Chapter 5

MOTOR CONTROL THEORIES
Theories about how we control coordinated movement differ in terms of the roles of central and environmental features of a control system.
Motor Control

- All motor controls attempt to explain how we control coordination and reduce the degrees of freedom problem.
Coordination

- The patterning of head, body, and/or limb motion relative to the patterning of environmental objects and events

- Chapter 2 Measuring Coordination
Concept 6: Movement-Related Coordination Measures

- A person performs a motor skills in a specific time (temporal) and space (spatial).
  - One way to measure a person performing is create a graphic angle-angle plot of the movement joints.
    ★ Angle (X) – angle (Y) plot at specific times during the movement can be compared (cross correlation).
  - Another way is a person repeats a movement pattern for a certain amount of time (relative phase).
    ★ From repeating the movement one can gain a sense of the relative timing of the movement phase.
    ★ Phases of the movement (parts of movement) can be described by a displacement-velocity graph of the temporal and spatial characteristics.
DEGREES OF FREEDOM PROBLEM

- How does the body (muscles and joints) move independently in one or more planes to carry out a desired movement?

- From the start to the end of movement we need to solve the degree of freedom problem, that is, be able to control the body to produce the desired movement within any given situation.

- Motor control theory account for how the nervous system solves the degrees of freedom problem
A Closer Look

- 792 muscles in the human body
- 100 joints
- Joints can move in many different planes

If you pick up a drinking glass that involves the shoulder joint (1), elbow joint (1), wrist joint (1), and all fingers (3 joints x 4 = 12 joints) and thumb (3) joints. The total is 18 joints that need to be controlled.
How is movement controlled once??

- 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.”
What wait?

- Does it not depend on the type of task…?
  - Ballistic Skills
  - Skills that are long in duration.
Let’s look at different skills?

- Throwing a dart at a dartboard.
- Driving a car
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*. 
Closed Loop Control of Executed Motor Program

1. Uses feedback to control movement

2. Motor program only contains initial movement instructions
Open loop control of executed motor program

1. Feedback is available cannot be used because of ballistic nature of the task.

2. Motor program sent includes all the information necessary to carry out the 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.
  - We need to provide variety in practicing the skill in differing real-life situations.
Difference between Open & Closed

- **Closed**
  - Feedback is used to update the system
  - Movement instructions only include information related to the initiation of the movement.

- **Open**
  - Feedback is there but cannot be used.
  - Movement information includes all commands necessary to carry out the skill.
Open or Closed Loop

- Juggling a ball
- A car suddenly comes out in front of you and you have to step on the brake to avoid hitting the car.
- Tying a knot, buttoning your shirt, or ironing your pants.
- Striking a key on the keyboard
- Side kick
Theories of Motor Control

- Motor program theory
  - Instructions are specified by the CNS
  - Control process is managed by a motor program
  - Motor program organizes, initiates, and carries out intended actions
  - Linear changes in movement behavior

- Dynamic System Theory
  - Instructions are influenced by environment and interaction of the body, limb, and nervous system
  - Nonlinear changes in movement in behavior
MOTOR PROGRAM BASED THEORY

- Hierarchical Oriented Theory
- Has a command-based center
- Solves the degree of freedom problem through the motor program
Motor Program

- Proposed by Schmidt and is defined as an abstract representation of a movement plan, stored in memory, that contains all the motor commands required to carry out the intended action.
- One does not need a motor program for each skill.
- Represents elements about patterns of movements (class of actions) that can be modified to yield various response outcomes
  - Some elements of GNP are fixed (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!

There were underlying invariant features that did not change regardless of how you wrote your name. But needed to adapt (parameters) to writing with different parts of your body.
INVARIANT FEATURES (Fixed)

- Regardless of how you 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 spelled your name the same way every time.

If your 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 of relative force and timing

- 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
Relative Timing

a. Normal speed (10 sec)

b. Faster (5 sec)

c. Slower (15 sec)

Time scale (sec)
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 and javelins than normal in competition; hitters swing heavier than normal bats. Does this technique involve a manipulation of invariant features or parameters?
In short, motor program

- Consists of pre-structured set of motor commands that are constructed at the highest cortical levels and then conveyed to the lowest centers in the hierarchy responsible for executing the movement.
The schema connection

- A short stop is able to throw to different bases from various positions on the fly 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?
  - The answer is the second aspect of Schmidt’s theory, that is the development of a schema
Schema Connection

Schema is a set of rules that guides decision making about the goal of the skill.

- it directs the decision making when a performer is faced with a movement problem
- it results from experiences with the movement (class of action)
Performing a skill….

Each time you perform a skill, you abstract 4 pieces of information.

- The environmental conditions as movement begins (initial conditions)
- The specific requirements of the movement (response specifications…speed and/or force)
- Sensory consequence of the movement (e.g., how it felt, appeared)
- The outcome of the movement (e.g., comparing the actual outcome to intended outcome. Were you successful or not successful?)
Schema & Performing....

The schema begins to develop when we group and store these 4 types of information. With each additional movement attempt the schema become stronger.

As we practice the movement two related but separate schema’s develop that help us perform the movement from trial to trial and in different situations.
Occurs through two mechanisms

◆ Recall schema: organizing the motor program so it can initiate the movement and control the movement. It updates the system!!!

◆ Recognition schema: assess and compare the outcome using sensory information. – It revises the system!!!
How do we improve?

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.
Application

- The environmental conditions as movement begins (initial conditions)
- The specific requirements of the movement (response specifications...speed and/or force)
- Sensory consequence of the movement (e.g., how it felt, appeared)
- The outcome of the movement (e.g., comparing the actual outcome to intended outcome. Were you successful or not successful?)

- Stress initial conditions
- Provide variety of the practice situation and variables
- Develop awareness
- Provide an environment were the outcome is apparent/subject engage in self-evaluation
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 grasp the ball
- lifting a finger from a key then grasp the ball, then striking the ball.
Dynamic System Theory

- Also know as dynamical system theory, ecological theory, and action theory

- Sometime referred to the “constraint led approach” to developing motor and sport skills.
Dynamic System Theory

- Very different from Motor Program Theory
  - Nonlinear changes in motor behavior
  - A movement pattern emerges (self-organizes) as a function of the ever-changing *constraints* placed upon it.
  - All the information for movement is found in the environment and can be directly observed by the individual
Theorists advocate that there is an integration of small systems (e.g. biological, muscular, skeletal, neurological) cooperatively functioning together to meet the environmental demands.

Cooperation of the small systems has no “supreme commander”

The smaller systems cooperate and interact with each other to produce movement or through self-organization.
Self-organization

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

Movement is then 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.
What is a constraint?

- They 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.
DPT Concept: Attractor States

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

We prefer stable, coordinated, and energy efficient movement. This state is known as attractor state.

Attractor – A stable state of the motor control system that leads to behavior according to preferred coordination patterns.
Attractor States (continued)

- It is the preferred behavioral state
  - E.g., we like to walk at certain pace
- Transition from one movement pattern to another occurs automatically and spontaneously.
  - E.g., from walking to a run occurs automatically and spontaneously
- Attractor states represents the coordination pattern which is the most stable and energy-efficient.
Attractor State (continued)

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

Because the movement pattern becomes a combination of the old and new techniques.

With practice, the movement pattern will reorganize and the new technique will begin to take over and stability is regained.
DST Concepts: Order & Control parameters

These are variables responsible for and associated with coordination of the movement

1. Order parameters or collective variables. This variable enable a coordinated pattern to be reproduced and distinguished from other patterns.

2. Control parameters represents the variable that when manipulated will influence the stability and may or may not change the order parameter.
DST concept: Order parameter

- The most prominent of the order parameters is the “relative phase” for rhythmic movements.
  - Relative phase is an index of the coordination between two limb segments or limbs during performing a cyclic movement.
  - When running, what is the relationship between right and left arms or right and left legs?
    - E.g., Are they moving in-phase or out-of-phase?
DST Concept: Control Parameter

Control parameters are variables that are manipulated and may or may not affect order parameters (in phase or out-of-phase coordinated movement).

Manipulating control parameters can move the performer into a new attractor state.

- Direction, force, speed, and perceptual information are some examples of control parameters.
DST concept: Coordinative Structures

- This aspect relates to how we control movement.
  - Constraints cause one to use specific muscles and joints in different ways to produce a movement pattern (skill).
  - Muscles and joints need to work cooperatively (coordinative structures)
  - When the muscles and joints work cooperatively it reduces the degrees of freedom problem.
  - Coordinative structure (a.k.a., muscle synergies) develop through practice to produce an action.
Perceptual-Action Coupling

- The view emphasizes the interaction between the performer and the physical environment.
  - The outcome and skilled performance is dependent upon one’s perception (information) about the situation.
    - E.g., Is the object moving or stationary
    - E.g., Am I stationary or moving
    - E.g., The speed, size, and color of the object
    - E.g., Tau (time to contact)
DSP Concept: Relearning a patient to walk!

Patient broke their hip and initial attempts to walk left the patient walking with a limp (attractor state at this point in recovery).

The patient will display a given gait pattern as result of the present constraints imposed him or her

- E.g., Structure constraints are lower leg strength and weight.
- E.g., Task constraints is slow speed of gait, small stride length, and walking with a limp.
- E.g., Environmental constraints walking on different surfaces and in different situation are difficult.
DST Concept: Relearning a patient to walk!

Physical Therapist manipulates (e.g., weight training) the patient’s legs to become stronger which leads to changes in the walk (order parameters).

- Increases in lower body strength through strength training is a control parameter

Walking improves (coordinative structures) through practice

- Coordinative structures is where the constraints placed upon the client changes how the muscles and joints work in a coordinated manner.

- In the practice one manipulates structural (strength), all different environmental (perceptual action coupling) and task constraints (speeds) causes the client to move to a new gait pattern (attractor state).
Relearning a patient to walk!

In short, through a well designed rehab program or practice where structure, environmental and task constraints are manipulated causes the client to self-organize (walk faster with a longer stride with no limp).

Remember self-organization is where a movement pattern emerges as function of the ever-changing constraints placed on the learner.

Therefore it is said that the Dynamic System Theory is a constraint-led approach to acquisition of motor and sport skills.
Ecological Task Analysis Approach to Motor Development

Constraint-Led Approach
Example used in practice
Motor Development Program

Organization of Motor Development Clinic

- Station to station approach

Object of the day: Manipulative Skills

- striking
- throwing
- Throwing
- Catching
ETA Model

Task Goals

Student Choice

Manipulate Learner & Environment & Task constraints

Instruct
Client Choice

Let the client or students at each station practice the movement without prior demonstration or instruction.

Movement specialist role is to observe and assess the student stable and unstable movement (attractor states) based upon movement form (desired or not desired) and developmental (immature and mature) stages.
Manipulating Performer, task, and Environment

The client is encourage to choose how they want to perform the movement.

The movement specialist then changes the environment, task, or performer constraints.
Environmental Changes (Constraints)

With or with implements
Practice in blocks
- Stay at one station throughout the entire session or lesson
Practice stations randomly
- Practice all the station but in no set order

Spatial changes
- Distance between object & targets
- Distance between partners
- Distance short or long

Locations
- Sitting, standing,
- moving (walking, running, skipping, etc.)
Task Changes (Constraints)

Object size changes
Object weight changes
Object color changes
Object type changes
Pathways change
  - straight
  - low or high
Performer Changes (Constraints)

- Fast or slow
- Hard or soft
- Light or heavy
Instruction

Instruction is not provided immediately but after the first three stages.

1) Goal of the activity
2) Choice
3) Manipulation of constraints
4) Instruction

Instruction is provided through demonstration and verbalization.

Peer can be used for the demonstration.
Student are provided practice.
ETA Model

- Task Goals
- Student Choice
- Manipulate Learner & Environment Task constraints
- Instruct
PRESENT STATE OF THE CONTROL THEORY ISSUE

- Opinions vary to resolve the motor control theory debate
- Some believe 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!!!!