A computational approach to arm movement on the sagittal plane performed by parietal lobe damaged patients : An attempt to examine a computational model for handwriting for its neurobiological plausibility from a neuropsychological symptom.

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[Abstract]

We measured arm movement on the sagittal plane of parietal lobe damaged patients and normal subjects. In neurological patients, (1) the hand height did not become lower as the motion duration became shorter; (2) the hand jerk of measured trajectory increased when motion duration lengthened; (3) the velocity of measured trajectory differed from that theoretically predicted from the minimum jerk model. These results suggested that the parietal lobe is involved with realizing smooth arm movement. The performance of patients with parietal lobe lesions may reflect their difficulties in planning a trajectory with smooth movement.

[Summary]

Introduction

Wada et al.'s (2001a,b) research on arm movement including vertical direction in writing Japanese characters reported that the height of the hand became lower as the motion duration became shorter. For quantitative and computational examination of the results, they also measured hand height in arm movement on the sagittal plane which is assumed to be similar to vertical hand movement. Their findings confirmed that hand height varies as motion duration varies and demonstrated that the minimum command torque change model explains the relationship between hand height and motion duration well. We still do not know to what extent this computational model is neurobiologically plausible. The present study investigates the neurobiological plausibility of the model through analysis of arm movement of patients with neuropsychological symptoms.

Purpose

The purpose of the present study is (1) to quantitatively analyze arm movement on the sagittal plane in neurological patients and normal subjects, and (2) to investigate the functional role of the parietal lobe in arm movement on the sagittal plane.

Procedure

Seven normal males five of which also served as subjects in Wada et al.'s studies (2001a,b) and seven neurological patients (four males and three females) served as subjects. The neurological subjects had left parietal lobe lesions accompanying agraphia. All subjects were right-handed. The subjects were required to move their hands back and forth between the starting point and the final point on a desk along a board placed at a right angle to a horizontal plane. They were also asked to raise their hands in the air during the movement. The subjects repeated several trials of the task with three different distances (0.200, 0.175 and 0.150m) and three different speeds (normal, fast and slow). Each trial consisted of seven back and forth movements. The position of the subject's shoulder and hand were measured using FASTRAK (Polhemous Inc.) with a sampling frequency of about 60 Hz.

Result and discussion

To quantitatively compare the arm movement of neurological patients with that of the normal subjects we examined the following three points.

(1) The relationship between hand height and motion duration

In the measured trajectory of normal subjects, hand height tended to become lower as the motion duration became shorter. However, the measured trajectory of the neurological patient ’s hand height did not show a similar tendency. To compare the difference between the two, we represented hand height data in an exponential function. The exponential function revealed a high correlation between hand height and motion duration in the normal subjects as opposed to a low correlation between the two in the neurological subjects. It is mathematically deducted from the minimum command torque change model that by lowering hand height, subjects minimize the extent of rise in commanded torque which is produced as motion duration become shorter. The low correlation coefficient between hand height and motion duration shown by the neurological patients suggests that the patients could not command the torque by lowering the hand height as the motion duration became shorter.

(2) The relationship between hand jerk and motion duration

We standardized the hand jerk of measured trajectory by dividing the hand jerk predicted by the minimum jerk model and investigated the relationship between motion duration and hand jerk. It is well known that both the minimum command torque change model and the minimum hand jerk model predict trajectory of human arm point-to-point movement well. Therefore, we used the latter model for the sake of computational convenience here. The hand jerk of measured trajectory in the neurological patients increased when motion duration lengthened. On the other hand, hand jerk of the normal subjects was smaller than that of the neurological patients. Furthermore, the hand jerk of measured trajectory of normal subjects varied only slightly when motion duration became longer. The results suggest that the movement of the neurological patients was not as smooth as in normal subjects as the motion duration became longer, if we assume that the value of hand jerk is an index of movement smoothness.

(3) Velocity

We calculated the correlation coefficient between the velocity of a minimum jerk (optimal) trajectory and the velocity of a measured trajectory. The neurological patients' correlation coefficient between the two velocities proved to be smaller than that of the normal subjects. For the arm movement between the two points, the minimum jerk model predicts that the velocity profile of a smooth trajectory which minimizes hand jerk produces a bell shaped curve with a single peak. The high correlation coefficient between the velocity of measured and optimal trajectories in the normal subjects suggests that their smooth movement is predicted from the computational model, while the lower correlation in the neurological patients imply that they did not realize smooth movement.

Conclusion

Our results suggested that the patients with parietal involvement had more difficulty in planning a trajectory with a smooth movement as compared with the normal subjects and consequently that the parietal lobe is involved in realizing smooth arm movement.