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Optimal viewing angle for touch-screen displays: Is there such a thing?

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Abstract

While developing touch-screen displays for the food-service industry, the need for adjustability was investigated. Although there are many guidelines for the design and placement of monitors and keyboards in the office environment, there are few such guidelines for touch-screen displays in common service areas. In order to determine the optimal viewing angle or range for a given touch-screen display, an anthropometric/workstation analysis and a user study were conducted. The anthropometric/workstation analysis used a worldwide range (2.5th percentile Japanese female to 97.5th percentile United States male) of user heights for consideration in several scenario drawings. The user study measured the preferred touch-screen display viewing angles (at a standing position) of 26 participants whose stature ranged from 152.4 cm (5 ft) to 194.3 cm (6 ft 4.5 in). The results of the anthropometric/work-station analysis showed a recommended range of 30° to 55° off the horizontal, whereas the results of the study showed that the participants adjusted the touch-screen between the angles of 19° and 54.5° off the horizontal. The outcome of the analysis and study gave reason to conclude that there is no optimal viewing angle for touch-screen displays in a food-service environment with a dynamic set of user heights and a static workstation height. The displays should be adjustable through a range that accommodates multiple users and work-stations, and provides adjustment to compensate for other miscellaneous variables such as glare.

Relevance to industry

Computer-based consumer interactions are becoming increasingly common. Effective interactions are crucial to commercial success and aspects such as vision and control are likely to be important determinants.

Keywords: Touch screens; Visual displays; Anthropometry

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1. Introduction

As IBM began development of a new point-of-sale (POS) product for the food-service market, requirements dictated the product be designed around a touch-screen display. Further, workstation space constraints pushed the product toward slim liquid crystal display (LCD) technology, away from bulky cathode ray tube (CRT) monitors. It was quickly understood that several elements would influence the operation of the device: display technology, touch technology, lighting in the work area, workstation design, and the users themselves. The technology is controlled, to a point, by the development team. They try to include the latest available technology (cost permitting). Lighting and workstation design are controlled by the retailers providing the products to their employees, the users. Because of the expense involved (several thousand dollars in a typical food-service establishment), the lighting and workstation often are straight-forward in design, are static in nature, typically with no adjustment whatsoever (one size fits all), and are not necessarily upgraded when new POS equipment is installed. In some instances, retailers may fasten the touch display to the workstation counter top, thus eliminating adjustment of the distance to the display from the operator edge of the counter.

So, what can the users control? The users can control only a few things relative to the display. They may be able to control brightness and contrast (typical in most displays) and they may be able to control the angle of the display. The adjustment of the display angle is very important, as the touch-screen display must be easily viewed and easily reached by food service users from a standing position.

Although there is research on the correct positioning of CRT monitors and keyboards for seated office environments or for CRT touch monitors in kiosks, similar research is not readily available on the placement of LCD touch-screens in standing work environments. Hence, there are few guidelines to help develop products within the restrictions of the food-service environment. For seated operators, Sears (1991) evaluated touch monitors set at 30°, 45°, and 75°. His experiment had the touch CRT monitor imbedded in the top surface of the desk. He found that the 75° angle (from the horizontal) was the least preferred and caused the most fatigue. The 75° angle is typical of a monitor on a desk. Beringer and Peterson (1985) set a touch monitor to angles of 90°, 75°, 60°, and 45° for seated operators. Their results showed that the angle of the screen did not have a significant effect on the response time of users, but they did not deal with user preference of the viewing angle. Two studies have dealt with the users of touch monitors in standing positions. In one, Miles and Underwood (1986) combined seated and standing subjects in the measurement of touch forces. In another, Hall et al. (1988) conducted two experiments (one with seated and the other with standing subjects) to study the accuracy of touch points.

Although the previous research was helpful in some ways with the development of new products, it did not identify if there was an optimal viewing angle or range of angles for touch-screen displays used by standing food-service operators. For the present study, it was hypothesized that adjustability of a LCD would be necessary to provide suitable viewing angles for the full range of possible users. It was also hypothesized that an optimal range of viewing angles, rather than a single, optimal angle, could be determined despite the large range of user heights.

In order to investigate viewing angles more thoroughly, a two-pronged approach was taken. The first task was to create scenario drawings that would display a worldwide range of users viewing the LCD touch-screen at the typical counter height found in food-service venues. The workstation analysis would yield a hypothetically optimal angle, or range of angles. The second task was to conduct a study with a sample population of the standing users of the LCD touch screen that would validate, or at least supplement, the results found in the workstation analysis.

2. Method: Workstation analysis

CATIA® was used to create scenario drawings (Figs. 1–4) of several users in the typical food-service situation. Using anthropometric data available through Humanscale® (Diffrient et al., 1974), the middle 95% of potential worldwide population was rendered by using a 2.5th percentile Japanese female and a 97.5th percentile United States male. A 2.0 cm (0.79 in) heel height was used for the female. A 3.0 cm (1.18 in) heel height was used for the male. All dimensions on the drawings are in centimeters.

Workstation counter height and placement of the display on the counter were set after field surveys revealed what was typical in the United States and many non-US fast-food environments. The typical food-service counter height is 91.44 cm (36 in). The display is 15.24 cm (6 in) from the operator edge of the counter and 15.24 cm (6 in) high (when placed in the horizontal position) from the top of the counter.

For the workstation configuration selected, two extremes for potential height of user were analyzed. The 5th percentile Japanese female is used as the small end of the range in accordance to the data on female heights in Humanscale®. The 95th percentile United States male is used as the large end of the range in accordance to the data on male heights in Humanscale®. For each user, the viewing cone displayed in Humanscale® as defined from 'normal standing sight line (10°)' to 'easy eye movement (30°)' line was considered 'preferred'. The 'normal standing sight line' is the relaxed line-of-sight 10° down from the 'horizontal eye level'. The 'easy eye movement' line is 30° down from the 'horizontal eye level' and represents the lower end of the easy eye movement range, as defined in Humanscale®. A vector which bisected the preferred viewing cone for a given user was used to establish the best viewing angle of the display.

Plaisant and Sears (1992) demonstrated that 'biases exist when touchscreens (sic.) are mounted at an angle other than perpendicular to the users line of sight'. Minimizing the biases caused by parallax and foreshortening is a goal in the use of LCD touch-screens. Thus, to minimize biases within the preferred viewing cone for a specific user, the angle of the LCD display was adjusted until it was perpendicular to the bisecting vector of the preferred viewing cone. Further, the amount of forward head tilt necessary to achieve a perpendicular angle between the display surface and the bisecting vector of the preferred viewing cone was determined geometrically.

3. Results: Workstation analysis

The results of the workstation analysis begin with the 2.5th percentile Japanese female (Figs. 1 and 2) as an operator. In Fig. 1, the user is shown with the head and neck in their most upright position, Position 1. In Fig. 2, the same Japanese female is shown in Position 2 with the head tilted forward 15° (which is within the 30° range of easy head motion). With the head in the tilted position, the preferred viewing cone from the 'normal standing sight line' to 'easy eye movement' line spans the middle of the display screen. In this scenario, a touch-screen display angle of 55° from horizontal is necessary to create the desired perpendicular angle between the bisecting vector of the preferred viewing cone and the middle of the screen. The 55° display angle creates one extreme boundary of the preferred touch screen display range. Note that arc (a) is the minimum viewing distance of 33 cm (13 in) and arc (b) is the maximum viewing distance of 72 cm (28 in).

The other extreme boundary of the workstation analysis was determined with the 97.5th percentile United States male (Figs. 3 and 4) as an operator. In Fig. 3, the user is shown with the head and neck in their most upright position, Position 1. In Fig. 4, the same US male is shown in Position 2 with the head tilted forward 40° (which is 10° outside the 30° range of easy head motion but within the 60° of maximum head motion). With the head in the tilted position, the preferred viewing cone from the 'normal standing sight line' to 'easy eye movement' line spans the middle of the display screen. In this scenario, a touch-screen display angle of 30° from horizontal is necessary to create the desired perpendicular angle between the bisecting vector of the preferred viewing cone and the middle of the screen. The 30° display angle creates the other extreme boundary of the preferred touch-screen display range. Again, note that arc (a) is the minimum viewing distance of 33 cm (13 in) and arc (b) is the maximum viewing distance of 72 cm (28 in).

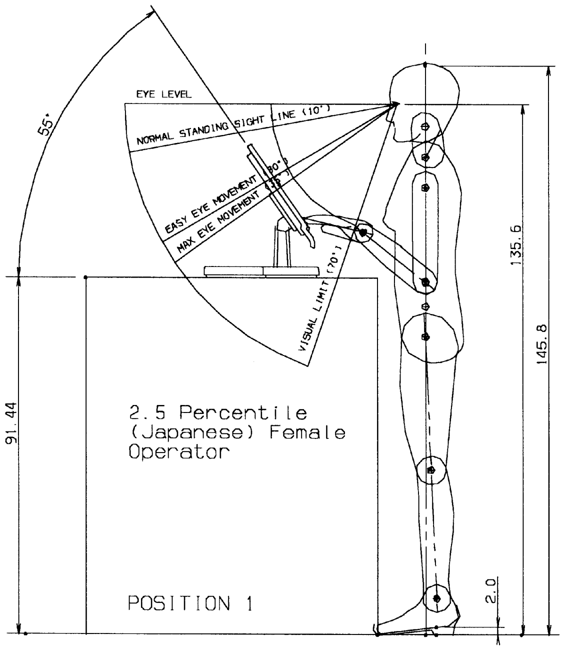

Fig. 1. Small female – head upright.

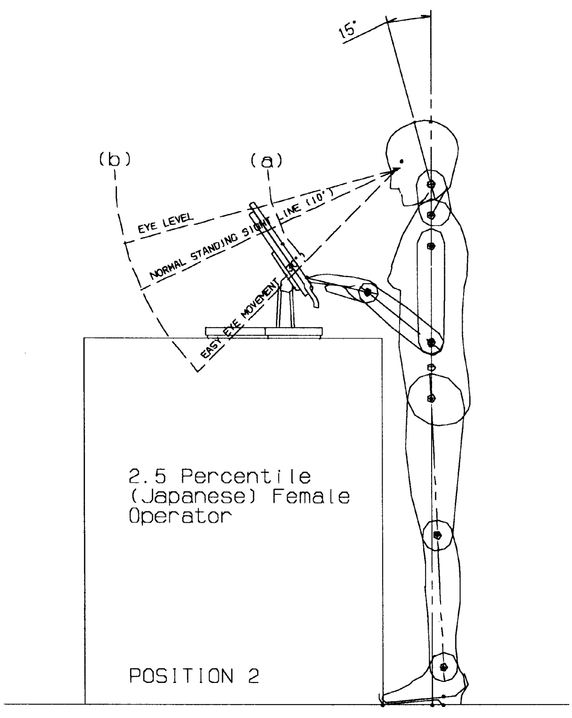

Fig. 2. Small female – head at 15°.

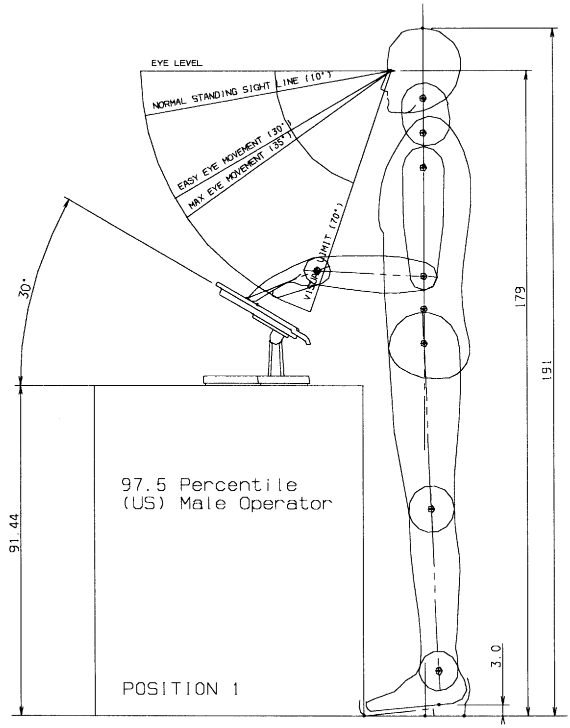

Fig. 3. Large male – head upright.

4. Method: User study

4.1. Subjects

Twenty-six (10 female and 16 male) IBM employees voluntarily participated in the experiment. There was a mix of age, handedness, education, and previous touch-screen experience. Their heights ranged from 152.4 cm (5 ft) to 194.3 cm (6 ft 4.5 in). They were not compensated for their participation in this study.

4.2. Materials

The following materials were used:

- One IBM 4659 POS system comprising a PS/2-compatible POS order-entry controller and one IBM 8470 Touch (touch-screen) liquid crystal display (LCD) running fast-food software.
- One 91.44 cm (36 in) table – used in place of a counter top.

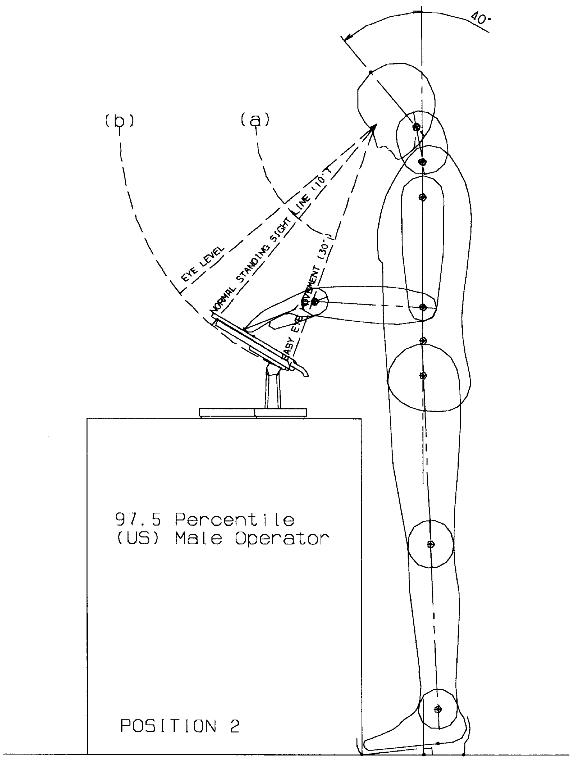

Fig. 4. Large male – head at 40°.

- One anglometer – used to measure the preferred angle.
- Ambient room light (742lx) emitted by diffused fluorescent ceiling lights (not directly over the top of a subject or the touch-screen display).

4.3. Procedures

The following procedures were used by each participant:

1. Subjects were asked to read and sign the standard instruction and release forms.
2. Subjects were asked to stand within a comfortable reaching distance, approximately 15 cm (6 in), from the touch-screen display.
3. The tilt capability and contrast adjustment (via software) were demonstrated for the subject, and the display was returned to the horizontal position.
4. The subjects were asked to adjust the angle and the contrast of the display until it was most comfortable for them to view and touch.
5. The angle was measured from the horizontal and documented along with the contrast adjustment, subject gender, and subject height.
6. The subjects were debriefed and thanked for their participation.

5. Results: User study

The frequency data (Fig. 5) show a wide variation in the angle preferences for the touch-screen displays. A range from 19° to 54.5° was collected. While 92% of the subjects adjusted the display to an angle between 30° and 55°, almost half (46%) adjusted it between 44° and 49°. As can be seen on the scatter-plot (Fig. 6) a slight negative relationship can be observed between the viewing angle and the height of the subject; the data are not significant.

6. Discussion

The workstation analysis results in display angles in a range from 30° to 55°. The drawings did not and could not take into effect lighting or glare and it is understood that both can greatly effect what is considered to be comfortable by the user. It would make sense to go beyond these limits if the product design were capable of such.

The workstation analysis used only one height of counter and one display location. In reality, these items could be different at every single store that uses the product.

The user study resulted in range of display angles from 19° to 54.5°. The data clearly show that, as hypothesized, there is no single angle that is appropriate for all people, especially in scenarios involving a single workstation height. Even the outliers show a personal preference for initial comfort.

The user study used only one height of counter, one display location, one level of lighting, one type of lighting, and one position of the lighting. In reality, these items could be different at every single store that uses the product.

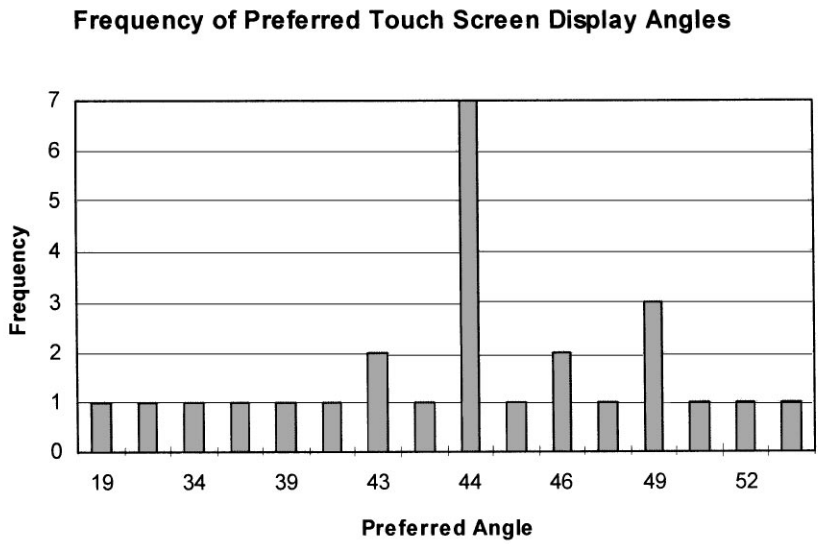

Fig. 5. Frequency of preferred touch-screen display angles.

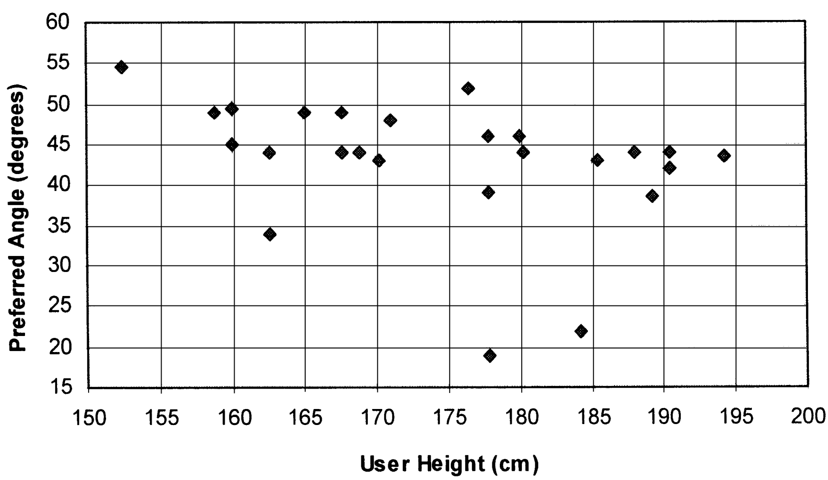

Fig. 6. Correlation of touch-screen angle to user heights.

Both the workstation analysis and the user study indicate there is a range of angles that will yield positive user reaction for the majority of the population. This range should be used as the basis for our adjustable displays. In general, the more adjustability that can be included in these types of displays, the better for the user. For, as Povlotsky and Dubrovsky (1988) discuss in their paper on 'recommended' versus 'preferred', adjustability becomes a larger issue when you start to look at individuals instead of populations, as there are so many specific factors that are brought into play that might not be part of the population norm.

Further data collection and analysis may be conducted on this topic in the future to see if a significant linear (or other) relationship between

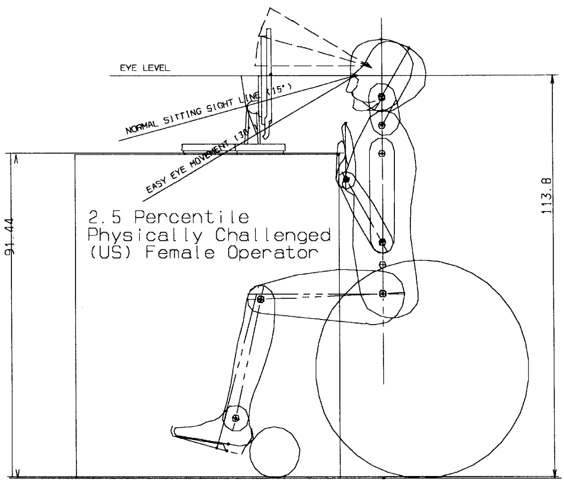

Fig. 7. Physically challenged female operator.

preferred viewing angle and height of the subject may exist and if a significant regression equation could be constructed.

7. Conclusions

As a result of various additional customer requirements, two POS touch-screen display products were developed. The 4695 Model 002/012 is designed to be distributed and has a full 120° range of tilt, ranging from $-40°$ to $+80°$ off the horizontal.

The 4695 Model 201/211 is an integrated unit that has only 20° of adjustment – that being the maximum that could be offered in its mechanical design. In order to accommodate the greatest cluster of users (85% of subjects in this study), a range of tilt from $+30°$ to $+50°$ off the horizontal was implemented in the 4695 Model 201/211.

The low end of the workstation analysis optimal (30°–55°) range is being used because the workstation used in the study is the tallest operators are likely to use, but they could potentially use shorter counters. Based on the results of the workstation analysis and user study, it is presumed that as the counter height is reduced, the preferred display angle will also decrease. Taller operators would prefer a lesser display angle in order to maintain a perpendicular, or as near perpendicular as possible, line of sight on progressively shorter counters.

Fig. 7 is included as a reminder to keep the physically challenged in mind when designing touch-screen displays or any other mechanical devices. The United States has the Americans with Disabilities Act to help aid in this endeavor but, as can be seen in the drawing, adjustability of equipment alone cannot accommodate certain situations. The workstations and environments must be more closely investigated as well.

The workstation analysis and user study described in this report is only a start of what could easily become a large body of work. The continuous rise in kiosk popularity alone should create a demand for more research in this area. Like its cousins, the desktop monitor and keyboard, the future will probably have guidelines and standards for desktop, countertop, wall and ceiling mounted, as well as gaming touch-screen displays. Unless people become the same size and display technology enables viewing from any location, there will probably never be a single, optimal viewing angle. However, there may always be an optimal range that is dependent on the user set, the environment, and the tasks.

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