Skill acquisition

- Motor learning theories
  - closed loop theory
  - schema theory
  - hierarchical theory
- Motor learning practice
  - Fitt’s three stages
  - motor imagery
  - physical changes

Skill acquisition: Closed loop theory

- Feedback guides learning a motor skill
  - memory trace selects and initiates given movement plan
  - perceptual trace compares movement in progress with correct memory of the movement
  - practice reduces the error

• Problems
  - requires feedback
  - more feedback doesn’t always improve performance
  - difficult to apply to complex movements (e.g. speech)
  - Difficulty with rule-based learning: applying learned concept/strategy to novel situation
Schema theory
• During skill acquisition, form a schema, or generalized program
  • able was i as a saw elle
  • able was i as a saw elle
  • able was i as a saw elle
  • able was i as a saw elle
  • able was i as a saw elle
  right hand
  braced right hand
  left hand
  teeth
  foot!
  – such an abstract motor plan could be tailored to specific conditions required for learning a motor task

• Allows for more variability and novelty compared to closed-loop theory (analogous to speech?)
  – also accounts for consistency, by the fact that different end effectors are using the same general plan
  – variability comes from modifying parameters of plan

• Predicts variable practice leads to better transfer to new -but related- task
Hierarchical learning
(mechanism for schema generation)

- movements coded in motor programs that are stored in LTM
  - distinct levels of control
  - allows for rule based behaviour because highly flexible
  - efficient because information can be stored in chunks (a motor program is an example of chunking)

Memorize the following twelve letters:

FB, ICI, AKG, BUP, S
recall
(stop looking at your notes)

FB I, CIA, KGB, UPS

easier?
Hierarchical learning

- FB, ICI, AKG, BUP, S

- These groups make contact with already learned chunks in LTM

2nd example: German & English speakers practiced sentence in one language (speeding occurred) and then switched to the other language -- speeding only continued at the same rate if meaning of sentence retained -- indicates the development of some cognitive structure dealing with meaning (the formation of a higher level unit)

Fitts’ 3-stage theory of learning

- CAN BE THOUGHT OF AS THE DEVELOPMENT OF GENERAL PROGRAMS
  - cognitive stage
    - learn basic procedures to be followed
  - associative stage
    - transition from conscious to automatic control
3 stages of motor learning, continued
– autonomous stage -- this stage involves motor programs i.e., transition from closed loop to open loop control
  • little conscious involvement at this stage

• Role of feedback in the autonomous stage of learning
  – feedback necessary during learning, but not to the same extent later, skilled performers monitor their performance, and make intermittent corrections as necessary

Review of advantages-Hierarchical theory:
• distinct levels of control

• allows for rule based behavior because highly flexible

• efficient because information can be stored in chunks

Question: How do you have a ‘motor program’, and how does it get stored in long term memory?

Procedural memory
• Memory for formation of long-term motor abilities

• Questions:
  – are the features that are known about declarative memory applicable to motor memory?
  – Where might these processes occur in the neuromuscular system?
Stages of declarative memory formation
- Incoming information enters short term memory (fragile)
- Maintained by rehearsal
- Either transferred to long term memory (consolidation) or forgotten

Medial temporal lobe structures required
- Evidence for different memory system: patient HM (e.g., that guy the movie 'memento' is based on) able to learn new motor skills

Medial temporal lobes not required for learning motor memories

Source: www.brainconnection.com

Source: Blakemore, 1977

Source: Blakemore, 1977
Procedural memory: consolidation?

• QUESTION: are similar processes involved in the formation of motor memories?
  – does motor memory have consolidation?
  – if so, where?

• Use fact that interference can disrupt consolidation for declarative memory
  – does one see something similar for procedural memory?

• Series of experiments by Shadmehr and colleagues examine this question
  – use movements in altered “force fields” to test acquisition of new motor skills


Experimental setup

Visual display

Motor memory task

• Displace targets on screen by pushing robot handle
• Robot can impose forces against hand

• Once accustomed to new force field, removal produces after-effects
  – indicator that the altered force environment was "remembered" by the motor system

• Some subjects learn slightly different force fields at different delays

SKILL B: REVERSE THE DIRECTION OF FORCE FIELD
Practice Skill B at different times following Skill A learning
• Question: will learning of a different (opposite) force field interfere with learning of first?
  – Would be evidence of a disrupted consolidation process.

• SKILL B: REVERSE THE DIRECTION OF FORCE FIELD
  Practice Skill B at different times following Skill A learning

<table>
<thead>
<tr>
<th>GROUP</th>
<th>TIME BETWEEN learning B1 &amp; B2</th>
<th>RECALL second B1</th>
<th>RECALL third B1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>XX</td>
<td>24 hr</td>
<td>5 months</td>
</tr>
<tr>
<td>2</td>
<td>5 minutes</td>
<td>1 week</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>30 minutes</td>
<td>1 week</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>2.5 hours</td>
<td>1 week</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>5.5 hours</td>
<td>1 week</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>24 hours</td>
<td>1 - 9 days</td>
<td>-</td>
</tr>
</tbody>
</table>

**Question:** Will Skill B “interfere” with the consolidation of Skill A?

**Answer:** Yes !!

(if the two skills are sufficiently similar)

**Question:** what is the time course for interference?
Motor memory consolidation: summary
- Different motor skills can be learned and retained, but only if tasks are separated by 5-6 hours or more
  - empirical question: *how different is different?*

- Suggests distinct change in the state of resistance of motor memory within hours of acquisition

Question: *where* does this transition from a fragile to a more solid state occur?
- **Test by scanning during learning and recall of novel force field**

Changes in brain activity associated with procedural memory
- Areas selectively active between early and late learning
• other areas selectively active between late learning and recall (after 5.5 hours)

• see changes in parietal, premotor, and cerebellum

Motor imagery (mental practice)

• Evidence that just “practicing in your head” can improve performance

• mental practice may be assisting to formulate ‘generalized motor plan’, despite lack of muscle activation

• Imaging studies show activation of various brain areas, other than primary motor area, during motor imagery
  – one study found 30% overlap of motor imagery and motor performance activation sites
Question: what aspect of movement is entered into memory?

- Is this short-term motor memory initially encoding
  - movement amplitudes? Endpoint locations? Limb postures?

- Ask a subject to move to a remembered location, or a remembered distance (eliminate feedback - why?)

- Kelso and Holt (p. 106) showed that, when feedback was eliminated, subjects reproduced finger locations more accurately than finger distances.
  - Recent data suggest memory for final posture may be superior to memory for spatial location.
  - Think about this in terms of the hierarchical model.

Final question: what is the nature of these motor memories?

- Older idea of “motor programs”
  - abstract representation of a motor sequence stored in LTM

  - Definition: ‘a set of muscle commands that are structured before a movement sequence begins, and that allow the sequence to be carried out uninfluenced by peripheral feedback’
• but this idea has not had much support as a concept of how motor skills are represented internally

• Recent focus has been on the concept of **INTERNAL MODEL** already discussed

• Association between the desired trajectory of, for example, the hand and the required muscle torques
  – example: walking with a glass

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**Review:** these models are used by the neuromuscular control system to predict the mechanical dynamics of a task (inverse), and the sensory feedback from a task (forward)

And *where* might these internal models exist??

PARIETAL
PREMOTOR
CEREBELLUM!
Physical changes

• Obviously, skill acquisition involves not just changes of the nervous system, but changes of the periphery as well!
  – Pattern of muscle activity changes, movements smoother
  – Coordination between limbs improves, less co-contraction

Individual differences

• Why are some people more coordinated naturally than others? (or rather, why can your kin prof outskate most people but can’t jump rope without inflicting serious self-injury?)
• Apart from inherent interest, identification of “dimensions” of motor ability gives clues as to the organization of the motor system
  – i.e. if ability A is independent of ability B, the two are probably controlled separately
  – Dimensions of motor control can be determined by which aspects of performance are independent within individuals

• Factor Analysis, a statistical technique, has been used to isolate factors that relate correlations between pairs of tasks
  – Test subjects on numerous tasks and correlate performance between them. E.g., if you’re good at typing, how good are you at juggling? At swimming? At tennis?
• The analysis suggested 5 factors that enable some to perform better than others:
  – Control precision: precise movements with large body segments
  – Multilimb coordination: several limbs moving concurrently in a coordinated fashion
  – Reaction time
  – Finger dexterity
  – Arm-hand steadiness
Summary
• Psychological theories regarding the organization of movement sequences and skill learning
  – allow one to propose testable hypotheses
• Procedural versus declarative memory
  – similarity in their organization, but otherwise quite different
    • different underlying neural structures
    • coding must be different because storing a representation of a motor act

• Features of short-term motor memory
  – aspect being encoded
  – motor buffer

• Possible form for long-term motor memory, and it’s implementation
  – internal models