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Display Station Anthropometrics: Preferred Height and Angle Settings of CRT and Keyboard

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This study investigates display station physical adjustments preferred by a sample of visual display terminal operators. Participants in the study were selected to assure representation of extremely short and extremely tall persons, as well as persons of midrange physical stature. Individual operators were led through a step-by-step sequence to determine their preferred initial settings of seat height, keyboard height and slope angle, and CRT height and tilt angle. Each operator then performed a brief text input task, after which final preferred adjustments were measured.

Intermeasure correlation strongly suggest that "flat" (low slope angle) keyboards are inappropriate for short operators who select low seat heights. In addition, the keyboard angle adjustments preferred by most operators substantially exceed a current German ergonomic display station requirement.

INTRODUCTION

Recent research reports (Smith, Stammerjohn, Cohen, and Lalich, 1980; Springer, 1980) and newspaper and trade press articles (Bronson, 1980; Eisen, 1980) have given increasing attention to adverse effects purportedly caused by sustained use of visual display terminals (VDTs), such as eyestrain, backache, neckache, arm fatigue, etc. However, there is also growing recognition that these problems may be the result of many factors other than the display hardware, such as inadequate operator seating, poor ambient light control, and constraints imposed by display station furniture that prevent the optimal adjustment of CRT, keyboard, and source material, for the individual operator (Stewart, 1980).

The present study takes its rationale from the judgment that operators' postural preferences are, in fact, badly neglected in most existing display workstation configurations. Consequently, a vital concern for those who design and develop display station hardware is the determination of that set of human factors requirements that are directly influenced by the physical variability among representative users. To assure that the study would allow adequate opportunity for the expression of variability requirements, two guidelines were followed. First, an effort was made to emphasize the representation of operators who were extreme in stature, as well as those falling in the middle range. Second, specially

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designed workstation furniture was utilized, providing an unusual variety of physical adjustment capabilities to accommodate the preferences of each operator.

Within these governing guidelines, the objectives of the study were to secure preliminary answers to the following questions:

(1) What are the average values that operators choose for display screen height, keyboard height, display screen tilt angle, keyboard slope angle, and seat height?
(2) What are the range limits for the variables that are needed to accommodate individual operators adequately?
(3) What correlations exist among these variables that may have implications for improved product design?

METHOD

Subjects

Subjects were selected from a pool of available display station users at a computer development and manufacturing site where more than 800 terminals are in active use and more than 4000 employees are authorized to use them. Sixty-six volunteers responded to a posted announcement seeking participation by persons who were "notably taller or shorter in physical stature than the average person." From this initial group, 37 operators were selected. The final group included people of midrange stature, as well as individuals who were either extremely tall or extremely short.

Fifth, 50th, and 95th percentile values of physical stature for U.S. as well as Japanese civilian adult men and women (National Aeronautics and Space Administration [NASA], 1978a, 1978b) were used to guide the selection of a "U.S. sample" and an "oriental sample" of operators. The U.S. sample consisted of 27 whites and 2 blacks. The oriental sample consisted of 3 persons of Japanese ethnic origin and 5 of Chinese ethnic origin. Of the 37 persons selected, 22 were men and 15 were women. Figure 1 shows the distribution of the selected subjects with reference to their most appropriate male or female surveyed population sample. Extreme and midrange individuals were fairly well represented within the U.S. men (N = 17), and U.S. women (N = 12), if not the oriental men (N = 5). However, the three oriental women included two who far exceeded the 95th percentile, and none of the three were near the 5th percentile.

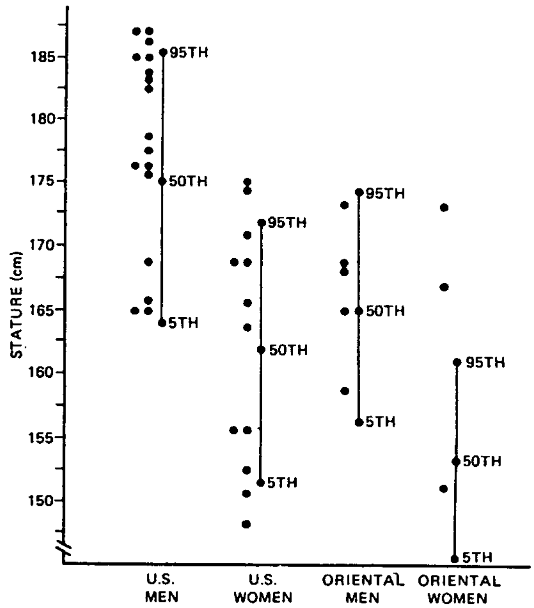


Figure 1. *Distribution of stature.*

Apparatus

A scale with an attached anthropometer rod was used to measure the stature (unshod) of each prospective participant in the preliminary screening. For the subsequent display station study, two operator chairs by N.K.R., which were adjustable using gas cylinders, were used. Also employed was specially designed N.K.R. display station furniture that permitted independent adjustment of tilt and height for the CRT and, with some structural modifications, slope angle as well as height of the keyboard. Due to mechanical limitations, the minimum possible angle of adjustment of the keyboard slope was 14 deg. Two articulated-arm document holders were also provided, allowing maximum freedom of document placement.

The operators worked with a VDT that had a display screen midpoint 238 mm high when the unit was placed on a horizontal support surface. A tape measure and protractor were used for direct measurement of all dimensions and angles. For additional documentation of the operators' postural orientations, videotape recordings and still photographs were taken of each operator during the typing task.

Procedure

After attaining a preferred adjustment of seat height and backrest height and tension, each operator was instructed to sit at a comfortable distance from the workstation. The experimenter then adjusted the keyboard support surface twice; from below the preference point and from above. The participant was asked to inform the experimenter when the preferred keyboard height was reached during each movement. The keyboard support surface was set at the average of the two chosen heights. The keyboard slope angle, CRT height, and CRT angle were all adjusted in the same manner. The operator was also given a choice of two document holders (on the right of the keyboard or the left) and was instructed to adjust the holder as preferred.

Each participant was then asked to transcribe a page of text. During the input task participants were urged to make any readjustments they deemed necessary. The entire input process was videotaped and photographed. Following the task, measurements were taken of final preferred furniture adjustments.

Some operators required special arrangements to achieve a desired furniture adjustment. To accommodate several tall participants, incremental table-leg extenders were used to raise the table. Some of the short participants required the removal of chair casters. Occasionally, as additional compensation for short participants, wooden panels (as shown in Figure 2) were used to raise the effective floor height.

RESULTS AND DISCUSSION

Means, high and low values, and standard deviations (SD) of stature, seat height, CRT angle, CRT height, keyboard angle, and keyboard support surface height are shown in Table 1.

Spearman rho correlation coefficients among the measured variables were also calculated. The correlation coefficients that proved significant at the 0.05 level are shown in Table 2.

A summary of means and extremes of the adjustments that were preferred by the total group is shown schematically in Figure 3, which also includes median values. Although there were more individuals of high stature than low stature (16 high, 11 midrange, 10 low), differences between the means and medians were very small; the largest was a 12-mm difference in preferred seat height.

Figure 2. *Operator accommodated with added floor panels and removal of chair casters.*

TABLE 1

Operator Stature and Preferred Adjustment of Seat, CRT, and Keyboard*

	Total Group	Men	Women	U.S. Sample	Oriental Sample
Stature					
Mean	1706	1758	1629	1719	1658
Highest	1875	1875	1753	1875	1735
Lowest	1486	1588	1486	1486	1511
SD	111	89	96	116	76
Seat Height					
Mean	438	456	410	445	408
Highest	520	520	500	520	450
Lowest	350	400	350	365	350
SD	45	35	44	44	37
CRT Angle					
Mean	3	3	3	3	3
Greatest	7	7	6	7	5
Least	0	0	2	0	0
SD	1.6	1.8	1.3	1.7	1.4
CRT Height**					
Mean	925	934	912	933	896
Highest	1060	1057	1060	1060	990
Lowest	783	783	842	842	783
SD	59	52	69	58	59
Keyboard Angle***					
Mean	18	17	19	18	18
Greatest	25	20	25	25	19
Least	14	14	16	14	14
SD	2.2	1.5	2.4	2.3	1.7
Keyboard Support Height					
Mean	630	646	607	632	623
Highest	725	725	657	725	649
Lowest	560	576	560	560	576
SD	39	35	33	42	25
n	37	22	15	29	8

* Heights in mm; angles in degrees.
** Measured to display screen centerline.
*** Includes 15-deg angle slope of keyboard + variable angle of support surface.

Keyboard Adjustments

A finding of considerable interest was the −0.71 correlation between keyboard angle and seat height (total group). This relationship raised a question about the desirability of fixed angle keyboards, with particular reference to recent German regulations that require keyboard inclination "to be kept as low as possible, preferably lower than 15°" (Trade Cooperative Association, 1980, Section 4.3.2). The total consistency shown for this relationship in the secondary analyses (men, women, U.S. sample, oriental sample) strongly suggests that fixed, low-slope angle keyboards may be generally inappropriate for operators who prefer low seat heights.

Keyboard slope angle ranged from 14 deg to 25 deg with an overall mean of 18 deg, which exceeds the German recommendation. However, the 14 deg lower-limit angle settings cannot be accepted as a true minimum since the mechanical constraints prevented any effective angle adjustment lower than 14 deg. Nevertheless, the distribution of keyboard angle settings preferred by the operators (Figure 4) appears to strongly contradict the German recommendation that keyboard slope should be kept lower than 15 deg.

The correlation between stature and keyboard angle was also negative (r_s = −0.43, total group). In view of the finding that stature also correlated highly with preferred seat height (r_s = 0.93, total group), and it is known, additionally, that hand length is positively correlated with stature, r = 0.654 (Roebuck, Kroemer, and Thompson, 1975, p. 429), it is reasonable to suppose that preferred keyboard angle is influenced by stature and hand length or both. One possible explanation is that an increased keyboard angle may serve to shorten finger travel distance from home row to the top row or space bar, thereby better accommodating those with shorter hand lengths.

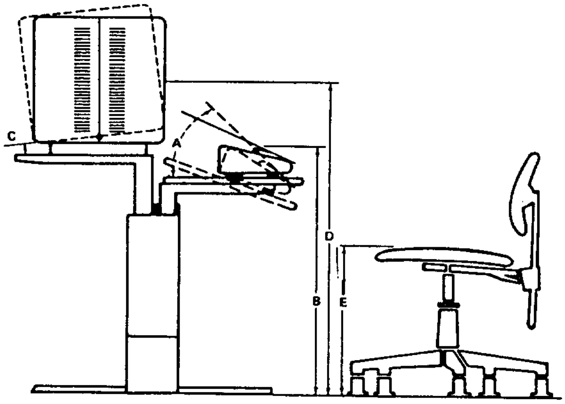
Keyboard slope has historically received

TABLE 2

Intercorrelations of Operator Stature and Preferred Adjustments of Seat, CRT, and Keyboard*

	Total Group	*Men*	*Women*	*U.S. Sample*	*Oriental Sample*
Stature and:					
Seat Height	0.93	0.93	0.96	0.91	0.81
Keyboard Support Height	0.71	0.67	0.60	0.78	NS
CRT Height	0.71	0.57	0.71	0.62	0.86
Keyboard Angle	−0.43	NS	NS	−0.45	NS
CRT Angle	NS	NS	NS	NS	NS
CRT Height and:					
Keyboard Support Height	0.57	0.50	NS	0.61	NS
Seat Height	0.74	0.51	0.70	0.68	NS
Keyboard Angle	NS	NS	NS	NS	NS
CRT Angle	NS	NS	NS	−0.44	NS
Keyboard Angle and:					
Seat Height	−0.71	−0.47	−0.68	−0.70	−0.88
Keyboard Support Height	−0.37	NS	NS	−0.47	NS
CRT Angle	NS	NS	NS	NS	NS
Keyboard Support Height and:					
Seat Height	0.74	0.74	0.65	0.82	NS
CRT Angle	NS	NS	NS	NS	NS
Seat Height and:					
CRT Angle	NS	NS	NS	NS	NS

* Significance level of Spearman rho correlations shown is $p \leq 0.05$.



		LOW	MEAN	MEDIAN	HIGH
A	KEYBOARD ANGLE	14°	18°	17°	25°
B	INCLUSIVE KEYBOARD HEIGHT(mm)	637	707	711	802
C	CRT ANGLE	0°	3°	3°	7°
D	CRT HEIGHT (mm)	783	925	922	1060
E	SEAT HEIGHT (mm)	350	438	450	520

Figure 3. *Means, medians, and extremes of preferred adjustments (total group).*

relatively little systematic study (Alden, Daniels, and Kanarick, 1972). In one study in which keyboard slope was varied from 0 to 40 deg (Scales and Chapanis, 1954), no significant differences in keying errors or speed occurred. However, the operators did express a preference for substantial amounts of slope; half of the individual preferences ranged between 15 and 25 deg. The task in this study consisted of keying 10-character alphanumeric groups.

Galitz (cited in Alden, et al., 1972) studied keyboard performance with experienced typists, comparing slope angles of 9, 21, and 33 deg. Again, no significant performance differences were found. In this study, the participants preferred the 21-deg slope, which was closest to their normal typewriter slope angle (between 16 and 17 deg).

Adjustability of keyboard slope is evidently essential to accommodate individual preferences. To further our understanding of keyboard slope angle preference in relation to seat height and stature, additional research studies should be done to measure speed and error rates based on sustained periods of work at varied keyboard angles. Comparison of specific keyboard applications, such as word processing and data entry, would also be highly desirable.

Preferred keyboard support height in the present study ranged from 560 mm to 725 mm, with a mean of 630 mm (total group). Since the keyboard itself had a fixed home row height of 77 mm, the inclusive keyboard height—the distance from the home row key tops to the floor—is calculated to have ranged from 637 mm to 802 mm, with a mean of 707 mm. (A negligible error is introduced in this calculation as the slope angle is increased from 15 deg and the home row is pivoted downward; i.e. at 25 deg, the maximum angle recorded, the actual distance from home row to the floor is overstated by about 16 mm). Keyboard height for the total group correlated positively with stature ($r_s = 0.71$),

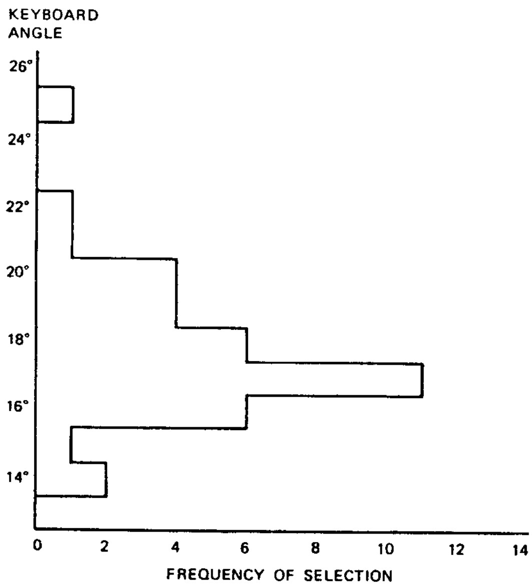


Figure 4. *Distribution of preferred keyboard angle settings.*

with seat height (r_s = 0.74), and with CRT height (r_s = 0.57).

Based on a ±2 SD estimation, a keyboard height adjustment ranging from 63 to 78 cm would encompass the preferred height settings of 95% of the operators. Since the operator selection process for this study intentionally emphasized the representation of persons of extreme stature (tall or short), there is probably a liberal bias in this estimate. However, the authors believe that a liberal bias in this case serves as a desirable safeguard, helping to assure that the 95% range estimate does not fall short of functional effectiveness. As a direct comparison of interest, these estimated range limits agree very well with corresponding adjustment range limits of 64 cm and 76 cm recommended by Roebuck et al. (1975, p. 316).

Cakir, Hart, and Stewart (1980, pp. 126 and 160) emphasize the importance of striving for minimal thickness as a design characteristic of both the keyboard and the underlying keyboard support in helping assure an adequate "working level." Working level is described as including the distance between the seat of the chair and the upper surface of the thighs, the distance between the upper surface of the thighs and the underside of the desk, the thickness of the desk and the height of the keyboard measured between the desktop and the home row of keys (Cakir et al., 1980, p. 160). The present study demonstrates that working level must also make provision for adjustability of keyboard slope angle; depending on how that variability is achieved, the importance of minimal thickness in the keyboard and keyboard support is further underscored.

CRT Adjustments

Inclusive CRT centerline height ranged from 783 mm to 1060 mm with a mean of 925 mm (total group).

Based on a ±2 SD estimation (subject to the same intentional liberal bias noted earlier), the height of the CRT centerline would need to range from a low of 81 cm to a high of 104 cm to accommodate the preferred height setting of 95% of the operators.

A very restricted range of variation in preferred CRT angle was found, from a low of 0 deg to a high of +7 deg, with a mean of only 3 deg (total group). It can be inferred from this finding that adjustability of CRT angle may have its main justification as a means of minimizing glare from ambient light sources. In the absence of such glare conditions, and if other workstation parameters can be optimized, very little departure from the 0-deg angle appears necessary.

Table 2 indicates that in five sets of correlations involving CRT angle as one of the paired variables, 25 correlations in all, only one significant correlation occurred (r_s = −0.44 for CRT height and CRT angle, U.S. sample).

CONCLUSIONS

Since the results of the present study are derived from a rather small total sample of subjects and the input task performed was of short duration, the findings reported here should be regarded as preliminary. Additional studies are essential to extend or qualify these initial findings. In particular, some of the questions that need to be addressed include the following:

(1) In what ways do different applications (word processing as compared with data entry, for example) affect preferred workstation adjustments?
(2) How stable are the operators' preferred adjustments over sustained periods of work?
(3) Are there demonstrable gains in operator productivity associated with the introduction of adjustability in the display workstation configuration?

Pending further investigations, the results to date lead to the following preliminary conclusions and recommendations:

Keyboards

(1) Operators need to be able to conveniently adjust the slope angle of their keyboards. An upper angle limit of at least 20 deg is recommended (preferably 25 deg).
(2) The keyboard slope angle preferred by operators is inversely related to their preferred seat height and inversely related to their stature.
(3) Keyboard height measured from the home row keytops to the floor should be conveniently adjustable by means of an adjustable keyboard support platform. An adjustability range from 63 cm to 78 cm is recommended.

Display Screens

(1) Display screen height, measured from the center of the screen to the floor, should be conveniently adjustable, either by means of a hardware feature or an adjustable display support platform. An adjustability range from 81 cm to 104 cm is recommended.
(2) Very little departure from a vertical (0 deg angle) screen position is needed if screen height, seat height, and keyboard height and angle are sufficiently adjustable to satisfy individual operator preferences. However, since an adjustable screen angle can help to eliminate potential glare (and augment the value of other antiglare measures such as display screen antireflective treatment and well-planned room lighting), an adjustable screen angle range between −5 deg and +20 deg is suggested.

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