Feedback Versus Adaptation in the Motor Control System: Does the Brain Use Internal Models for Bimanual Coordination and Timing?

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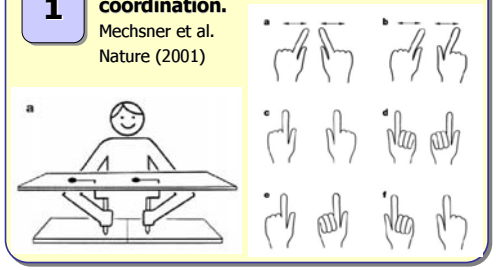
INTRODUCTION

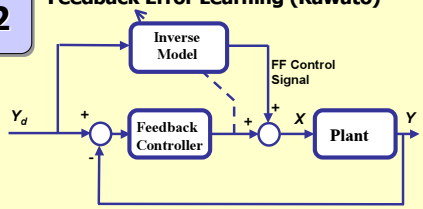
- Rowing a boat, playing drums and performing complex surgery require bimanual coordination.
- Untrained individuals prefer symmetry and are unable to produce non-harmonic polyrhythms.

1 Perceptual basis of bimanual coordination.
Mechsner et al. Nature (2001)



- It was recently shown that the preference for symmetry in bimanual coordination is perceptual.
- In the study of reaching movements, subjects are able to adapt to complex force perturbations in order to preserve the straight line path invariance.
- The notion of internal models is very useful to explain this adaptation capability.
- Can we develop a simple computational model to capture the brain's capability for adaptation to new environments and at the same time keep the well-known preferences for symmetry in bimanual coordination?

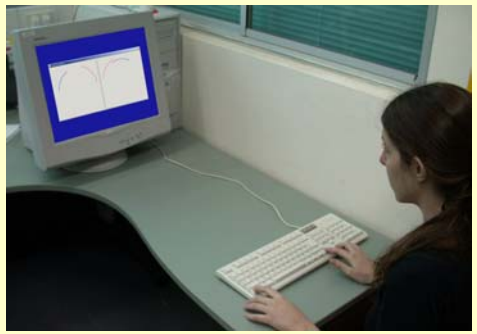
2 Feedback Error Learning (Kawato)



METHODS

- Subjects are asked to tap with the index fingers on two keys (or to rotate two handles) while an altered visual feedback is provided.

3 Bimanual Index Tapping Experiment



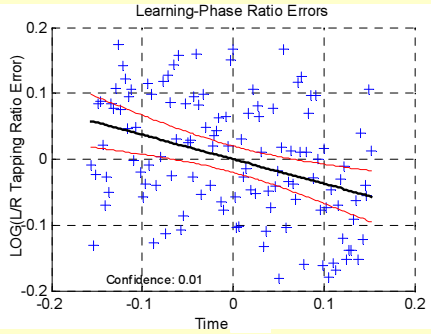
4 Bimanual Circling Experimental Setup
Two rotating handles below an opaque plate with computerized target/feedback display. It also includes passive damping as well as motors to facilitate the generation of various force fields.

- The right hand received slower feedback such that when the display shows rotation at equal speeds the subject produces a non-harmonic polyrhythm, with a left/right tapping frequency ratio of 2/3.
- In one condition (Sym) the target markers circled at the same rate with mirror symmetry and the gear was between the hand and the blue markers. In a second condition (Asym) the target markers moved according to a target gear ratio.
- After 540 seconds of training in 2/3 target ratio. In the last 30 seconds the target ratio switched back to 1/1.

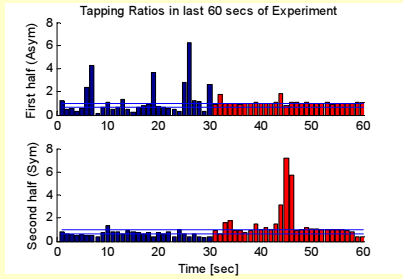
RESULTS

- Learning was observed ($p \ll 0.01$)
- An otherwise difficult task becomes relatively easy with the altered feedback
- First indications of after-effects were observed

5 Learning Curve Regression (Standardized Data)
log of 6 subject mean of left/right tapping ratio error. The squared error is calculated from the target ratio of 2/3.



6 After-Effect Indications
The last 60 seconds of each half in the experiment



DISCUSSION

- Introducing the notion of internal models to the study of bimanual adaptation calls for various experiments in different transformations to determine the structure and limitations of the internal representations.
- This study may help us to distinguish between feedback and adaptive control and understand the nature of the temporal and structural hierarchy of adaptation in the biological motor control system.

7 The temporal structural hierarchy of wide sense adaptation in the motor control system.