Kinesthetic orientation judgments during lateral head, body and trunk tilt

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The effects of body, neck, and trunk tilt on judgments of kinesthetic verticality were compared using 104 Ss. The results showed that head tilt and body tilt produced equal and significant E effects and that trunk tilt produced no significant E effect. The data were interpreted as showing that otolith information is an important determinant of the kinesthetic E effect.

With the body tilted, visual and kinesthetic judgments of verticality and horizontality undergo change. This has been demonstrated in vision (Aubert, 1861; Muller, 1916) and in kinesthesis (Wapner & Werner, 1952). The extent and direction of this change in both vision and kinesthesis is a function of the extent and direction of body tilt (Bauermeister, 1964; Bauermeister et al, 1964). With body tilts of less than 30 deg judgments of verticality are made in the opposite direction to the body tilt (E effect); with body tilts of more than 30 deg judgments are made in the direction of body tilt (A effect). Wade and Day (1968) have interpreted the visual E and A phenomena as instances of perceptual constancy, since the visual projection of object tilt is equivocal and information about body tilt is necessary to resolve this ambiguity.

In the same way as various combinations of visually inspected objects and body tilts result in identical orientations of the retinal image, various combinations of kinesthetically inspected objects and body tilts will give rise to identical and therefore ambiguous kinesthetic orientation information. Thus the kinesthetic information from an edge tilted 30 deg to the right of the vertical with the body in an upright position will be identical to the kinesthetic information from a vertical edge with the body tilted 30 deg to the left. Therefore, in the case of judgments of both visual and kinesthetic orientation, information with regard to body tilt is necessary to resolve perceptual ambiguity. The otolith, neck, and trunk receptors are all capable of providing this information. Wade (1968) has investigated the visual E effect in terms of the relative contributions from these receptor systems.

In the present experiment, the relative contributions of the otolith, neck, and trunk receptor systems to kinesthetic verticality will be evaluated using an experimental design similar to Wade's.

An assumption of Wade's experimental design was that head, body, and trunk tilt stimulate the three sets of receptors in their three possible pairings. However, consideration of the actual two-stage procedure by which the trunk tilt condition was obtained indicates that this assumption was not completely justified. Trunk tilt was obtained by tilting the head in one direction and immediately tilting the body in the opposite direction so the head returned to an upright position. If the initial head tilt resulted in residual stimulation of the otoliths, there were three receptor systems activated during this condition, not two as required for the interpretation of the three logical pairings. Accordingly, a complementary trunk tilt condition was included in the present experiment; that is, first the whole body was tilted and then the head alone was tilted back in the opposite direction to vertical. Thus there were the following four conditions of tilt, with right-left counterbalancing: In the head tilt condition, the otoliths and neck were stimulated equally and in the same direction; the trunk receptors were not stimulated. In the body tilt conditions, the otoliths and trunk receptors were stimulated equally and in the same direction; the neck receptors were not stimulated. In trunk tilt (a) stimulation of the neck and any residual stimulation of the otoliths was in the same direction, while trunk receptors were stimulated in the opposite direction. In trunk tilt (b) stimulation of trunk receptors and any residual stimulation of the otoliths was in the same direction, while the neck receptors were stimulated in the opposite direction.

Wade (1968) found that head tilt (HT), body tilt (BT), and trunk tilt (TT) of 30 deg produced significant effects. The magnitude of the effect produced by HT was greater than that produced with BT, which suggested participation of proprioceptive systems in the neck and trunk. He concluded that the otolith system was an important source of information in visual orientation constancy as manifested through the E effect, but that this was not to the exclusion of the other systems.

It is impossible to make predictions about the differential involvement of modal systems, from situations involving visual judgments (Wade, 1968) to the present experiment where kinesthetic judgments with the outstretched arm are involved, because of the differences in the relative location of the receptor systems involved. Visual and otolith receptors are both in the head, whereas the kinesthetic receptors activated in the present experiment are located in the joints of the arm.

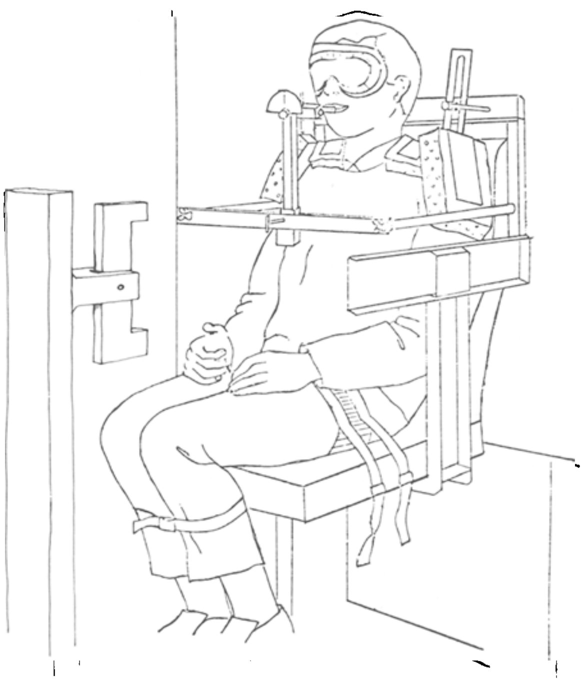

Fig. 1

METHOD

Apparatus

The chair shown in Fig. 1 was designed to allow independent tilt of head and body. Body tilt was achieved by tilting the chair laterally by means of a rotary adjustment wheel and securing it at a given position by means of a brake. The S was secured with an adjustable seat belt, 3¾ in. wide, anchored to the chair on each side. The S's knees were strapped together, and his feet were strapped to a foot-rest. Foam-rubber padded shoulder supports adjustable in height, angle of inclination, and width apart were slotted into a metal frame on the back of the chair. A crossbar could be screwed across the front of the chair, with biteboard adjustable in height. The biteboard could be rotated laterally, the degree of rotation being indicated on a protractor. The bar for judgments of verticality was adapted from equipment used by Singer and Day (1965). The centrally-pivoted bar, with raised stops defining a 12-in. excursion of the S's hand, was mounted on a timber frame. The angle of the bar could be adjusted with either the S's right or left hand by suitably placed rotary controls. The angle of the bar was indicated by a pointer on a scale to the nearest 0.25 deg. The bar was mounted on an upright aluminum rod so that it was in the vertical plane and could be swivelled to left or right and adjusted in height, being secured at these various positions by a metal screw.

Subjects

One hundred and four Ss, male and female, from introductory courses at Sydney University were randomly allocated to one of eight experimental conditions.

Procedure

The degree of head, body, and trunk tilt was always 30 deg, with left-right counterbalancing and the arm opposite to the direction of tilt was always used in making the judgments.

For all conditions, the S was seated in the center of the chair, his teeth gripping the biteboard. This was covered with dental modelling wax, which was renewed for each S. The biteboard was adjusted to a comfortable height. The shoulder supports were adjusted to be of firm but equal pressure on the S's shoulders, both sideways and downwards.

The kinesthetic bar was adjusted such that it was a comfortable distance from the S with arm extended, and at a height such that excursions of the S's arm up and down the bar would be roughly equal.

Each S was given five practice trials involving an adjustment of the kinesthetic bar to the apparent vertical. Each trial commenced from one of five starting positions (+5, +2½, 0, −2½, −5 deg) in random order. Vision was occluded with goggles. After a minute's rest, the S made five pretest judgments in an upright position and a single test judgment immediately after the appropriate condition of tilt was induced.

RESULTS

The difference between the mean of the five pretests while the body was upright and the judgment made during the tilt conditions was the measure for the E effect. Judgments made in the same direction as the body tilt were scored negative, and those in the opposite direction were scored positive.

Table 1 shows the means and variances for all eight groups. Planned contrasts (Rodger, 1965) were used to test the significance of the difference between the relevant means.

DISCUSSION

The data show that HT and BT produced equal and significant E effects and that TT produced no significant E effect. There was no significant difference between left and right tilts. These data seem to indicate that stimulation of the otoliths (the common element in HT and BT) is responsible for the effect. An alternative interpretation is that stimulation of the neck and trunk receptors produces the effect under conditions of HT and BT, respectively, as neck and trunk stimulation in these conditions is in the same direction; when stimulation is in opposite directions, as in the TT condition, the effect is cancelled out.

Table 1

Means and Variances of Differences Between Pre- and Post-Test Judgments of Kinesthetic Verticality as a Function of Lateral Head, Body or Trunk Tilt

Tilt Condition	Mean	Variance	Number in Non-Expected Direction
HT (left)	5.90	17.7	0
BT (left)	7.57	17.1	1
TTa (left)	−1.79	7.6	9
TTb (left)	1.85	13.1	4
HT (right)	2.87	11.8	1
BT (right)	3.52	24.9	3
TTa (right)	−1.23	40.9	6
TTb (right)	1.35	14.9	6

This second interpretation which was put forward by Wade for the data of the visual E effect is less plausible in the case of the kinesthetic E effect, since the effects resulting from the two complementary TT conditions, although not significant, show trends in opposite directions. Since neck receptors and trunk receptors were stimulated equally in both conditions it seems that residual otolith stimulation determines the direction of the effect, which was in the direction predictable from otolithic stimulation. Data on the adaptation of the otoliths are inconclusive and therefore the argument for a residual effect due to this adaptation is weakened.

It appears that kinesthetic orientation constancy is largely dependent on otolith information and that if information from neck and trunk receptors plays a role in the resolution of ambiguity it is small. In terms of body anatomy, it would not be surprising if neck receptors were of less importance for kinesthetic orientation constancy than for visual orientation constancy.

The data on the whole are in agreement with Wade's finding on the visual E effect, except that TT also produced a significant effect in his experiments which may be an indication that the involvement of the neck receptors is different for visual tasks and the particular kinesthetic task used in this experiment.

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(Accepted for publication September 20, 1968.)