B. OTHER SENSORY DISPLAYS

Although much of the information that a worker obtains is visual in nature, displays may involve other types of sensory stimulation. For example, the behavior of a worker may depend on, and be controlled by, auditory cues, either spoken words (as in a communication network) or mere sound stimuli (such as the noise made by a motor at different speeds). The use of different knob shapes and sizes on levers and switches may constitute a "tactual display." Skilled machinists often refer to the "feel" of their controls. The use of these sounds, shapes, and built-in "feels" on controls should thus be considered as auxiliary ways of insuring that the worker receives all the information he needs. Some of the highlights of what is known about the average worker's capabilities in these sensory fields are discussed below.

1. Auditory Displays

Auditory displays may be used effectively as warning or information signals to the worker, thus relieving his visual senses of additional responsibilities. To be most effective, of course, such an auditory information system must be employed in the sound range where the human ear is most sensitive. This applies with respect to the frequency, intensity, and duration of the sound.

The ability of the human ear to detect a change in the frequency of a sound increases with the pitch from a very low value, and then lessens for extremely high tones. The greatest pitch sensitivity is found for tones (of moderate loudness) whose frequency is between 400 and 800 cycles per second. This is the range that should be utilized for auditory information. Intensity discrimination is also poor at low frequencies when the sounds are faint. Under such conditions, the greatest sensitivity to a loudness change is at about 2000 cycles per second. For moderately loud tones (that is, about 40 decibels), however, a normal ear is equally sensitive to loudness changes at all frequencies.[24,71]

To avoid continuous tones, which might become distracting or annoying, auditory cues should be as short as possible. However, they must be sufficiently long to afford the opportunity for adequate pitch and loudness discrimination. The best evidence indicates that both frequency and intensity may be discriminated from durations as short as 20 to 40 thousandths of a second.

2. Tactual Displays

Although the tactual sense of form and size is greatly inferior to that of the visual sense, it is nevertheless possible to code equipment knobs in this respect in order to reduce errors in control operation.[55] The use of knobs of various shapes reinforces visual information and assists in avoiding accidental movements when

[55] P. M. Fitts, Engineering psychology and equipment design, in S. S. Stevens, ed., *Handbook of Experimental Psychology*. Wiley, New York, 1951, pp. 1287–1340.

controls must be selected and used without the aid of vision. Shape coding is particularly useful in situations where a specific control is located in different positions in different situations. The "habit interference" that is experienced in these circumstances can be alleviated by this method of coding. A considerable knowledge now exists concerning the shapes that are maximally discernible.[56] These are illustrated in Figure 9. During blindfold tests conducted by the Air Force, it was found that these shapes were the most easily distinguishable, caused the least hesitation and the fewest mistaken identifications.

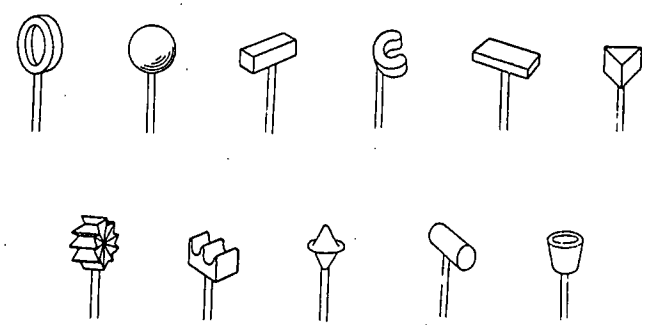

Figure 9. Eleven shapes found most suitable for the coding of control knobs. During experimental tests errors of identification of the knobs in this group were either absent or extremely rare. (After Jenkins[57] and Chapanis *et al.*[54])

3. Kinesthetic Displays

Resistance to movement may also give the operator of a control a cue as to the extent of its activation and thus may be considered as a form of display. There is only limited knowledge concerning kinesthesis (muscle sense) so only tentative recommendations can be given. It is known that people tend to overestimate small pressures and underestimate large pressures. We also know that arm and leg pressures become more accurate and consistent after a certain small force is already exerted. In order to provide as many cues as possible, the range of resistance of the control should extend from this small force up to an amount that will not cause fatigue when pressure must be maintained for a prolonged period.

C. CONTROLS

Industrial workers are sometimes required to perform repetitive tasks; to work at high rates of speed; to reach for, locate, and operate controls without the aid of vision; to make sudden or corrective responses; or to operate over long periods of time without undue decrement of performance. Under these and other

[56] W. O. Jenkins, "The Tactual Discrimination of Shapes for Coding Aircraft-Type Controls," in P. M. Fitts, ed., *Psychological Research in Equipment Design, Rept.* No. 19. USAAF Aviation Psychology Program. U. S. Government Printing Office, Washington, 1947, Ch. 14.