CHAPTER 4

MOTOR CONTROL THEORIES

THIS CHAPTER'S CONCEPT

Theories about how we control coordinated movement differ in terms of the roles of central and environmental features of a control system

SESSION OUTLINE

- Theory & Professional Practice
- The Degrees of Freedom Problem
- Open & Closed Loop Control
- Theories of Motor Control
- Motor Program-Based Theory
- Dynamic Pattern Theory
- Control Theory Issue

THEORY & PROFESSIONAL PRACTICE

- Theory helps understand phenomena
- Theory explains the reasons why phenomena exist or behave
- Motor control theory provides one a base that leads to effective skill instruction and practice environments

DEGREES OF FREEDOM PROBLEM

- How does the nervous system control a given pattern?
- Reflects the number of independent components of the system(e.g. controlling a helicopter)
- Motor control theory account for how the nervous system solves the degrees of freedom problem

OPEN & CLOSED LOOP CONTROL

- Provides basic understand of control process
- Both systems have a control center (executive)
- Executive generates and sends movements instructions to effectors (muscles and joints)
- Effectors (muscles and joints) produces desired movement

Application

- When we first learn or relearn a motor skill, all performers operate in a closed loop fashion.
  - Need for feedback
  - Need for instruction
- As we become better at the motor skill we switch to more open loop control.
  - Effective practice

Two Theories of Motor Control

- Motor program theory
  - Instruction are specified by the CNS
  - Control process is managed by a motor program
  - Motor program organizes, initiates, and carries out intended actions
- Dynamic System Theory
  - Instructions are influenced by environment and interaction of the body, limb, and nervous system

MOTOR PROGRAM BASED THEORY

- Hierarchical Oriented Theory
- Solves the degree of freedom problem through the motor program

GENERALIZED MOTOR PROGRAM

- Proposed by Schmidt accounts for adaptive and flexibility of coordinated-movement behavior
- Represents a patter of movement (class of actions) that can be modified to yield various response outcomes
  - Some elements of GNP are fixed from trial to trail (invariant)
  - Some elements of GNP are flexible (parameters)

Fixed Vs. Flexible Features

ON a blank sheet of lined paper write your name according to the following instructions:

1. With your dominant hand
2. With your non-dominant hand
3. Holding the pen/pencil in your mouth
4. Holding the pen/pencil in your toes

What did we learn from this exercise?

You have elicited a general motor program that enabled you to write your name in different ways!

INVARIANT FEATURES (Fixed)

- Regardless of how your wrote your name several underlining features of your signature remained constant.
- Fixed features are similar to fingerprints (can identify each of us)
- Three Common Invariant Features
    1. Relative timing
    2. Relative force used
    3. Sequence of actions or components

Invariant features (continued)

Regardless of the constraints, you spell your name the same way every time.

If you name is Spike, the “p” always follow the S. Regardless where the ball is set, the approach, jump, arm swing, and ball contact must be sequentially executed.

The *sequence of action* or order of the components is an invariant characteristic.

Invariant Features (continued)

The components of a skill occur in a specific order, but they are also relate to one another in certain invariant way.

- relative timing (internal rhythm of the skill)
- relative force (similar internal ratio of forces)

Swimming example

- Arm movement in freestyle stroke consists of 5 components.
  - 35% is accounted by the entry
  - 13% is accounted by the catch
  - 08% is accounted by the mid-pull
  - 12% is accounted by the finish
  - 32% is accounted by the recovery
- These percentages remain the same regardless of the frequency in relative timing and force

PARAMETERS

- Defines how to execute the program
- Changes from situation to situation
- Changes from one trial to another
- Includes
    1. Time can increase or decrease (overall duration)
    2. The size of the movement can increase or decrease (overall force)
    3. Specification of Muscles & Limbs used

Common Question?

The use of overweight implements is a common training method for conditioning in many sports. Throwers use heavier shots, discuses and javelins than normal in competition; hitters swing heavier than normal bats. Does this technique involve a manipulation of invariant features or parameters?

The schema connection

- A short stop is able to throw to different bases from various positions on the file by assigning appropriate parameters values to the motor program.

- But how does the performer know exactly how much force or how fast the ball should be thrown?

Schema Connection (continued)

- The answer lies in the development of a schema which is Schmidt's second aspect of motor program theory.

- Schema is rule or relationship that directs decisions making when a learner is faced with a movement problem.

Performing a skill....

When you perform a skill in a situation, you subconsciously subtract 4 pieces of information.

- Initial conditions (start of the movement)
- Response specifications (parameters used in execution of the movement, such as speed)
- Sensory consequence of the movement
- Response outcome (end result)

Schema & Performing….

These four sources of information is stored in memory following a movement attempt.

The schema begins to develop.

With each additional movement attempt the schema become stronger.

What result from practice is the development of the motor response schema.

Motor Response schema

- Consists if 2 relationships:
  - Recall schema: responsible for organizing the motor program capable of initiating and controlling the movement.
  - Recognition schema: responsible for evaluating the last executed movement attempt based on the initial conditions, past actual outcomes and past sensory information.

Motor Response Schema

With every attempt, the recall schema updates the instruction to the muscles based on the recognition schema (continually revises the initial conditions, past outcomes, & past sensory consequences) which leads to a more accurate response.

IN SUMMARY

Learner decides what movement to execute in a given situation by subconsciously retrieving the general motor program from memory based on the existing schema and parameters.

The desired movement is therefore organized in advance by the motor program and sent to the rest of the body to carry it out!

How is movement controlled once the motor program is issued??

- The answer lies in:

"does the motor program contain all the information needed to carry out the action from start to finish or are continuous adjustments made to the movement based on response-produced feedback."

Open & Closed Loop Control

If the motor program contains all the information needed to carry out the action the movement operates under *open loop control*.

If one while performing is continually registering and evaluating the accuracy of the movement then the movement is being controlled through *closed loop control*

DIFFERENCES BETWEEN THE SYSTEMS

Open Loop

- does not use feedback
- command center provides all the information

Closed Loop

- uses feedback
- command center issues information to initiate movement

EMPIRICAL SUPPORT FOR MOTOR PROGRAM THEORY

- Investigated relative timing invariance across differing duration parameters
  - Walk & Run Study is consistent with the hypothesis of relative timing invariance
  - With-in each gait pattern, relative timing was maintained but duration parameter differed

Empirical Support

If a motor program organizes the details of the movement in advance, it seem logical that a task increasing in complexity, the amount of time needed to organize the motor program would increase!

Henry & Roger Study tested this notion:

- lifting a finger from a key
- lifting a finger from a key plus grasphing ball
- lifting a finger from a key then graphing the ball, then striking a tennis ball.

DYNAMIC PATTERN THEORY

- Very different from Motor Program Theory
  - Not hierarchical in manner
  - Motor program theory only tell us part of the story
- A movement pattern emerges (self-organize) as a function of the ever-changing *constraints* placed upon it.

What constraints?

- Boundaries that limit the movement capabilities of the individual (Newell, 1986).
  - Structure or functional: body shape, weight, height, emotional, cognitive, etc.
  - Environmental: gravity, temperature, light, wind, etc. Wind effects the force and direction of the throwing a discuss.
  - Task constraints: rules of the game, goal of the task, and the implements (i.e. size, shape, weight) manipulated.

Self-organization

A movement pattern emerges as function of the ever-changing *constraints* placed on the leaner.

Movement is a function of the system self-organizing the available degrees of freedom into a single functional unit that is designed to carry out a specific task.

Attractor States

The individual, the task, and environment all effect the system in how it self-organizes.

We prefer states to be stable. These states or stability is known as attractor states.

When a change in constraints occur, the stability of the system is endanger!

The movement patter first becomes a combination of the old and new techniques.

In time, the movement pattern will reorganize and the new technique will begin to take over and stability is regained.

Control parameters

Constraints act as control parameter when they lead to change in the movement.

Control parameters are variables that move the system (you) into a new attractor state.

Direction, force, speed, and perceptual information are some examples of control parameters.

The acquisition of motor skills can be seen as finding the optimum values of control parameters (constraints) that will meet the demand of the task for each individual.

Empirical Support

- Studies by Kelso and his colleagues where participants move their right and left index fingers at specified rate of *speed out of phase*
- *The finger movement out of phase shifted to a* in-phase *relationship when speed of movement was systematically increased*
- *The linear increase in movement speed led to nonlinear change in the movement*

How does learning occur?

- Newell suggests that motor acquisition is a process of optimizing the control parameters (constraints) in a way consistent with the task & environment.
- *What does this mean???*
  - During practice we compress the degrees of freedom through self-organization with the cooperation of many sub-systems.
  - Newly acquired movement emerges as a series of phase shifts where attractors stabilize and destablize as a function of control parameters (restraints).

Relearning a patient to walk!

After an injury the patient will display a given gait pattern as result of the constraints imposed on the system.

Patients leg strength serves as a control parameter.

As the patient's legs become stronger it leads to changes in the walk.

In other words, increases in leg strength could cause a phase shift and a new gait (attractor state) could self-organize.

Orthotic function

Explain how orthotics function from a dynamic system perspective?

PRESENT STATE OF THE CONTROL THEORY ISSUE

- Opinions vary to resolve the motor control theory debate
- Kelso contends that aspects of motor program theory will be subsumed into dynamic pattern theory
- At this point motor control theory is still the predominate theory of motor control

THE END!!!!