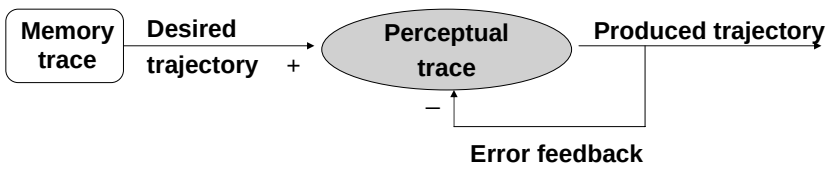
Skill acquisition

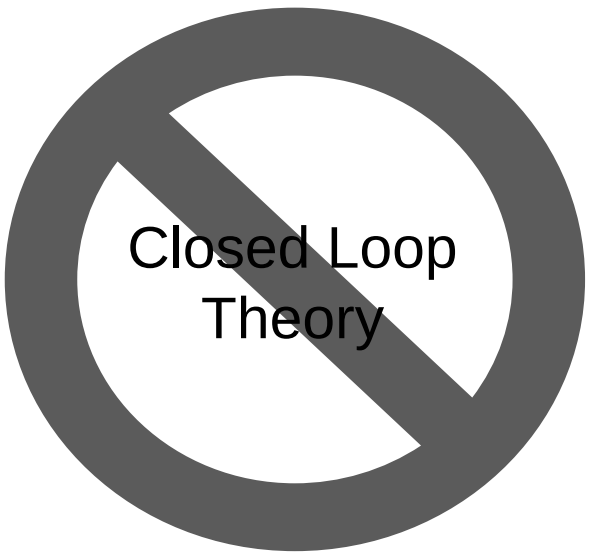
- Motor learning theories
  - closed loop theory
  - schema theory
  - hierarchical theory
- Motor learning practice
  - Fitt's three stages
  - motor imagery
  - physical changes

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

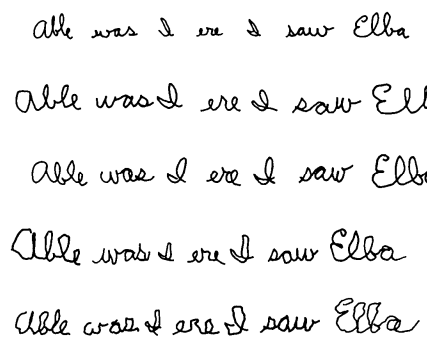


- Problems
  - requires feedback
  - more feedback doesn't always improve performance
  - difficult to apply to complex movements (e.g. speech)
  - Difficulty with rule-based learning: applying learned concept/strategy to novel situation



Schema theory

- During skill acquisition, form a schema, or generalized program



Able was I ere I saw Elba	**right hand**
Able was I ere I saw Elba	**braced right hand**
Able was I ere I saw Elba	**left hand**
Able was I ere I saw Elba	**teeth**
Able was I ere I saw Elba	**foot!**

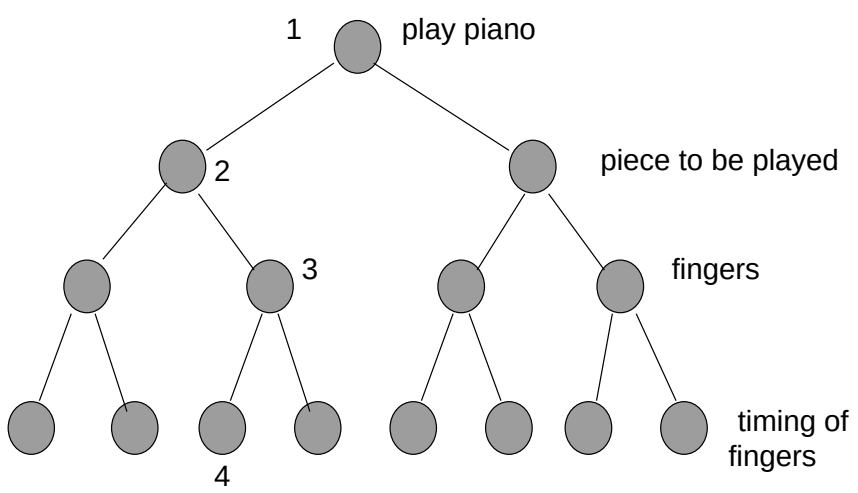
  – **such an abstract motor plan could be tailored to specific conditions required for learning a motor task**

- 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 <u>motor programs</u> that are stored in LTM
  - distinct levels of control
  - allows for rule based behaviour because highly flexible
  - efficient because information can be stored in <u>chunks</u> (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 (<u>the formation of a higher level unit)</u>

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

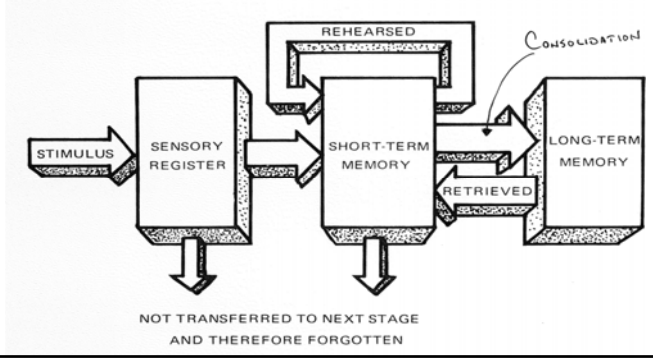
Question: How do you have a 'motor program', and how does it get stored in long term memory?

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?

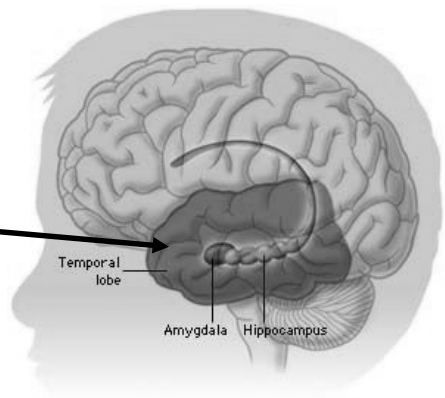
Stages of **declarative** memory formation

- Incoming information enters short term memory (fragile)
- Maintained by rehearsal
- Either transferred to long term memory (**consolidation)** or forgotten



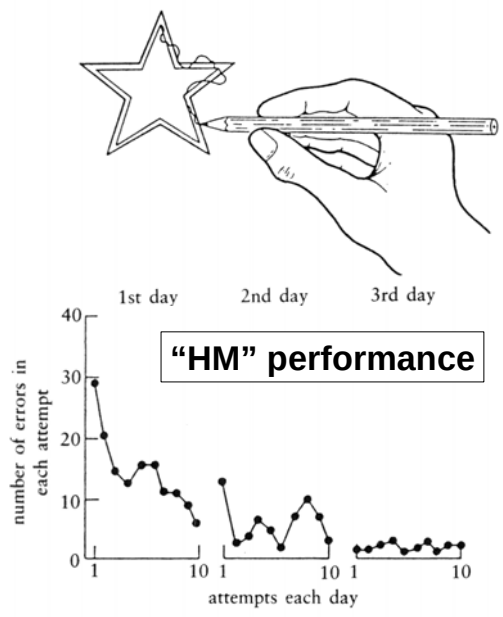
- ***Medial temporal lobe structures required***
- Evidence for different memory system: patient HM (e.g., that guy the movie 'memento' is based on) able to learn new motor skills

These structures are known to be involved in declarative memory formation.



Source: www.brainconnection.com

- Medial temporal lobes *not* required for learning motor memories



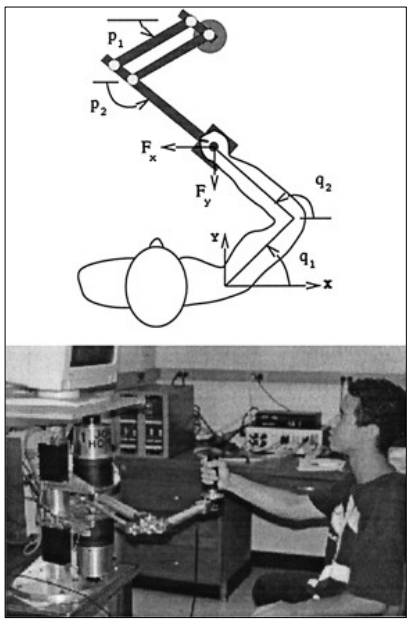
Source: Blakemore, 1977

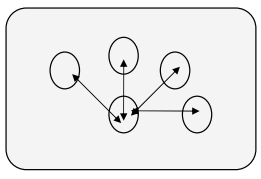
Procedural memory: consolidation?

- 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

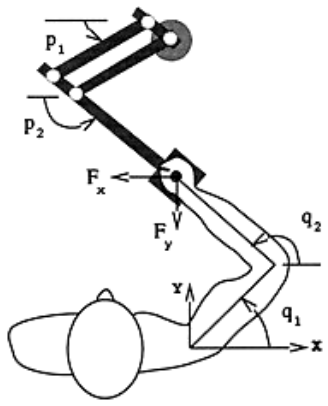




Visual display

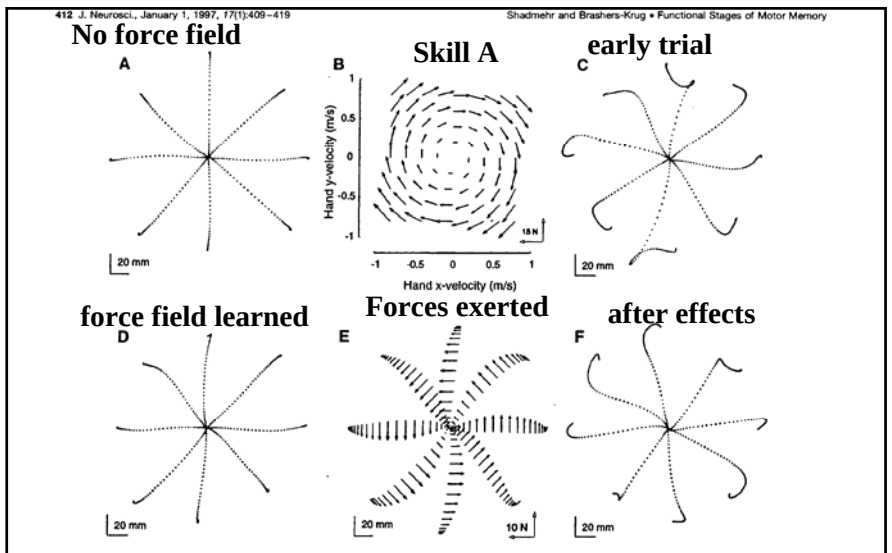
Source, next 3 slides: Shadmehr and Brashers-Krug, J.Neurosci,17:409-19,1997

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

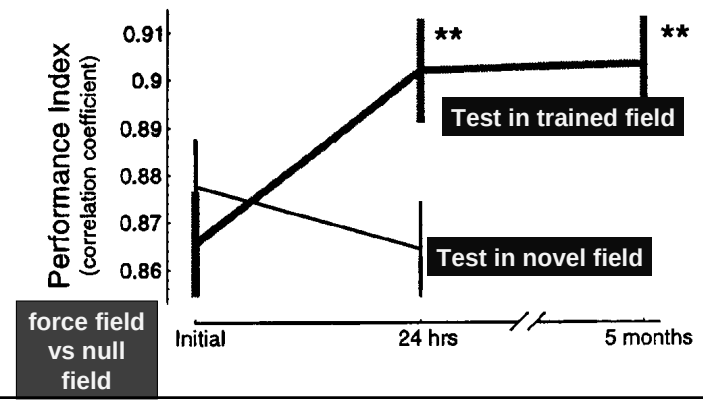
- **Question: will learning of a different (opposite) force field interfere with learning of first?**
  - Would be evidence of a disrupted consolidation process.

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

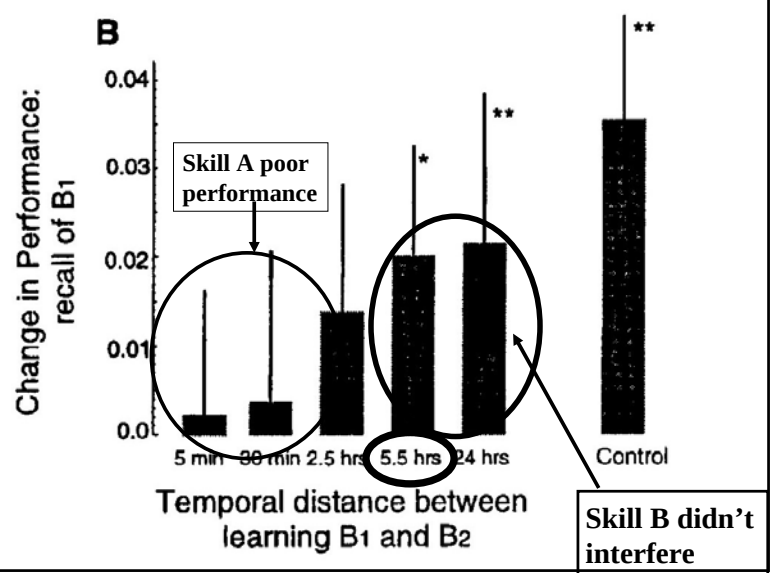
GROUP	TIME BETWEEN learning B1 & B2	RECALL second B1	RECALL third B1
1	XX	24 hr	5 months
2	5 minutes	1 week	-
3	30 minutes	1 week	-
4	2.5 hours	1 week	-
5	5.5 hours	1 week	-
6	24 hours	1 - 3 days	-

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?

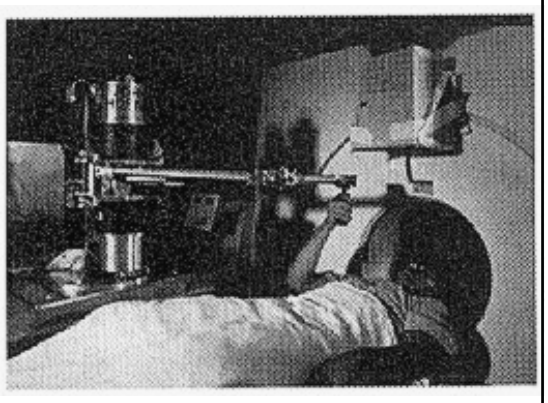


Motor memory consolidation: summary

- 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?

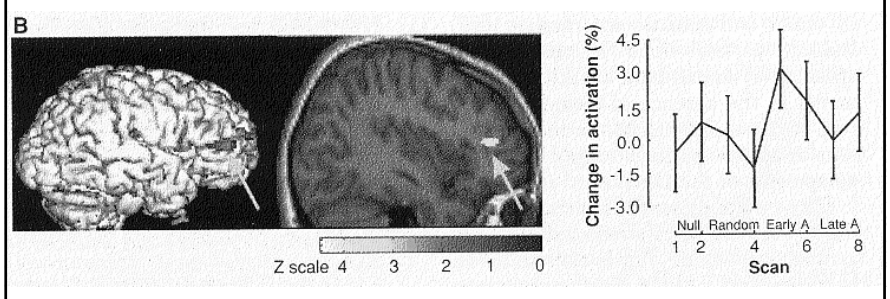
- ***Test by scanning during learning and recall of novel force field***



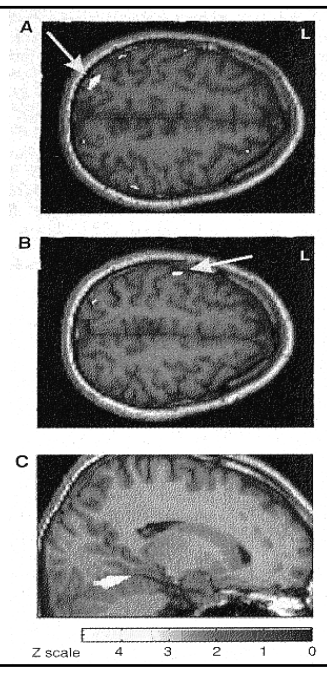
Source, next 2: Shadmehr & Holcomb, Science,277:821-25, 1997

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)

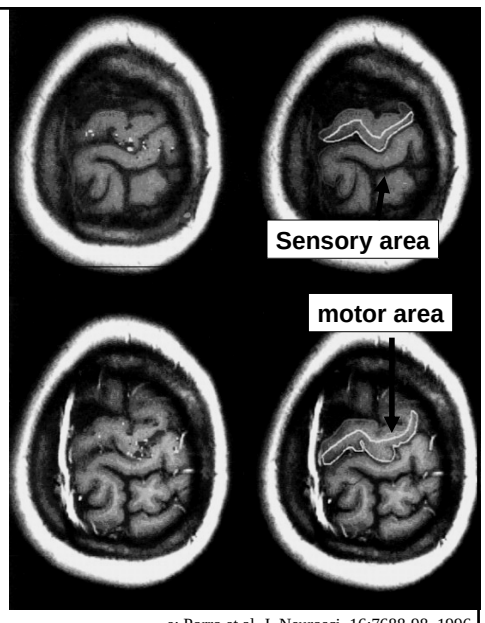


- see changes in parietal, premotor, and cerebellum

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

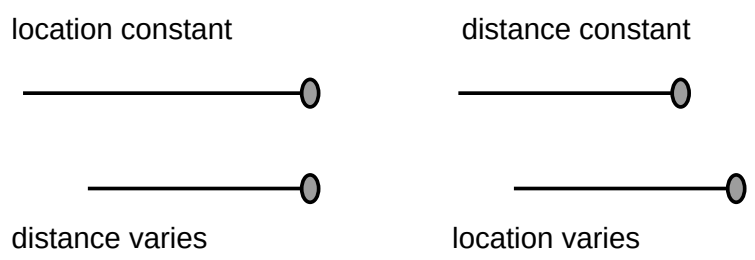
- Imaging studies show activation of various brain areas, other than primary motor area, during motor imagery
  - one study found 30% overlap of motor imagery and motor performance activation sites



e: Porro et al. J. Neurosci. 16:7688-98, 1996

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?)



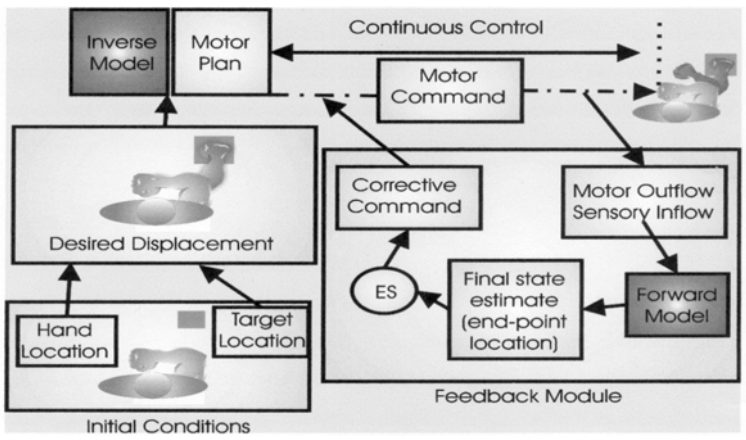
- Kelso and Holt (p. 106) showed that, when feedback was eliminated, subjects reproduced finger locations more accurately than finger distances
  - Recent data suggest memory for final posture may be superior to memory for spatial location
  - Think about this in terms of the hierarchical model

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

- 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)

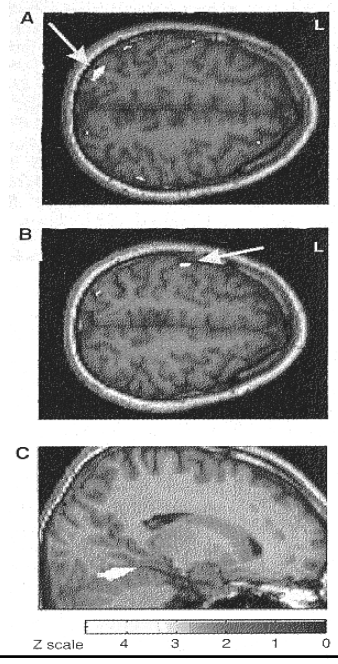


And *where* might these internal models exist??

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

Curt Harnett, cycling god

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