PERCEPTION OF HAND MOTION DIRECTION USES A GRAVITATIONAL REFERENCE

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INTRODUCTION

Kinesthetic sense, or perception of motion, has primarily been studied at the joint level by considering measures such as the time to detect passive motion or the angle through which a limb segment is slowly moved until motion is detected[1]. Such measures may be important in relation to control of joint stability, but the purpose of most limb movements is to place the endpoint (hand or foot) in a specific location. Thus, understanding the frame of reference used in sensing direction of hand motion would provide important information relevant to mechanisms underlying control of upper limb movements. Thus, the purpose of the present research was to determine whether the frame of reference used for kinesthetic perception of hand motion uses intrinsic (i.e., body-fixed) or extrinsic (earth-fixed or visually specified) axes.

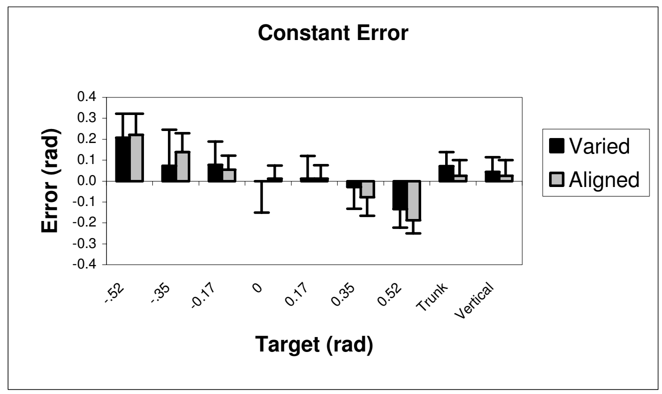
METHODS

Adult human subjects (n = 6) were instructed to set unseen motion of the hand (imposed by a motorized linear slide apparatus operating in the frontal plane) parallel to specific axes while in two different body postures: (1) Fixed - normal upright seated posture and (2) Varied - experimenter-imposed tilt (lateral flexion) of the head and trunk to the right or left to different orientations on each trial. Direction of hand motion was controlled by the subject pressing the right and left buttons on a mouse to rotate the hand motion counter-clockwise (ccw) and clockwise (cw), respectively. Hand motion was aligned to visually specified axes presented on a head-mounted display (that also blocked vision of the external environment), to the trunk-fixed longitudinal axis and to the earth-fixed gravitational axis in different conditions. Subjects completed 42 trials when aligning hand motion to visual axes (six trials each for seven visual axes) and 24 trials when aligning the hand to the trunk-fixed longitudinal axis and the earth-fixed vertical axis. Digital encoders in the motorized slide apparatus recorded motion of the hand in the frontal plane. Orientations of the head and trunk were recorded using a 3D electromagnetic system (Ascension Technologies minibird system).

Errors on individual trials were computed as the signed angular difference between hand motion direction and target axis direction in the frontal plane. Constant errors (CE) were computed as the mean of the signed errors. Variable errors were computed as the standard deviation of the signed single trial errors. In addition, correlation analysis was used to assess whether single trial errors for each axis depended on orientations of the head, neck and visual axis.

RESULTS AND DISCUSSION

CEs clearly differed ($p < 0.05$) for the different visual axes with axis angled ccw (-30°, -20°, -10°) having positive (cw) errors and axis angled cw (10°, 20°, 30°) having negative (ccw) errors (Fig. 1). Constant errors for setting hand motion parallel to the trunk and vertical axes were generally small and cw. VEs were clearly smaller ($p < 0.05$) for setting hand motion parallel to earth-fixed vertical than to visual axes and the trunk-fixed longitudinal axis when head and trunk orientation were varied (Fig. 1). Furthermore, single trial errors depended strongly on neck orientation when setting hand motion to visually specified axes in each subject ($R = 0.6$ to 0.9), but not to trunk or vertical ($R = 0.0$ to 0.8).



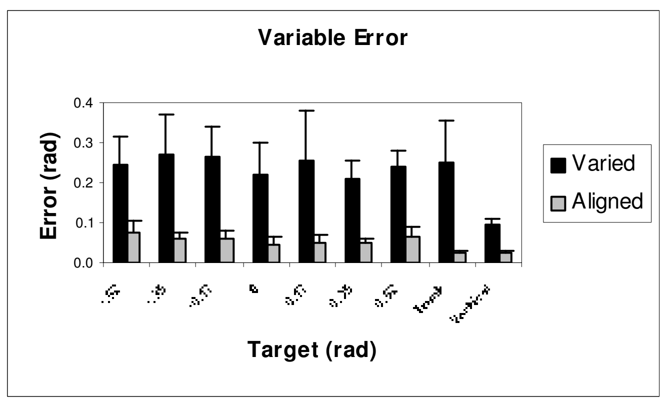


Figure 1: Constant errors (top) and variable errors for aligning hand motion to visual axes (-0.52 to +0.52 rad), trunk-fixed longitudinal axis (Trunk) and earth-fixed vertical (Vertical).

CONCLUSIONS

The low errors, and lack of dependence of errors on neck angle, when setting hand motion to vertical show that perception of hand motion uses an earth-fixed frame of reference. This is consistent with our previous findings on perception of static forearm orientation perception[2] and motion of an external object[3].

REFERENCES

1. Hall LA & McCloskey DI J Physiol 335:519-533
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3. Darling WG, Pizzimenti MA Exp Brain Res 141:174-183.