Quantifying the Dynamic Complexity of Visuo-Motor Tracking Performance

R.E. Ganz[1], W.H. Ehrenstein[2], L. Schlykowa[3] and C.R. Cavonius[2]

[1]Institut für Medizinische Psychologie, Universitätsklinikum Essen, Germany
[2]Institut für Arbeitsphysiologie an der Universität Dortmund, Germany
[3]Carl-Ludwig-Institut für Physiologie, Universität Leipzig, Germany

Abstract

We introduce a method developed from the theory of non-linear dynamics that allows one to calculate the dynamic complexity (correlation dimension D) of subjects' movement patterns during a visuo-motor tracking task. In a computer-aided experiment, we measured time series (4096 data points in steps of 15 ms) of the spatial deviations of tracking movements from a sinusoidally accelerated target (0.1 Hz) and used Takens' method of time delays to reconstruct the phase trajectory from these data. Following Grassberger and Procaccia, all pairs of points on this trajectory within a small distance r from each other were summed to yield a correlation integral C(r) that, for a sufficiently high embedding dimension m ($m \geq 2D+1$**Error! Switch argument not specified.**), corresponds to r^D. The D-values obtained for two exemplary subjects suggest that motor training results in an increase in the dynamic complexity of the movement patterns.

Introduction

The extensive biodynamical analyses of the Russian physiologist N.A. Bernstein suggest that the major result of motor learning is the development of skills of correction rather than the refinement of stereotyped patterns of movement (Bernstein, 1988). Here the term "motor correction" tries to capture the idea that the result of the continuous interplay of action and perception is under constant revision. We introduce a new method developed from the theory of non-linear dynamics (chaos theory) that allows us to quantify the dynamic properties of these corrections.

Experiment

The subject's task was to track a light spot that moved sinusoidally along a 16-deg horizontal path at 0.1 Hz on a computer screen by moving a digi-pad stylus so as to hold the spot in the virtual centre of a 0.6-deg window. The stylus was constrained to move along a rail (width 10 mm) on a compatibly-oriented digi-pad (GENIUS: HiSketch 1212, accuracy 0.2 mm) (i.e., rightward movement of the stimulus spot required rightward movement of the stylus, and vice versa; for further details, see Ehrenstein et al., 1996, this volume). Using a custom-made timer-card (precision 0.2 ms) and software, we were able to obtain data on a micro-scale: we recorded time series (4096 data points, precision 0.04 deg) of the spatial deviations of the subject's