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Direction and Reliability of Head Tilt in Humans

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ABSTRACT

It has been proposed that asymmetry in the inner ear underlies various manifestations of brain-behavior asymmetry in the human. Specifically, Previc (1991) argued that an otolith imbalance manifests itself in an asymmetrical head posture, and later (1994) suggested that head tilt may be consonant with other measures of human laterality. The present study tested the reliability of head tilt across days and assessed its relationship with handedness, footedness, and eyedness. As in Previc's earlier studies, a majority of our subjects tilted rightward. Head tilt proved to be highly stable across days but was not correlated with the other laterality measures. These findings suggest that head tilt may reflect an underlying asymmetric substrate which appears not to be directly related to other measures of cerebral hemispheric dominance.

INTRODUCTION

The direction in which posture deviates from vertical when people are instructed to stand erect has recently been offered as an important index of human laterality. Previc (1991) proposed that postural imbalances arise from an asymmetry of the otolithic pathways of the vestibular system, with people characteristically leaning towards the side of their weaker otolith organ (cf. Gresty et al, 1992).

In a subsequent study, Previc (1994) examined human head tilt using measurements performed on photographs of individual subjects. In that study, the percentage of right-head-tilted individuals was found to be slightly over twice that of the left-head-tilted group, indicating that this index of laterality falls into the general pattern of rightward-biased behaviors.

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An important next step in investigating this phenomenon is the determination of the degree to which the direction of tilt is reliable within subjects across days, i.e. to ask whether the direction of head tilt is a stable characteristic of normal human subjects. Such reliability tests are critical in assessing the stability of directional behaviors when questioning whether such behaviors are directionally consonant with others (Noonan & Axelrod, 1989). An investigation of head-tilt reliability constituted the primary goal of the present study.

Previc's (1991, 1994) arguments for a potential relationship between otolith asymmetry and cerebral lateralization suggest that direction of head tilt might be expected to be consonant with other indices of laterality such as handedness and eyedness. Alternatively, Geschwind (1975, 1985) has suggested that there may be at least two independent clusters of lateral behavioral biases, one for the distal bilateral appendages (i.e., handedness and footedness), the other for the axial musculature (which would underlie asymmetries in trunk flexion and turning biases). Within this view, one might expect head tilt to fall into the latter category and be independent of the handedness-eyedness cluster. Previc's (1994) study has already shed partial light on this issue, and seems to support the latter point of view in that he found head tilt to be unrelated to handedness. However, there was evidence of an indirect link between head tilt and sighting dominance. A secondary goal of the present study, therefore, was to provide further data relevant to this question by obtaining handedness, footedness, and eyedness measures along with head tilt in order to further assess the degree of consonance among these measures.

METHOD

Subjects

The subjects who completed this study were recruited from the students and staff of Canisius College. Eighty-six individuals were originally recruited. Nine subjects failed to return for their second session. Upon debriefing, three revealed medical conditions which may have influenced their posture or laterality and were subsequently dropped from consideration. Five subjects were judged by a “blind” observer to have noticeably turned (as well as tilted) their heads despite instructions to face ahead, and those were discarded. The remaining 69 subjects constituted the subject sample for this investigation. They included 32 males and 37 females, ranging in age from 18 years to 55 years (mean age = 21.8 years).

Volunteers were not recruited solely on the basis of handedness, although left-handers, when they were surreptitiously observed while engaged in normal campus activities, were specifically targeted for recruitment. Forty-seven subjects were right-handed; 17 were left-handed, and five showed mixed-hand dominance (as later defined). Neither general recruits nor left-handers were ever informed that the study would focus on head tilt, nor was there any mention of laterality. In an effort to keep the subjects blind to the actual purpose of the study, they were told that they were posing for pictures to be used later in a "computerized mug-shot face recognition study".

Procedures

The initial session lasted approximately five minutes. In it, two images (e.g. see Fig. 1) of the head and shoulders of each subject were obtained about one minute apart using a tripod-mounted video camera. Upon initially entering the testing room, the subject was instructed to stand in front of a grid, with shoes removed, and to look straight ahead at the camera with both arms down at the side. The experimenter stood out of the subject's view, observing events on a video monitor on the opposite side of a screen that served to divide the testing room into two halves. The experimenter counted to three and clicked a dummy camera shutter as an audible signal to the subject that an image had been captured. (In actuality, the entire session was videotaped in real time.) After the first image had been "captured", the subject was asked to step aside and write his/her name on a list. The subject then returned to the original position in front of the grid so that a second image could be obtained in the same way.

Between two and nine days later, in a second session, two additional video images were obtained, using the same procedure. Because it has been demonstrated that what may appear to be minor environmental asymmetries can strongly influence the expression of some lateral preferences (e.g., Noonan & Axelrod, 1981), we attempted to counterbalance any possible influence of external asymmetries in the testing room by having the camera and subjects positioned on the opposite sides of the room during this second session.

After the two video images were captured in the second session, each subject was asked to perform a series of motor tasks which were designed to assess sighting dominance, handedness, and footedness. (In an attempt to continue to observe behavior that remained unaffected by any conscious focus by the subjects on laterality, we told the subjects that this next task sequence was being developed for an upcoming study on children's motor development.)

Eyedness

Sighting dominance was assessed in two ways. First, the subject looked through the wide end of a small megaphone with both eyes open, aligning the small end so that the experimenter's nose could be seen. The eye of the subject visible to the experimenter through the megaphone was recorded as dominant. Each subject was then asked to read letters visible inside a monocular slide viewer, and the eye used by the subject was recorded. Use of the left eye was coded as -1, and use of the right eye was coded as +1. The average eyedness of each subject was then calculated as the average of the two tests (i.e., left = -1, mixed = 0, right = +1).

Handedness

First, the hand used by the subject when asked to sign in was noted. Each subject was also asked to throw three bean bags into a box and the throwing hand was noted. Again, left was coded as -1 and right as +1, and average handedness was calculated as the mean of the two scores.

Footedness

Footedness was assessed by two tests. In the first, the subject kicked three bean bags, and the foot used was noted. Second, each subject was asked to stand on a tape line and to get into position as if about to run a race, and the foot placed in back was observed. Once again, the left foot was coded as -1 and the right as +1, and the average of the two tasks was used for analysis.

Assessment of Head Tilt

A laboratory assistant, blind to the other laterality assessments, was responsible for capturing four images (digitized video frames) for each subject (two from each session) from the video tapes. The moment of frame capture was synchronized with the audible click of the dummy shutter on the sound track of the video tape. Each of the four images was then saved on the computer in its normal orientation and also in its mirror-reversed orientation (yielding eight images per subject). The mirror-reversals were carried out to guard against, and counterbalance, any asymmetries inherent in our processing of the images -- due to handedness of experimenter, etc.

Using the Image Pro computer program, one of us (CB), while remaining blind to the subjects' laterality measures, determined the direction and extent of head tilt for each image by obtaining the deviation of a line joining the outer canthus of each eye (the lateral junctions of the upper and lower eyelids, see Fig 1) from a horizontal grid line behind the subject. This measurement was expressed in angular degrees from the horizontal, with leftward tilt in negative numbers and rightward tilt in positive numbers. Each subject's head tilt for any image was computed as the average of the angular value obtained on the two measures of the same image (normal orientation and mirror reversal -- with the mathematical sign for the mirror-reversed image inverted, of course). Each subject's average head tilt was computed as the mean of all eight angular values (again, with the sign inverted for the reversed images).

In order to assess inter-rater reliability, eight other blind assistants also assessed head tilt in the same way for one set of the eight images per subject. To assess comparability across laboratories, one of us (FP) independently assessed the head tilt on one printed image of each of our subjects, using the facial landmarks and procedures described in his earlier report (Previc, 1994).

Figure One: Example of subject, in this case tilting 5 degrees leftward.

RESULTS

The head tilt measurements obtained on the same images in normal and mirror-reversed orientation were very close to one another (the mean deviation was only 0.33 deg; range .00 to 2.97 deg), and highly correlated (mean Pearson-*r* value .987; range .978 to .994). There were also very high correlations for all ratings of the same images by different individuals (that is, between those values obtained by CB and those obtained by the eight independent blind research assistants). The Pearson-*r* statistics comparing the eight sets of independently obtained angular values with the values obtained by CB for the same eight image sets ranged between .979 and .991. Additionally, there was a very high (*r*=.974) correlation between those angles determined independently by FP in Texas when compared to either assessment of the same images at Canisius in New York.

The sample-wide mean head tilt was 0.36 deg, i.e. slightly rightward. The largest left-leaning angle observed in any one image was -10.0 deg and the largest right-leaning angle was +9.5 deg. Forty-one (59.4%) of the subjects were right-head-tilted and 28 (40.6%) were left-head-tilted (X^2 (1) = 2.4; p = .12). Thirty subjects exhibited averaged head tilt scores leaning rightward by more than one degree. Nineteen leaned leftward on average by more than one degree. The average head tilt for the remaining 20 subjects was within one degree of the horizontal. There was no significant difference in the mean head tilts for females as compared to males, $F(1)=0.490$.

Substantial reliability in measured head tilt was found both within and between days. For the two images obtained moments apart on the same day, the Pearson's r was .832 for the first session and .735 for the second session (both $p < .001$). For the average of the two angles from the first session compared to the average of the two angles derived from the second session, the Pearson's r was .820 ($p<.001$). The direction (left or right) of the mean tilt in the first session was the same as that obtained in the second session for 57 (82.6%) of our subjects. The mean difference between the average head tilt from the first session and the average head tilt from the second session was only 0.44 deg, and this difference was not influenced by the number of days intervening between the sessions ($r = -.06$).

Not surprisingly, there was a high point bi-serial correlation between the results of our two handedness measures (writing hand and throwing hand): $r = .836$, $p < .001$, and between our two eyedness measures (megaphone eye and viewer eye): $r = .731$, $p <.001$. Our two footedness measures were not significantly related however: $r = .082$, ns. There was a significant correlation between our subjects' average handedness scores and their average eyedness scores: $r = .458$, $p <.001$, and between average handedness and the foot used for kicking: $r = .733$, $p < .001$. The foot placed rearward in the run-a-race position test was not significantly related to handedness or eyedness.

Direction of head tilt was not found to be significantly correlated with average handedness either before ($r = -.099$) or after ($r = -.085$) the five mixed-handed subjects were excluded. Neither was there a significant relationship between average footedness and head tilt ($r=.052$), nor between average eyedness and head tilt ($r=.045$). Correlations between average head tilt and the measures on each laterality subtest (i.e., writing hand, throwing hand, megaphone eye, etc.) were, in all cases, negligible and nonsignificant. An analysis of variance (ANOVA) on average head tilt using average handedness, average footedness, average eyedness, and sex as factors revealed no significant relationship among the variables, whether the mixed-dominance subjects were included or excluded. There were likewise no significant Chi Square relationships found when average head tilt was taken as a dichotomous variable (left or right) and compared separately, or collectively, (using the BMDP4F computer program) with similarly dichotomized versions of the handedness, footedness, and eyedness variables.

DISCUSSION

Clearly, head tilt is a reliable laterality index, as well as one that is easy to measure with high inter-rater reliability. Subjects characteristically exhibited consistent head tilt between images taken within the same videotaping session, and also between images taken across days, and this was not affected by the interval between sessions. As Previc (1991) proposed, head tilt appears to be a consistent internally mediated postural asymmetry, with a rightward bias in the adult human population. We found no sex differences in degree of head tilt which contrasts to an earlier report by Ragan (1982).

In our study, the direction of handedness, footedness and eyedness were all partially correlated with each other, a finding which corresponds to evidence from numerous other studies (e.g., Coren & Porac, 1978). Such consonance presumably reflects a common hemispheric-dominance underlying these behavioral biases. The fact that, in the present study, head tilt was itself stable yet not significantly correlated with the other indices of laterality suggests the presence of an independent underlying neural mechanism. This can be viewed as compatible with the view advanced by Geschwind (1975, 1985) that motor biases involving the axial musculature are regulated independently from handedness and eyedness. It will be interesting in future studies to see if head tilt is consonant with other biases of the trunk, such as turning biases. In work on rodent laterality, there is evidence for separate underlying neural substrates for various directional preferences (cf. Glick & Shapiro, 1985; Robinson et al., 1985; Noonan & Axelrod 1989). It should not be surprising if a similar arrangement is ultimately recognized in humans as well.

Alternative strategies for measuring head tilt under different circumstances are possible, and some have already been employed in other investigations (Greenberg, 1960; Peters, 1983; Previc, 1994). It is possible (indeed likely) that head posture varies with the subject's physical environment (e.g., with or without visual input), task (e.g., standing vs writing), and social/emotional circumstances (cf. Ragan, 1982). It will be important in future studies to further compare the angles of tilt assessed by different measures, and to similarly assess their association with handedness and eyedness.

Our data cannot address whether or not the direction of head tilt arises from asymmetrical functioning of the vestibular organ as hypothesized (Previc, 1991; Gresty et al., 1992; Curthoys & Halmagyi, 1995). It remains to conduct future investigations in which the proposed relationship between head tilt and otolith imbalance is more directly tested, as well as the hypothesized connection between otolith imbalance and other manifestations of cerebral lateralization.

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