt posture is visual in nature. The operator has moved *away* from the text. This may or not be a problem, depending on the operator's eyesight as well as the size of screen characters and copy. Screen characters tend to be larger than those on paper copy, and if one has to deal with Library of Congress cards, I suspect the backward tilt will present some real difficulties.

A solution to this problem is found in some models of ergonomic chairs that contain a forward tilt option. The principle operative here is that a slight forward tilt of the seat surface rotates the spine forward, placing it in a posture close to that of the standing spine.[15] This accomplishes much the same function as the lumbar bulge in upright sitting with the added benefit that the operator is rotated forward into a better operating posture with respect to both the hands and the eyes. A disadvantage with this posture is that extra pressure is put on the legs and with that the nature of the seat fabric is very important; otherwise the operator will have a tendency to slide forward.

There are clear advantages and disadvantages to all three seated postures. The most reasonable recommendation, given the present state of the art, is to obtain a chair that allows the operator to move between all three positions. Thus, the operator might use the forward tilt for a time while keying in material from a Library of Congress card, then switch to backward tilt while calling up files from a database (a task which requires much less keying or reliance on hard copy). This flexibility has homeostatic advantages as well in that the operator spends much less time in any one fixed position.

Summary: Integration of Ergonomic Chair and Work Surface

The chair cannot be considered independently of the work surface. The system functions to support the individual by getting the elbow, arm, and head into proper operating position. It is difficult to do this unless there is adjustability of work surface and flexibility of screen and computer. This is a fairly new concept. There have been somewhat adjustable chairs for a number of years. However, prior to the gas cylinder, true flexibility in chair adjustment was, for all intents and purposes, ignored. However, the notion that the work surface should be adjustable did not seem to occur to many people in the office environment. (The medical community, of course, has always required adjustable operating tables; dentists and barbers have adjustable chairs.)

This situation has recently changed. It is now possible to purchase a variety of split-level tables that allow one simultaneously and independently to adjust the work surface containing the keyboard and the work surface containing the terminal. The requirements for work surfaces to be adjustable relate to the criteria already discussed. That is, even if the chair is adjustable, it will be virtually impossible to fit a range of people of different sizes and shapes with only a single-height table. Some people are going to be extremely uncomfortable, most people will be moderately uncomfortable. This is made worse if the keyboard is not detachable from the screen. It is virtually impossible to get into anything like an optimal posture if the keyboard and screen are a single unit. Even with an adjustable table, where an office worker may be able to get the keyboard to a point where it is at a proper level (with arms either flat or angled upright slightly), the screen will then be so low that the worker will have to bend his or her head down considerably.

Other design considerations relate to the requirement of having to alternate between a screen that is nearly vertical and copy that is flat on the table. A copy holder that allows paper copy to be in the same plane and at the same distance to the screen from the eyes will alleviate additional strain. Finally, the importance of a flat wrist angle may require the wrist/palm rest described earlier.

It might be pointed out that the ideal workstation is really most appropriate for what is called the "dedicated" operator. This is the person that spends several hours at one time at a terminal. These considerations become successively less important if terminals are to be used briefly. In a library system, for example, with an online card catalog to be used by a population of short-term patrons, most of the considerations that have been talked about are somewhat less important. However, factors such as angle of view and copy holder still are concerns. There must be space for people to write down the information they have just retrieved. These are obvious considerations, but they are often neglected by designers.

My favorite example of designer neglect has to do with the credit-card telephones that are in all of the airports these days. These are the phones with the little video display screens on them. They are examples of high technology at its best. However, if you have ever tried to look up a number in the phone books attached to one of these stations, you will have found that it is virtually impossible to take the phone book out of its little rack underneath the telephone, slide it out, and rotate it upward as it's supposed to be, without knocking the phone off the hook. It is a minor annoyance, but it indicates a failure of ergonomic systems design.

Visual Factors

Mechanisms of Visual Function

The initial flurry of complaints regarding VDTs had to do primarily with visual demand and eyestrain.[16] Two basic visual functions that must be considered in any discussion of visual work are focusing and adaptation.

With regard to focusing, the conventional wisdom is that the eye is like a camera. That analogy can be very misleading at times, but for our purposes we could agree that our eye is like a camera in the sense that it has a lens system which changes its focal length in order to keep objects clear rather than blurry. If you look at text on a piece of paper and move your hand back and forth while attempting to read the text, you can actually feel the muscles of the eye changing. Increasing or decreasing the tension on the lens muscle causes the lens either to stretch out or collapse. In technical vocabulary this is called *accommodation,* and it is part of what happens when the eye works to keep an object in focus. When objects are moved closer to the eyes, at some point the object will appear blurry. This is called the *near point.* As people age, the near point starts getting so near, until they reach the point where, as the joke has it, you can't read your newspaper anymore because your arms aren't long enough. This condition is called *presbyopia,* and it is a normal result of aging. Almost everyone who has reached the magic age of forty-three and onward needs reading glasses to correct for this movement away of the near point. Some people need glasses called bifocals in which a special reading correction is typically placed at the bottom of spectacles used normally for distance viewing. However, reading corrections are made to compensate for the postures used in ordinary reading, and these corrections are inappropriately placed with regard to postures used in viewing the VDT screen. This point illustrates the close connection between visual and postural concerns.

A more direct problem potentially related to accommodation concerns the way in which most VDTs generate their textual characters. On many display screens, particularly those that are less expensive, characters are made up of patterns of dots—the "dot matrix." These dots can typically be seen as individual elements with a low-power magnifying lens or even with the naked eye. The result is that dot-matrix characters may appear blurrier than characters seen in conventional paper copy printing. An increase in blurriness means that the eyes' accommodation system is working harder. This additional work may be related to eyestrain, although it has not been conclusively demonstrated. Morover, if the display is out of focus or the screen is covered with dirt, the problem is made worse.

Accommodation is not all that is involved. As eye focus shifts from far to near, or near to far, the two eyes work together—either converging or diverging. In addition, the pupil diameter is systematically changing. This simultaneous three-way interaction is probably related to visual fatigue. Exactly how, however, is not known.[17]

A second function is *adaptation.* As an example of adaptation, picture being out of doors on a bright, winter, sunlit day; the snow is covering the ground, it is high noon and there is not a cloud in the sky. Then, because it is too cold to be outside, you decide to go to a matinee. You walk into the theater, but the movie has already started. Your ability to see suddenly drops, and unless somebody is there with a flashlight, you cannot even see where the seats are. After a few minutes, though, the eyes "get used to the dark" and you can make out, with some degree of clarity, the rows of seats and people. This phenomenon is called *adaptation,* and it refers to the automatic adjusting of the light-sensitive cells in the retina to the prevailing level of illumination. Engineers call this an automatic gain control system.

Adaptation is, of course, bidirectional. You leave the theater after two hours and walk outside again. It is still bright although the sun is not exactly overhead, and you really cannot see. In fact, it is almost painful to keep your eyes open. Here again it takes time, in this case a few seconds, to let your system readjust itself to the prevailing level of illumination.

These examples of adaptation are actually rather extreme, occurring over several seconds or minutes. However, we also have the ability to carry out adaptation over what we might call *microtime*. One example of this is when the sun moves across the clouds briefly. The overall light level changes and our sensitivity changes with it, but we are barely aware of it. A more interesting example is the case of blinking which occurs very quickly. One hypothesis is that the function of blinking is to give little rest breaks to the retina by periodically lowering the amount of light that gets in. One authority has called these the windshield wipers of the eye.[18]

Adaptation over microtime becomes very crucial in consideration of the lighting and glare. We all know intuitively what glare is; it is basically unwanted light. Glare is to the visual system what noise is to hearing. In the case of the video display terminals, a good example of glare might be the very frequent situation where the screen is facing the window and the terminal is located between two banks of windows. This produces a double whammy. Since the operator is sitting with head erect, she/he is likely to be looking directly at a window. If the outside is sunlit, the light levels at that window may be something like three to four hundred times greater than the light level on the screen itself. At the same time, remember that all VDTs contain a glass faceplate over the display surface. Now, what is the definition of a mirror? A mirror is a piece of glass against a dark background. Therefore, by definition, most VDTs also act as mirrors. As a result, anything behind the mirror, in its direct optical pathway, is reflected in the mirror. So, if there is a second window or a row of overhead lights behind the screen, these objects are reflected in the screen. The result is that these images are, in a sense, competing with the character display.

Two things are going on here. First, assuming the operator is moving his or her eyes from screen to copy, those eyes are required to change adaptation rapidly from the paper copy, which consists of dark characters on a light background, to the screen, which is (typically) light characters on a dark background. However, the overhead lighting is an additional light source and it is very bright when compared with the VDT light, to which the focusing mechanisms of the eye must *also* respond.

Now, add to this the problem of reflected glare. By covering the screen face with an overall high level of illumination, the characters on the screen face are made difficult to read. This occurs because the contrast—that is, the difference in illumination between characters and background—is decreased.

Contrast is the basic optical characteristic that determines the visibility of an object as compared to its background. With print, for example, letters seen on an eighth or ninth carbon copy have an exceptionally poor contrast in the sense that the characters are "washed out" with respect to the background. The same thing happens when what is illuminated on the screen is covered with reflected glare. Therefore, as discussed before, the eyes' focusing mechanism is required to work harder.

Ergonomic Factors in Lighting and Glare Control

What is called visual fatigue or eyestrain is most likely a combination of excessive demand on the focusing and adaptational systems. I say "most likely" because although visual fatigue has been intensively studied for more than fifty years, physiological criteria of visual fatigue or eyestrain have yet to be defined.[19] Visual fatigue certainly exists as a subjective set of complaints or symptoms. Moreover, the factors just described are likely causes of this subjective state since, if these factors are improved, the symptoms are less likely to occur.

The next question is how to reduce eyestrain. Solutions are conceptually simple but sometimes complicated in practice. There must be sufficient illumination provided so that any paper copy can be easily read while at the same time avoiding large differences in illumination within the operator's field of view and also avoiding light sources that produce glare. Three factors complicate these requirements.

1. Unlike reading, the operator typically sits at the VDT with the head upright. Accordingly, the visual field of view is much more likely to include overhead light sources and windows. Thus there are many more potential glare sources in the visual environment of the VDT operator than has been true in the past when the predominant visual task involved bending the neck downward.
2. The mirror-like quality of the VDT presents additional glare control problems not seen previously.
3. The majority of VDTs now contain light characters on a dark background. This is exactly the opposite of paper text. Thus, there is an inherent difference in light levels moving from copy to screen even if all other factors are accounted for.

With sufficient funds and efforts all of these problems can be controlled. Creative light sources and fixtures can be used in combination to provide the required amounts of illumination. For some offices task lighting may be appropriate—i.e., small lights located at the workstation that illuminate only the copy. This is an old-fashioned approach that many designers object to because it tends to be messy. An additional problem of task lighting is that if there are rows of terminals, one operator's "task light" is another's glare source.

There are a number of ways glare sources can be minimized depending on the architecture and spatial orientation of the screens in the office environment. The problem is that most spaces in which many VDTs are now used were not designed with VDTs in mind. To solve this problem, there are simple and complex (i.e., expensive) solutions. Some simple solutions involve moving terminals around, reorienting them to avoid glare sources, hanging light barriers in front of offending light sources, and using curtains over windows. However, there are other human needs as well. Completely blocking out a window is definitely not recommended. Transparent screens or blinds on the market can give visual access to the outside while cutting down on glare.

Finally, there are various filters that reduce reflections on the screen face. Filters vary in price, but typically those that are very inexpensive tend to be counterproductive, causing more harm (by degrading contrast) than good. Although the final data on effectiveness are not in, I personally find useful either circular polarizers or micromesh filters. The best solution is to obtain samples and try them out. (This basic principle should also be applied to everything else I have said in this paper. There are not enough professional ergonomists to go around! Most will have to do ergonomic analysis on their own.)

Summary and Overview of Other Issues

There are many other ergonomic issues to be considered in the design of an efficient and comfortable interface between human and computer. This paper has ignored keyboard layout, key configuration, character format and design, screen format and design, mode of interaction (menu, command, joystick, mouse), program structure, ease of use, adequacy of reference materials (help commands), training, supervision by machine, monitoring by machine. To do all of these topics justice would require a book, not a short article.[20]

This review has attempted to focus on those ergonomic issues that seem to be health-related. Attention to details of ergonomic design will pay dividends in terms of increased operator performance and in terms of increased quality of work life. Ergonomic design considerations have "paid off" in office automation, and ergonomic design will certainly pay off in the special case of library systems.

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