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A PRIMER ON WORKSTATION ERGONOMICS

The science and practice of ergonomics has matured remarkably in the 1980's. Ergonomics concerns the softer aspects of the work environment, and addresses those physical and psychological issues which make a product easier to use. In a sense, ergonomic design standards and principles address equipment problems which might be called chronic rather than acute. By alleviating eyestrain, postural discomfort, and fatigue, the emerging standards for workstation furniture and displays have the benefit of helping workers to stay happier, healthier, and more productive. In Europe, some of these standards are mandatory; in the United States, they are clearly well-advised. We will concentrate on the recommendations in the recent American National Standard ANSI/HFS 100 (1988), Human Factors Engineering of Visual Display Terminal Workstations.

The scope of ergonomic investigation is broad, including the entire working environment. Even with our narrow focus on monitor products, we will have to address many factors. ANSI/HFS 100 covers three major areas:

- Postural effects: the "furniture" issues
- CRT related physical issues
- Software controllable display parameters

The first class of recommendations, contained in Section 8 of the Standard, fall outside the scope of this article. The complete workstation environment includes the chair, the desk, the CRT pedestal, the keyboard housing, overall lighting, and other issues more in the province of the industrial designer than the electrical engineer.

CRT ERGONOMICS

While there may be little the electrical engineer can do about the workstation furniture, he has almost total control over the visual impact and ease of use of the display. The recommendations of the standard are concerned with the visual effect seen by the user; they require a unified view of the interaction between the physical display hardware and its firmware.

ANSI HFS 100-1988, Human Factors Engineering of VDT Workstations
ANSI S1.13-1971, Method for the Measurement of Sound Pressure Levels
ANSI S12.10-1985, Method for Measurement and Designation of Noise Emitted by Computer and Business Equipment
ECMA TR/22(1984), Ergonomics Recommendations for VDU Work Places
ECMA-110 (1985), Ergonomics—Requirements for Monochromatic Visual Display Devices
MPR-P 1987:2, Sweden, National Council for Metrology and Testing, Testing Visual Display Units
DIN 66234, parts 1,2,3,5,(1980) VDU Workstations
ZH 1/618 (West Germany) (1980), Safety Regulations for Display Work Places in the Office Sector

TABLE 1: Ergonomic References

Visual ergonomic recommendations are based on the characteristics of the human operator. The human visual system, while remarkable, has its limits. There are constraints on luminance, chrominance, and spatial discrimination. Flicker, jitter, display asymmetry, and ill-chosen character formats and spacings will slow task performance and can soon introduce eye strain. The workstation screen must be easily readable in normal workplace illumination. ANSI's major recommendations, which are similar to those contained in the European ECMA standards, include:

HOUSING FINISH: To minimize distracting glare, the reflectance of equipment covers should be less than 45%, measured at a 60 degree angle.

ACOUSTIC NOISE: Ambient sound pressure levels should be below 55 dBA. This is an average "A" weighted reading above the nominal threshold of hearing sound pressure level of 20 dbPa. Broadband, or non-coherent noise, such as that typically produced by fans is less bothersome than discrete impulsive pops or continuous whistles. Recommended measurement methods are contained in ANSI standards S1.13-1971 and S12.10-1985.

RESOLUTION: The sharpness of the display can be measured in a variety of ways. This standard utilizes the Modulation Transfer Function Area (MTFA) as a figure of merit. At the present time, this method is only applicable to monochromatic displays. MTFA, as shown in Figure 1, integrates the margin between the photometric response of the CRT screen (its modulation transfer function) and the contrast/resolution characteristics of the human visual system. Although the MTFA can be calculated on the basis of direct photometric measurement of the screen characteristics, a simplified estimation formula requiring knowledge of the display luminance characteristics, viewing distance, and spot size is presented by ANSI. The MTFA must be at least 5.

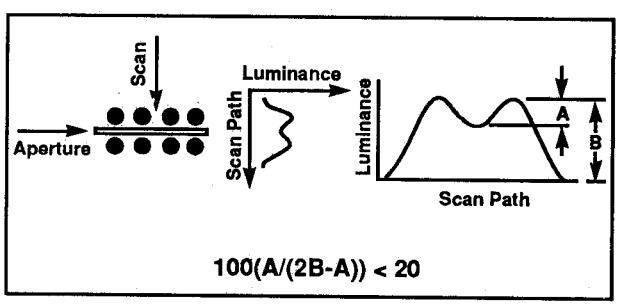

FIGURE 1: The MTFA measures legibility by integrating the "margin" of available discrimination. The vertical axis plots normalized intensity variations. For the display, the modulation is relative. For the user, what is plotted is the minimum contrast necessary for discrimination. The horizontal axis plots spatial frequency, normalized to account for viewing distance.

RASTER MODULATION: The percentage of raster modulation should be under 20%. Raster modulation is the variation in brightness of letter strokes due to raster scanning. Solid letters are easier to read than those composed of a visible array of dots. This is the same effect that makes letter quality printing preferable to a coarse dot matrix representation.

CONTRAST: The ratio between the luminance of characters and background should be at least 3 to 1 and preferably above 7 to 1. Smaller characters require higher contrasts.

IMAGE POLARITY: The standard makes no imposition of image polarity. Both light characters on a dark background, and the reverse display method are acceptable. It is pointed out, however, that the display of dark characters on a light background appears to minimize the effect of reflections on the CRT screen, but that the price to be paid is that a higher refresh rate may be required to reduce flicker.

COLOR USAGE: A minimum distance between adjacent colors—for example, letters on colored backgrounds—is specified in terms of distance units in the 1976 CIE Uniform Color Space. To allow for differences between devices, user color discrimination capabilities, and the effects of ambient lighting on apparent color, it is recommended that a limited number of colors—about 10—be used. It is also suggested that pure red and pure blue be avoided. The visual system's resolution is less acute for pure blue than for other colors. Pure red is poorly perceived by the partially color blind.

LUMINANCE CODING: Intensity can be used to communicate information, especially on monochromatic displays. Luminance intensity coding may be absolute or relative. Absolute coding should use no more than 2 levels for displays of medium brightness (60 to 100 cd/m^2) and 3 levels for brighter displays. If relative brightness is used to convey information, more levels can be employed. Adjacent areas, such as those in a pie chart, should have a luminance difference of at least 7 percent. If the areas to be coded are nonadjacent, the luminance steps must be greater—at least 20 percent. Because of the adaptibility of the visual system, perception of absolute levels is limited, and absolute luminance coding should be used sparingly.

BLINKING: Blinking of information should be between 0.8 and 5 Hz. If necessary, two blink rates may be used, if their repetition rates are separated by at least 2 Hz. A blinking duty cycle of 50% is recommended.

IMAGE LINEARITY AND STABILITY: There are several parameters which govern whether a display will be free of distortion. "Linearity" in this context encompasses two recommendations. The displacement of a character relative to an adjacent one should be no more than 5% of its size. With respect to columns and rows, linearity variations, defined as deviations from parallel relative to the display size, should be under 2%. "Symbol distortion" measures relative changes in the sizes of symbols across the display, and should not exceed 10%. Lastly, physical jitter of the display should be limited. Low frequency jitter is perceived as a "wobble" of the display. Jitter in the range from 1 to 3 Hz is most irritating. At high jitter rates—above 25 Hz, physical jitter can not be distinguished from image blurring. It is recommended that the peak excursion from the normal position of any symbol in a one second interval divided by the viewing distance be under .0002. In other words, jitter at a normal viewing distance of approximately 15 inches should be no more than .003 inches, or .006 inches peak to peak.

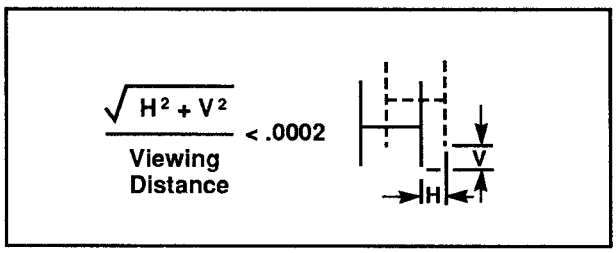

FIGURE 2: Display jitter must be strictly limited. The peak deviation allowed is expressed in proportion to the viewing distance.

LUMINANCE UNIFORMITY: The luminance of a display should not vary by more than 50% over its surface relative to that at the display center.

FLICKER: The display should appear flicker-free for at least 90% of the users. Flicker is governed by the interaction of the displays's refresh rates and phosphor persistence characteristics, the display luminance, and ambient lighting.

GLARE REDUCTION: The controlling of glare, through coatings, screens, polarizers, and workstation positioning is recommended, but not yet quantified.

CHARACTER SIZE: For legibility, the minimum character size shall subtend 16 minutes of arc at the normal viewing position, with a size of 20 to 22 minutes preferred. If characters are used in groups, as for text, a maximum size of 45 minutes of arc is also required. This recommendation strikes a balance between the acuity limits of human vision and the small size of the retinal fovea, where vision is acute. It is noted that for characters where quick recognition is not essential, the character size may be decreased further, to a minimum of 10 minutes of arc.

CHARACTER FORMAT AND PROPORTION: The dot matrix representation for characters used in continuous reading should be a minimum of 7 x 9. If lower case is used, at least one (and preferably two) extra vertical dot should be used to accomodate descenders. Similarily, if diacritical marks are used, the vertical height must be extended upwards two additional dot positions. A 5 x 7 matrix will suffice for numeric and uppercase-only presentations, and superscripts and subscripts may be displayed in a minimum 4 x 5 matrix. Fixed character width displays should endeavor to keep the height to width ratio of individual characters between 1:0.7 and 1:0.9. If a display format requires more than 80 characters on a line, the ratio may go as low as 1:0.5. The width of the strokes used to make up a character should be more than 1/12 of the character height, and inter-character spacing should be at least 10% of the character height.

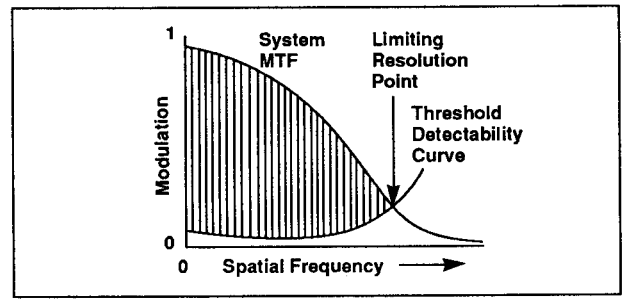

FIGURE 3: Raster modulation makes lines appear dotted. The measurement method uses a slit and a photometer.

LINE AND WORD SPACING: Words should be separated by a full character width, and lines must be separated by a minimum of 15% or two stroke widths, whichever is greater. Note that the interline separation starts below any descenders and above any accent marks.

VIEWING INCIDENCE: The angle between the viewers line-of-sight and a line perpinduclar to the display should be no more than 40 degrees.

VIEWING DISTANCE: The minimum viewing distance for the display should be 12 inches, unless there is some special requirement for closer operator requirement. Normal reading distance is 16 inches. It is pointed out that longer viewing distances may also be employed.

The "look" and "feel" of a product are affected by many factors. Ergonomic science has quantified many aspects of product performance that were formerly bundled together under the notion of styling and brought them into formal view where the designer can control them.

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