Maximize

YOUR COMPUTING COMFORT & EFFICIENCY

There are a host of ergonomic considerations that influence design of computers and workstations and the way they impact on users

By Les Solomon and Al Burawa

RESEARCH into the human-engineering aspect of computing has taken on a new dimension of importance as more and more people become computer users. The end goal is to reduce as much as possible any form of human strain or stress resulting from long sessions at a computer, whether it's a sore back, irritated eyes, tired wrists, or even unnecessary operating complexities related to "unfriendly" software.

The efforts of manufacturers to adapt systems to human characteristics, which is an application of ergonomics or biotechnology, is a factor that buyers of computer(s) should weigh, along with how much memory comes with a machine and other considerations. Moreover, one should consider improving work-station conditions to enhance computing productivity. The following is some insight to what's being done and could be accomplished to make a human being and a computer more compatible.

Similarities to Typing. There are some basic similarities between operating a computer and typing on an ordinary typewriter. For comfortable and efficient typing, ideal height of the computer keyboard from the floor with respect to the seated operator is well established. It's the same as for a typewriter. And, since inputting (typing) is the same in both cases, a similar type of lumbar (lower-back) support chair—one that promotes good posture for minimal fatigue while seated at the keyboard—should be used.

Other computing environment features to take into account would be ambient lighting (the same or only slightly different for typing and computing), comfort index of the air-conditioning system, ambient noise levels, and a variety of physical and psychological factors.

Perhaps the most important physical (hardware) item that determines user comfort is the computer or terminal itself. There is currently a controversy over which is the "best" type of keyboard input/video-display output (terminal) to use. Two general designs are available: (1) keyboard, floppy disk, and video display integrated into a single package; (2) systems in which these items are separate and interconnected by cables.

Two-piece terminals are most often described as having "detachable" keyboards. This configuration has two basic advantages over the integrated keyboard/display system. The keyboard can be located almost anywhere, independent of the video display unit, to offer a degree of setup flexibility not possible with integrated systems. Keyboard and video display unit, then, can be set up for the best possible arrangement for a given work station. The other major advantage of this configuration is that, should the keyboard become inoperative for any reason, *only* this item need be removed and temporarily replaced with an alternate unit until the original is restored to operating condition.

The major disadvantage of the two-piece approach is that the keyboard may prove to be *too* "portable." Since it's usually very light in weight, the keyboard unit might be placed in locations where it can be accidentally dropped, such as from a lap, or swept off a narrow work surface. Also, because the keyboard is connected to the video display unit via an umbilical cable, one can expect eventual problems with the cable or connectors due to flexing.

Virtually all modern integrated keyboard/video-display systems are ergonomically engineered to maintain the two subsystems in fixed positions designed for user comfort and efficiency. Another important advantage is that integration keeps everything neat.

About Keyboards. A tremendous variety of keyboards are in current use. Even among keyboards that perform identical functions, different manufacturers use different criteria for their designs. Shape, layout, and "feel" of the keys can be extremely important, especially in applications that require intensive keyboard use, as in word processing. Once again, ideal parameters for computer keyboards can be borrowed from those of the standard electric typewriter.

Professional word/data processing operators prefer the same layout and spacing of the keys (on the main keyboard) that closely approximates the geometry used in modern office electric typewriters. A standard QWERTY keyboard in which alphabetic and numeric keys are the same as for typewriters has been, in most cases, adopted as the "standard," although punctuation and special characters might be located on unfamiliar keys.

All main keyboard keys should be laid out and contoured to assure maximum speed and typing efficiency with minimal effort. Extra banks of keys (for numeral entry, cursor control, and special functions), not normally within easy reach of the main keyboard, should be in a logical, easy-to-learn arrangement and the keys themselves should be shaped and sized about the same as for the main keyboard.

The slope of the keyboard, height of the "home" keys above the level of the typing surface, and pressure required for positive and reliable keystroking are just as important as keyboard geometry. A keyboard that's too high or too low for comfortable typing will cause an operator's wrists, forearms, and even neck and back to tire quickly. Keys that require too much pressure will have a similar effect on fingers, while too little pressure will result in erratic entry of data.

The "feel" of the keys is frequently the most important ergonomic factor professional users take into consideration. It's not uncommon for an operator to reject a keyboard with perfect geometry because the keystrokes don't "feel" right. High-quality keyboards have a feel much like that of a good office electric typewriter and provide either tactile or audible feedback to assure the user of successful entry. Keys shouldn't feel "rubbery" or "stiff" and must move very smoothly, with no evidence of sticking or other erratic behavior. Any departure from these ideals will reduce typing speed, efficiency, and comfort.

Finally, the height of the front edge of the keyboard, where the operator usually rests his wrists or the heels of his hands, should be considered in selecting a unit. Very-low-silhouette keyboards might have the SPACE-bar row of keys only a fraction of an inch above the surface on which the keyboard rests, eliminating any concern in this area. But most keyboard assemblies, even those in ergonomically designed professional systems, place this row of keys an inch or more above the surface, which could place stresses on the hands and forearms unless corrective measures are taken. In such cases, professional operators might push the keyboard several inches away from them to allow their wrists to rest on the table surface. A more direct solution, and one that keeps the keyboard at a more comfortable proximity, is to use a device known as a wrist rest.

The terminal keyboard, then, is a very important part of a computing work station, ergonomically speaking. A wide range of factors must be taken into account, choices becoming increasingly more critical as time spent per session at the work station increases. All-day operation demands selection of the best human-engineered keyboard designs available.

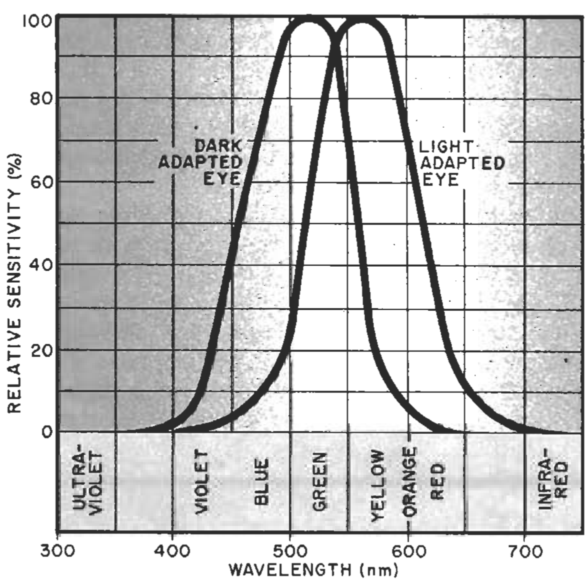
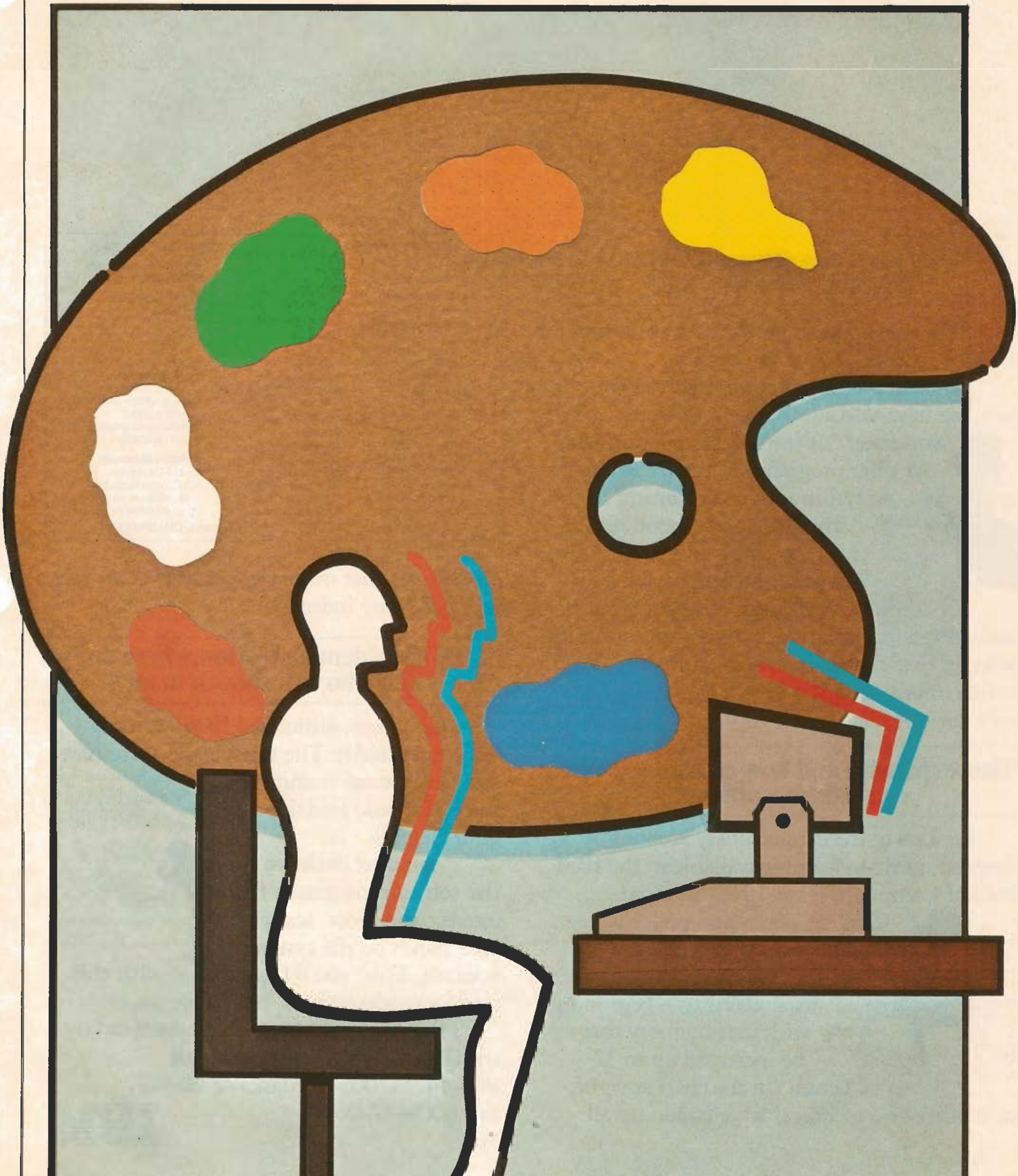


Fig. 1. Sensitivity to light of dark-adapted and light-adapted eyes.

Video Display Monitor. When personal computing first became a practical reality, no one really anticipated the severity of the operator problems that began to appear with prolonged sessions at video terminals. (One can't escape using a video monitor, basically because of the economy of displaying text and graphics on a CRT screen, and editing and correcting errors *before* printing it out in hard-copy form.) Since serious operators spend a large portion of their time at a terminal viewing video displayed material, the video display monitor has recently been the subject of much controversy.

Solving the ergonomics of keyboard design, didn't quite eliminate the complaints made by computer operators. Some of the remaining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complaints, it was soon discovered, specifically concerned the size of the CRT screen, displayed number of lines vertically and number of characters horizontally, distance away from the viewer, angle of view, and even color of the display.

Early attempts at relieving irritations induced by video displays resulted in integrated keyboard/display terminals with screens set at a fixed distance and nonadjustable angle for comfortable viewing. Screen size was more or less standardized at 10″ to 13″ diagonally, with 24 or 25 lines of 80 characters of displayed text the norm for professional systems. Addition of variable intensity, contrast, and focus controls made it possible for users to adjust displays for minimal eye stress. These changes, singly and in combination, went a long way toward solving many of the prevalent complaints. But they didn't solve all of them.

What Color? The latest controversy to come to the attention of computer terminal users revolves about, of all things, the *color* of characters displayed on video display screens. A steadily growing body of evidence is proving that display color is *very* important for operators who work at their computers for prolonged sessions. So much evidence has been gathered by very credible people and organizations, in fact, that it would be foolhardy to dismiss as unimportant the question of the color of the display.

Earliest full-screen video displays presented the viewer with white characters on a black background. In general, black-and-white displays have a high degree of contrast that viewers might initially find easy on the eyes. However, it was frequently found that white characters on a black background (and black characters on a white background) caused "burning" eyes and other temporary eye irritations. A few years ago, in an effort to relieve these problems, green-on-black character displays became popular. It was found that green displays helped to relieve many of the complaints of computer operators.

Until very recently, the only color choices available for monochrome video displays were white and green. Now, we're hearing and reading about yellow/amber, which some purport to be superior, ergonomically speaking, to both of the "traditional" colors. Some very impressive data has recently been compiled and published to support the contention that a yellow/amber display is, indeed, the best color to use for video displays. A brief review of the research that led to the announcement by proponents of yellow/amber displays is in order.

Confronted with complaints of eye irritations, a great deal of research has been conducted both here and abroad to determine the causative factors involved and to determine how to solve the problems. To make the research as meaningful and complete as possible, just about every physical and psychological parameter has been investigated, including time pressures, work loads, ambient lighting, air conditioning, video monitor placement, and the total work environment. Going a step further, even the physiology of the eye has come under scrutiny. These studies revealed many interesting facts about video monitors.

One very important fact noted early was that much of the eye problems encountered are attributable to the human eye mechanism with respect to color of the video display monitor. As early as 1976, only a year after the personal microcomputer became a practical reality, a study conducted by Skandia Insurance Company of Sweden revealed that the eyes were more frequently identified as a source of discomfort than either the back or shoulders, which ranked second and third, respectively.

Research into eye/video-screen interaction has revealed many psychophysical factors. At the top of the list is the spectral sensitivity of the eye in relation to the wavelength of light. As illustrated in Fig. 1, sensitivity to brightness is greatest at about 555 nanometers (nm), in the yellow/green range of the color spectrum. The graphed data also reveals a slight difference between light- and dark-adapted eyes.

A study of the spectral energy distribution of a "white" P4 phosphor commonly used in video CRTs reveals peaks in the blue and yellow regions about one diopter apart. It was assumed that the eye would continuously refocus between these two peaks, causing stresses and, if prolonged, headaches. While there's no concrete evidence to actually *prove* this premise, we do know that the eye oscillates naturally at about a 0.25-diopter amplitude at a 1-to-2-Hz rate.

After considerable study and ex-

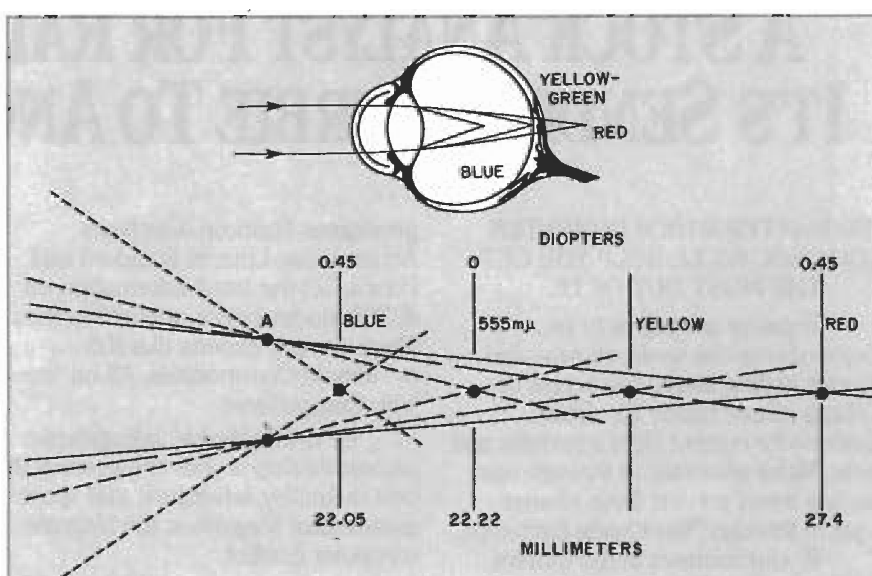


Fig. 2. Physical and diagrammatic representations of the chromatic aberration of the human eye.

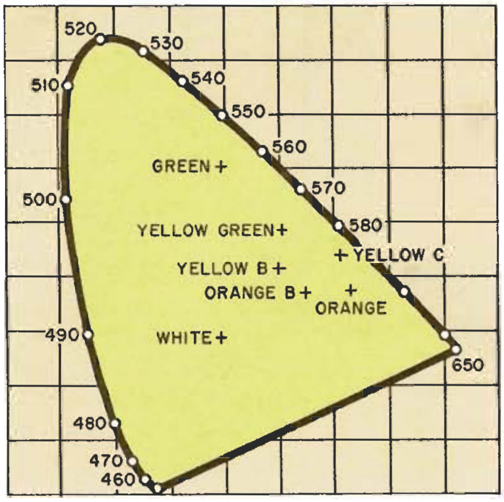


Fig. 3. At left are the positions of six different color symbols and white in the German Standard color diagram; and below are the results of a study of which are preferred on video monitors.

	Relative Performance	Preference Scores*
Green	+0.91	6.91
White	+1.83	6.48
Yellow-B (white with filter)	+5.58	7.18
Orange-A (white with orange filter)	−4.91	2.20
Yellow-A	+5.66	7.46
Yellow-C (yellow with amber filter)	+7.83	8.16
Orange-B (yellow with orange filter)	−16.5	1.65

*Scale ranges from 0 (no preference) to 10.

perimentation long before video terminals were developed, yellow proved to be such a highly visible color that it's now extensively used for road signs. The body of evidence that proves this point can be exemplified by a series of experiments conducted back in 1958 by Heinson. On a scale of 0 to 100, to rate quality of color visibility at a distance of about 200 yards, results were as follows: yellow rated 95; fluorescent yellow, 73; fluorescent orange, 69; orange, 54; fluorescent red, 51; red, 35; blue, 26; and green, 24.

Armed with the knowledge that the human eye is a highly chromatic but not color-corrected mechanism, Hartridge concluded in 1939 that it would appear that color fringes would be an important adjunct of vision. Absence of color fringing can be explained by assuming that yellow focuses at the retina of the eye and red and green focus slightly to either side of the retina, making circles of larger dimension, but of lmost equal size and combining to produce yellow. This slightly enlarges the blur circle. Furthermore, the blue end of the spectrum is so poorly focused as to be relatively dispersed and perhaps even below the threshold of vision (Fig. 2).

One recent study asserts that, if the symbol displayed is a different color from that of the background, the eye won't be able to bring the two into focus simultaneously. Actually, color contrast between symbol and background may be an aid to visual acuity, as long as the color differences are great enough.

In a German study, white and six different symbol colors were produced by CRTs with different phosphors (Fig. 3). Thirty test subjects (male and female between 19 and 42 years old), were required to make eye movements between the video screen and a sheet of paper for each combination of symbols and phosphors. With all tests completed, participants were asked to specify which color combination they preferred for their own video monitors. Results of the query, shown in the table accompanying Fig. 3, reveal that a yellow screen with an amber filter results in performance figures four times greater than those for a black-and-white display (7.83 to 1.83) and that green, yellow, and amber screens were preferred. Few of the test subjects cast votes for orange displays.

The German experiments also revealed that brightness and contrast of the displayed symbols were more important than the colors themselves when they were within the desired area of the spectrum. Filters placed in front of a white or other color phosphor offered no advantage, since they reduced spectrum bandwidth and luminescence. Only CRTs with phosphors that generate the desired colors were recommended. Finally, stray light impinging on the CRT screen had the effect of reducing contrast and creating blur.

An Austrian study focused attention on yellow and green. Some test subjects found no difference at all between the two colors, while others leaned definitely toward one or the other. Performance improvement was shown over a three-hour work period, with a higher rate of improvement for subjects who used yellow characters. Heart rates also declined during the test periods, but less for subjects who worked with yellow characters. Decrease of visual acuity during work (temporary myopization) correlated well with different lengths of working periods and ocurrence of breaks. It takes 10 to 15 minutes to regain good distance vision after focusing continuously on a video screen. Less myopia appeared among subjects who used yellow screens; yellow characters producing less reduction in visual ability than green characters.

The paper in which the Austrian test results and remarks appeared concludes that sustained working with a video display monitor does not change visual receptor functions but leads to functional changes in accommodation mechanisms and selective color adaption.

Although considerable scientific evidence is mounting in favor of using yellow/amber phosphors for video displays, manufacturers have been slow to move in this direction. Norway, Sweden, and Germany are now starting to use green, amber, and yellow in their terminal designs. German Trade Association Regulations covering design and use of video monitors have selected yellow, orange, or green for monochrome displays. While American manufacturers have been slow to follow the Europeans in this respect, there is some move in this direction. USI Computer Products Division, for example, is offering a line of amber video display terminals. The Heath Company's new H-100 series of all-in-one desktop personal computers offers buyers a choice of display colors, including nonglare white, green, and amber.

At this writing, very few of the companies worldwide that manufacture products for professional and home computing make available amber video displays. As support of amber displays increases, however, we can expect to see more and more terminal products incorporating the "new" color.

Use of neutral-density or color optical filters on a CRT for contrast or perception enhancement usually results in operators slightly increasing display brightness, which causes spots created on-screen to enlarge. One does obtain greater brightness, but at the expense of slightly defocused (blurry) images.

When the matrix that makes up a displayed character is observed in a slightly blurry condition, it takes on the effect of being displayed on a medium-to-low-bandwidth video monitor and may lead to eye fatigue.

At a viewing distance of 18", a typical user can usually separate dots (that form displayed characters) on the order of 0.005". Since viewers usually feel most comfortable with bright, sharply focused images that produce a brightness range of at least 30:1, screen filters should be carefully selected.

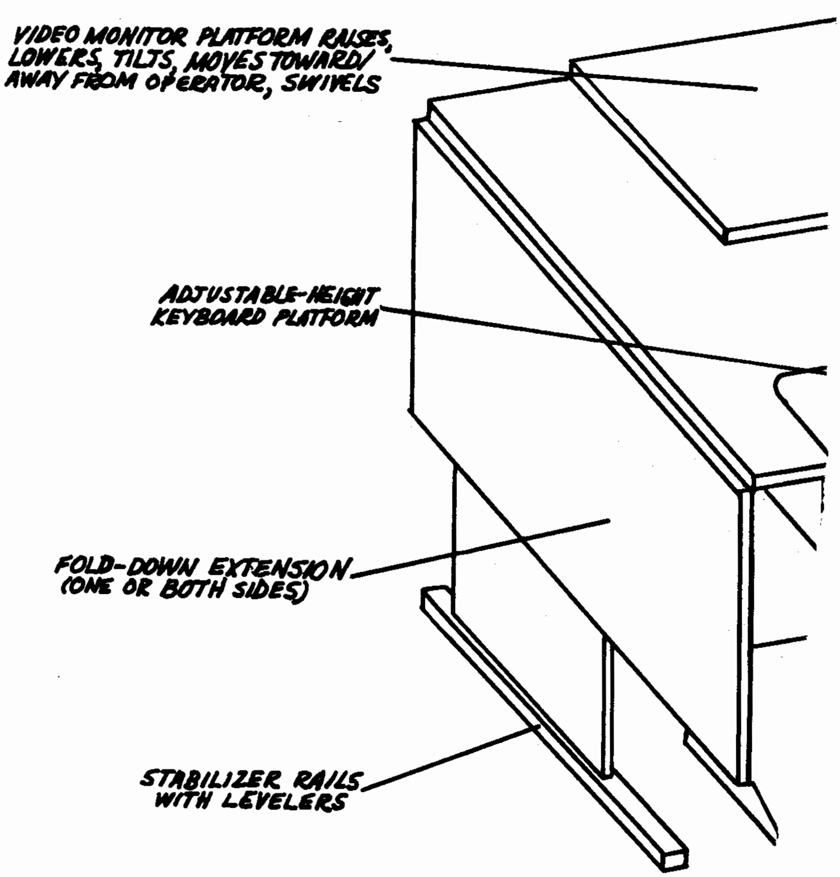
Computer Furniture. It would be inaccurate and unfair to place all the blame for operator ills on computer terminals. Except in relatively rare cases, manufacturers of computer products, having been made aware of the complaints, have striven to correct deficiencies. In general, professional and many home computer products are generally designed following sound ergonomic principles. Almost all of the complaints remaining can be directly attributed to factors outside the computer, perhaps the most important being the furniture used at computer work stations.

An ergonomic computer work station begins with the surface on which the video terminal sits. The task is greatly simplified for all-in-one computers and systems in which keyboard and video display monitor are integrated into a single terminal unit, since obtaining a typewriter-table height with sufficient depth and workspace on both sides will suffice. Standard office typewriting stations can be directly adapted for use in environments with this type of terminal or computer.

For stations at which only word and data processing functions are to be performed, a simple computer system table, preferably with adjustable height and with sufficient workspace on either or both sides of the terminal's location, will suffice. This type of "desk" is very similar to the typing returns common with secretarial desks, except that it's usually 30" deep. (Add-on returns, on the other hand, are only 24".)

As a rule, the computer system table is the least expensive type of "desk" available for the computer office. In its least expensive form, the table consists of little more than a work surface and the legs to support it. However, it can be made to suit just about any special need by adding an optional module that bolts to the bottom of the work surface to provide storage facilities for manuals, floppy disks, extra disk drives, etc. and bookshelves that mount above the computer or terminal.

In very elaborate single-operator setups, full-size desk-height modules can be bolted to computer system tables. Individual computer system tables can be bolted together with the aid of sturdy triangle connectors to give one operator more work space or to provide work sta-



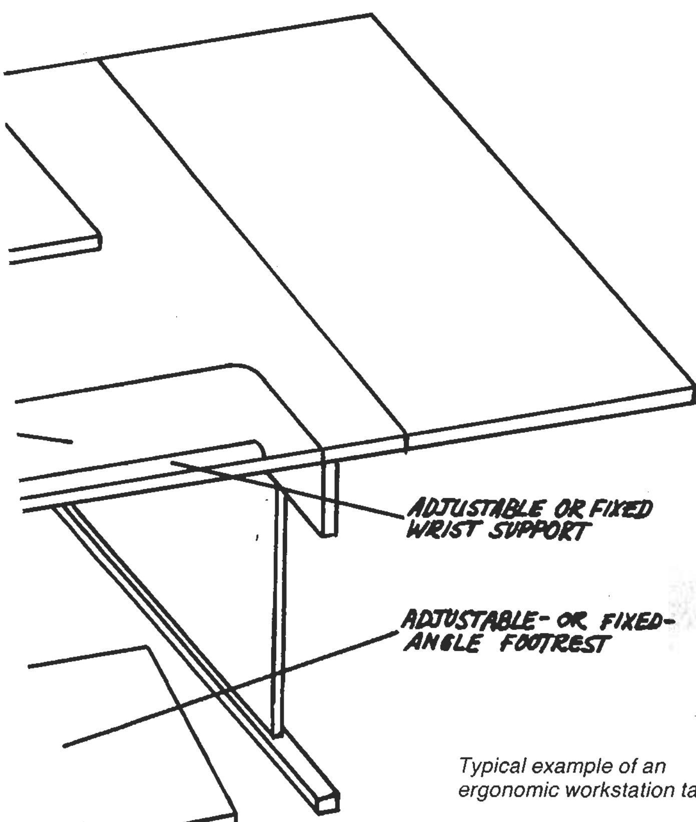
tions for two or more operators in multi-user setups.

Computer-system-table-based setups can be used with both integrated and two-piece video terminals, although they're more appropriate for the former. Most retailers who sell computer products to the professional market offer at least one version of these modular systems at point of sale.

Home computerists who buy from electronics specialty stores, computer outlets, discount stores, and mail-order houses can also obtain this type of furniture—but not presently from furniture or most office-supply stores. Local computer stores are good places to try. Even if they don't have the furniture in stock, most can order it.

True ergonomic computer work station furniture is designed for maximum user flexibility. For example, it allows you to adjust the height of the terminal keyboard independently of the video display monitor (in two-piece systems) to the most comfortable levels and positions. Additionally, a turntable accessory placed under the video display monitor can provide a means for swiveling the monitor and even tilting it by 5° to 10° up and down for easy viewing. If a work station is equipped with a video display monitor platform, it might be adjustable by 6″ or more in height above the work table, by as much as 9″ toward and away from the operator, and by 5° to 10° tilt up and down, with 360° of rotation around its perpendicular axis.

It's obvious from the foregoing that application of ergonomics to computer furniture isn't based on the size of the "average" person, as has traditionally been the case with other office furniture. By offering a wide range of controls, ergonomic computer furniture can be adjusted for operators who are much shorter or taller than "average."



Typical example of an ergonomic workstation table.

Ergonomics in the computer environment also takes into account conditions that formerly escaped consideration. For example, any work station can be equipped with an adjustable (or fixed) resilient wrist support that greatly reduces wrist, shoulder, and arm strain. Also, a fixed- or adjustable-angle footrest can be used to good advantage for comfortable in-place computing. Being seated at a computer terminal for hours at a time with the feet flat on the floor can and often does cause reduced circulation and tiring of the leg muscles. By slightly elevating the feet and placing them at a more natural angle while seated, a footrest promotes good circulation and places less stress on leg muscles.

The chair at a work station is a very important element of any computer setup. No matter how well designed the rest of the furniture at a computer work station, poor selection of the chair will erode operator comfort and result in decreased efficiency. The typical ergonomic chair is designed to promote good posture, which assures maximum comfort and encourages maximum efficiency.

Ergonomic chairs, like work stations, are sturdy and fully adjustable. Available with and without arm supports, they're equipped with casters for easy movement. They have facilities for adjusting height and horizontal positioning of lumbar-support backs, height of seat above floor, and arm-rest height (where applicable). Additionally, all seats, backs, and armrests are specially contoured and padded for comfort and to aid in circulation.

Physical Parameters. Just how everything at a computer work station should be arranged for maximum comfort depends on the individual operator. However, some generalized guidelines that roughly define limits of the physical parameters involved have been suggested by the National Institute for Occupational Safety and Health. The various dimensions and angles illustrated in Fig. 4 are defined as:

• A) Height of the home row of keys on the keyboard should be be-

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tween 28¼" and 31". The European recommendation is 28¼" to 29½", while the U.S. military specification is 29¼" to 31". In the design of ergonomic computer furniture, at least this, and usually greater, range can be accommodated via operator-adjustable controls.

- **B)** Viewing distance to the screen of the video display monitor should be between 17¼" and 19¾", but not over 27½", for screens measuring between 10" and 13" diagonally.
- **C)** The center of the CRT screen should be 10° to 20° below the horizontal plane of the viewer's eye level. There's some controversy here, however. At least one researcher recommends that the top of the screen be below eye level, while another researcher claims that the top of the screen should be 10° to 15° below eye level, with no portion of the screen at an angle greater than 40° below the horizontal.
- **D)** Recommended angle between upper and lower arms when seated at the keyboard is between 80° and 120° for maximum operator comfort.
- **E)** Angle of the wrist in the typing attitude should be no greater than 10°.
- **F)** The keyboard should be at or below elbow height.
- **G)** Sufficient room should be left under the work surface to accommodate all leg movement without hindrance.

The above recommendations should be followed to initially set up an ergonomic work station. With actual experience garnered from several extended-period sessions at the work station, the various parameters can be adjusted to suit individual needs and desires.

Environmental Conditions. Selecting an ergonomic computer work station and equipping it with an ergonomic chair doesn't complete the task of setting up an ergonomic center. One must also take into consideration other physical and psychological factors that will encourage efficiency.

Ambient lighting is an important factor to bear in mind. As a rule, the light level should be sufficient for *all* tasks to be performed, including viewing video-displayed text and any printed and written matter without strain. Generally, a mix of natural sunlight and indirect overhead fluorescent lighting is best, but fluorescent-only lighting is a good alternative. *Never* place a video display terminal in a location where the CRT screen will receive direct sunlight, for example. The same applies to man-made light. If a terminal can't be located where it will be shielded from direct overhead lighting, equip the display unit with a CRT visor, which can be obtained from most computer specialty products suppliers.

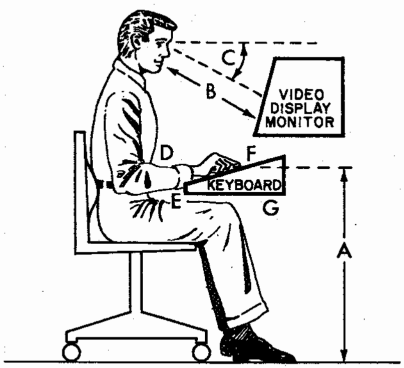

Fig. 4. Recommended workstation dimensions as detailed in text.

Ambient sound level should be minimized to eliminate distractions that can reduce operator efficiency. Some of the noise sources that greatly intrude on a computer operator's concentration include: constantly ringing telephones, typewriters, passing traffic, loud music, and even the hard-copy printer used with the computer.

If possible, locate computer work stations away from telephones (or reduce the level of the telephone's bell to minimum or replace the bell with a less insistent tone signal) and typewriting stations. There are two ways to deal effectively with traffic noise—select a room away from the street or acoustically treat the room (carpeting and acoustical tiles on walls and ceiling work wonders).

Music is OK in the computing environment, as long as it isn't intrusive. If you must have it, keep it soft and select a type that doesn't reduce concentration.

There's no need to keep a hard-copy printer at the computer work station, since all copy will normally be reviewed on the video display monitor's screen before it's printed out. Therefore, it's best to locate the printer where it will be convenient if necessary, but not so near that its normal operating noise will be intrusive. Of course, if the printer *must* be near the computer work station, you can consider buying one of the new low-noise printers or equip an existing noisy printer with a noise shield, which can be obtained from some computer specialty houses.

Adjusting ambient temperature for 68° to 72° F and humidity to 30% to 40% will eliminate any concern about the "air" factor and operator efficiency. (These are also the ranges recommended for optimum computer operation.)

One psychological factor sometimes overlooked in setting up a computer work environment—any office environment, for that matter—is the color scheme. The working environment can have a very beneficial effect if a color scheme that doesn't intrude is used. Very bright and highly contrasting colors can be disadvantageous. Some colors, specifically the fluorescent variety, can have a disturbing "pulsing" effect, while dark and drab colors (dark green, brown, gray, etc.) can set the wrong mood. Practically speaking, mixing neutral and earth-tone colors, such as pearl-gray, tans, toned-down oranges, wood-tone browns, and greens, sets a good psychological mood and contributes strongly to an efficient, comfortable working environment.

Summing Up. A carefully planned and executed ergonomic computer working environment is at its best when all factors, physical and psychological, are considered. This is particularly true in professional applications, where computer operators are required to spend hours at a time computing and word/data processing. ◇