ON THE TRACKING BEHAVIOUR OF PARKINSONIAN PATIENTS

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ABSTRACT

Suitability of visual tracking tasks for the modelling of mechanisms controlling the human motor activity is discussed. A simple model for motor control of movements with a single degree of freedom is introduced. A device which allows tracking with three degrees of freedom is described. A control mechanism model for movements with several degrees of freedom (which can be verified with measurements performed with the described device) is hypothesized.

INTRODUCTION

Analysis of the tracking behaviour is a possible way of measuring parkinsonian symptoms objectively 1,2 as opposed to the traditional measurement methods employing rating scales which necessarily depend on the subjective evaluation of the physician 3,4. On the other hand, tracking data may also be used to shed some light on the intricate and not yet fully understood mechanisms controlling the human motor action.

In a comparative study of 26 control subjects and 11 parkinsonians with and without medication (in this case a combination of 80% levodopa and 20% benzerazide), tracking tasks with a single degree of freedom (flexion and extension movements of the end phalanx of the thumb) were studied. It was found out that, with appropriate medication, the motoric abilities of the parkinsonian patients mimic those of the control subjects closely 5. However, other studies have shown the ability of parkinsonian patients to execute complex movements not to be significantly improvable with symptomatic therapy based on dopaminergic substitution 6.

A SIMPLE MODEL OF MOTOR CONTROL

The data obtained in the study mentioned above were also used to hypothesize and verify a simple PD-controller role for the basal ganglia in motor action with a single degree of freedom. The control structure underlying this model is composed of the control loops in the brain as shown schematically in Fig. 1.

A simple but realistic mathematical model of those loops is depicted in Fig. 2. In this model, the “idea” is processed with a delay in the cortex and then further processed in the basal ganglia before being sent to the periphery, which is also modelled as a simple delay. The input of the cortical processing is modified continuously during the execution of the action by comparing the “idea” with the visual and somatosensory feedback of the present state of the execution. The basal ganglia themselves are again modelled as a control loop, where the substantia nigra act as a PD-controller on the striatum.

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A MULTIAXIAL VISUAL TRACKING DEVICE

In order to test and modify this model for complex movements, a triaxial visual tracking device was built. Human factors were given considerable weight during the design of the device. Consequently, it includes many easily movable parts, which can be adjusted to the individual body measures of each subject.

The heart of the device is an IBM PC AT which is used (a) to control the reference signal for the tracking task, (b) to display the reference signal on its terminal, (c) to record the tracking data, and (d) to analyze the tracking data. As Fig. 3 depicts schematically, a program controls the x-, y-, and z-axis movements of the target to be tracked, which is displayed on the terminal display of the PC. The target is an ellipse which moves horizontally, vertically, and rotates around its center of gravity. The tracking task is to translate and rotate a rectangle (which is also displayed on the same display), such that it encloses the target in spite of the latter's movements. The rectangle can be moved by displacing the elbow, the wrist, and the thumb. The momentary positions of these joints are transduced by potentiometers electronically. The electrical signals from the potentiometers are fed to the PC where they are converted by another program to the position of the rectangle. Yet another program records the tracking data, which are then compared with the reference signal and analyzed offline by a further program.

A HYPOTHETICAL CONTROL MECHANISM MODEL FOR MOVEMENTS WITH SEVERAL DEGREES OF FREEDOM

It would be naive to assume that the model in Fig. 2 can also adequately explain the control mechanisms underlying the execution of complex movements with several degrees of freedom, which can be executed only by a concerted activation of several muscle groups. Obviously, this requires a strong degree of coordination in addition to the control loops needed for every single degree of freedom. Furthermore, since coordinated movements can hardly be performed without affecting each other, certain dynamic coupling between different degrees of freedom must also be hypothesized. Fig. 4 shows schematically the hypothetical control mechanisms needed for a movement with two degrees of freedom. It can, of course, be augmented to accommodate further degrees of freedom by including further blocks bordered by dashed lines and coupling elements. It is further hypothesized that the shaded blocks are situated in the basal ganglia. This can be reasoned by the established fact that patients with ailments of the basal ganglia—as in Parkinson's disease—show diminished motor control abilities.

References


