



HUMAN PERFORMANCE

M6X00915

LECTURE 7: LEARNING & EXPERTISE

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SKILLED PERFORMANCE



EXPERTISE

- Serena Williams: 23 grand slam titles, returns the fastest tennis serve.
- Magnus Carlsen: Norwegian chess champion: can beat 12 opponents simultaneously whilst blindfolded.
- Radiologist: can decipher extremely complex x-rays within seconds to spot suspicious tissue.

DIFFERENT EXPERTS, SAME COGNITIVE MECHANISMS?

- Athletes not generally faster than others of the same age.
- Planning ability of chess expert no better when away from chess board.
- Radiologist no better than anyone when they have to look for Wally.
- Yet they are superior in their chosen domain



EXPERTISE

- To understand how the brain of an expert works, we can use understanding of general aspects that we are all experts in....
 - What type of room is this?
 - If you walked in here in the dark where would you look for a light switch?
- Through years of exposure to rooms we understand their contents and variations.
 - We explicitly and implicitly remember things that occur together in the environment until it becomes routine.
 - This is the same for experts but their domains takes much longer to master.

SKILLED PERFORMANCE

- Skills can protect us from making errors
 - Automatisatation processes.
- We want to perform at optimal level
 - But not everyone can be skilled in every type of task
- If we knew the mechanisms involved or knew how skills were learned then wouldn't we implement them and all be brilliant at everything?
 - Problem for any theory attempting to explain skills acquisition is that changes happen in people as they learn.

SKILLED PERFORMANCE

- These changes can be:
 - Communicated by person saying they feel more competent
 - Can be measured objectively through task performance.
- Changes in performance style can also occur
 - e.g., driving: changes years after passing test.
- Even CRT changes due to practice.
- Skill acquisition can be shown graphically through learning curve

SKILLED PERFORMANCE

- Time taken on a task decreases as skill increases.
- Neves and Anderson (1981):
 - In early stages of learning, performance speeds up rapidly.
 - Once the person becomes more accustomed, the rate of improvement decreases.
 - Called diminished returns.
- Learning curve can be expressed mathematically:
 - Power law of practice (Newell & Rosenbloom, 1981).

SKILLED PERFORMANCE

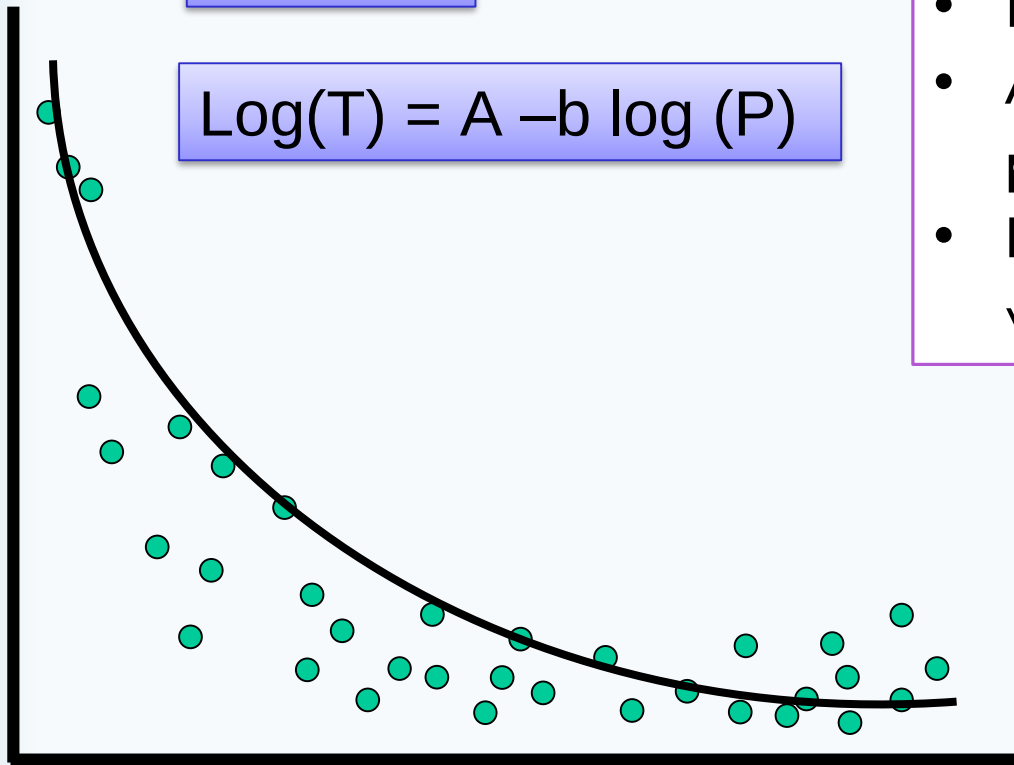
(Anderson, 1990; Neves and Anderson, 1981)

$$T = aP^{-b}$$

$$\text{Log}(T) = A - b \log(P)$$

- T: time taken to perform task
- P: amount of practice
- A: initial level of performance
- B: rate of improvement, which are constants.

Time to solution (seconds)



Number of problems

SKILLED PERFORMANCE

- In demanding tasks, the way a skilled person experiences the task is different to an unskilled person.
 - Why?
 - Experts can deal with stream of incoming info
 - Non-skilled person experiences overload whilst trying to execute performance.
- Annett & Kay (1956): skilled performer exploits redundancies in sequences from having previously responded in order to produce a more stable response.

SKILLED PERFORMANCE

- Types of error made by expert will differ to novice.
- Theories of skill acquisition must account for this.
 - They must also understand how different contextual factors affect how we learn skills
 - Also, even if we are skilled, how we then perform under different contexts.
- How do we learn?.....
 - Practice
 - Direct training
 - Incidental learning (e.g., words of song on radio)

SKILLED PERFORMANCE

- With formal instruction:
 - First phase of instruction
 - Then phase of practice.
 - Following appropriate amount of practice accurate skilled performance can emerge.
- Different types of tasks require different lengths of times for instruction & practice.
- Also, instruction can come from various sources.



SKILLED PERFORMANCE

- Distinction between cognitive and motor skills.
- Example of a cognitive skill?
- Example of a physical skill?
- Most performance is cognitive and physical:
 - Have to motorise response after working out a problem.
 - Footballer needs to use cognitive decision-making and planning to swerve an opponent player.
- Along with acquiring skills, other aspect to consider is **maintaining** skills:

THEORIES OF SKILL ACQUISITION

Phase Theory (Fitts, 1962): Learning happens in series of phases.

Cognitive

- Instruction through description
- Feedback given on errors

Associative

- Correct outputs practiced
- No errors: smoothly execute chunks of activity
- Performance flexible to changing task demand
- Extra processing capabilities incorporated to main performance.

Autonomous

- Automatic, unconscious, intrinsic
- Resistant to distractors/stressors
- Ability to handle tasks simultaneously

THEORIES OF SKILL ACQUISITION

- Most remain in **associative** phase for many skills
 - Key to moving to autonomous phase is **practice**.
- Main evidence:
 - Cigar makers perform better the longer they had been in service
 - Plenty of anecdotal accounts of people getting better with time
 - Average age of goal keeper is much higher than other players.
- Criticisms:
 - Descriptive
 - Little backing from empirical work.
- Fitts' theory focused on perceptual-motor performance.

THEORIES OF SKILL ACQUISITION

- Adaptive Control of Thought (ACT*): Anderson
 - Accounts for cognitive skills.
 - Based on some of Fitts' ideas
- Adds from philosophy of mind regarding difference between “knowing that” & “knowing how”.
- The difference between declarative and procedural
- As a skill is learned there is a change in the type of knowledge that underpins performance.

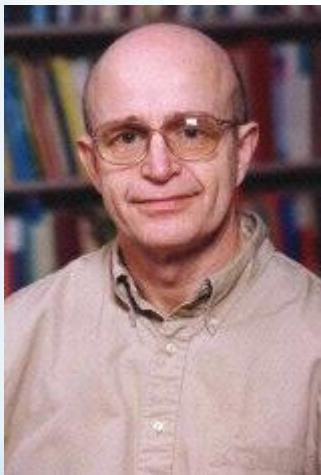
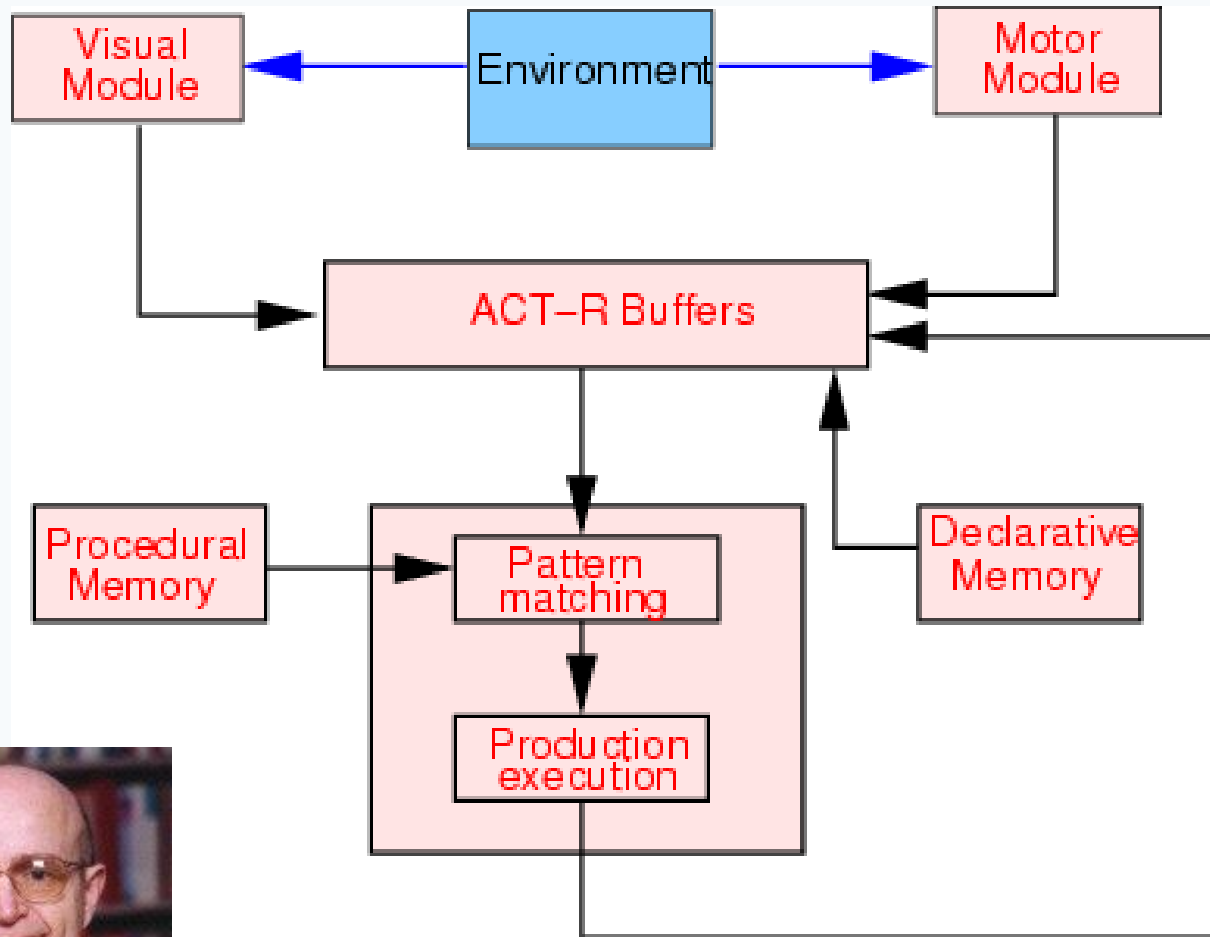
THEORIES OF SKILL ACQUISITION

- Early learning relies on declarative knowledge
- Later learning relies on procedural knowledge
- Unlike Fitts, Anderson is clearer about changes that take place in way knowledge is represented as a result of practice:
 - Involves process called **knowledge compilation**.
- Declarative knowledge is compiled into procedural knowledge
 - Thus stored in a different form.

THEORIES OF SKILL ACQUISITION

- Effects of practice on procedural knowledge happen through process of **tuning**.
 - Allows for generalisation of procedures to other contexts.
 - Less successful procedures eliminated at expense of successful ones.
 - A feature of a well practiced skill is that declarative knowledge is no longer available in its original form.
 - Task can be achieved but knowledge about it is not accessible.
 - Person who does task best not always best person to instruct the task.

THEORIES OF SKILL ACQUISITION



<http://act-r.psy.cmu.edu/about/>

ACT* Anderson (1982, 1983, 1995)

MODELLING SKILL ACQUISITION

- ACT* recognised as successful because it specifies detailed principles for modelling skilled performance.
- It represents cognitive architecture for skill acquisition which has been developed and tested using modelling principles.
- Processing units in ACT are production, which means it uses:



- If there is an input condition then action should execute.
 - E.g., Production rule for braking at traffic lights....
 - If traffic light is red, then put foot on brake in order to stop car.

MODELLING SKILL ACQUISITION

- Resembles S-R learning of behaviourism but goes further:
 - Productions in “if” part can be complicated
 - Conditions can also include persons goals
 - This flexibility of action and intentional control was missing from behaviourist approach.
- E.g., in some circumstances, traffic light production could be
 - IF light is red but there is no traffic and I’m late then I’ll just go.
- The first two parts of the condition relate to the stimuli
- The third refers to the goal.

MODELLING SKILL ACQUISITION

- Sometimes action is not the response
 - It could be development of another production
 - These can be linked together to form production systems, which allows for central processing of information.
- Production system models explain features of empirical data on skill acquisition and changes in style of performance as a result of becoming an expert.
- Anderson: early cognitive stages of skill learning is controlled by weak method productions
 - General-purpose productions that are flexible but ineffective.
- Processing is verbally coded & leads to difficulties transferring verbal instructions to muscle movements.

MODELLING SKILL ACQUISITION

- Trigger conditions for productions are held in WM at this stage, which we know is prone to errors due to overload.
- Feedback from errors initiates knowledge-compilation process.
 - This leads to acquisition of special purpose procedures for controlling the various components of the skill.
- Different levels of skill acquisition are referred to as:
 - Strategic: deciding on general approach to solve a problem
 - Tactical: specialised knowledge on how to achieve sub-goal.
 - Novices think about superficial features of a problem whereas experts organise their thinking around abstract principles.

MODELLING SKILL ACQUISITION

- When one reaches association or automatic stages of skill learning, components of the skill become proceduralised:
 - For experts these incorporate rules covering all inputs the person is likely to encounter so appropriate action can be executed regardless of the circumstance.
 - The person learns an overall strategy for handling a task but doesn't acquire fixed routines for handling individual stimuli.
- View that skilled performance is controlled by large number of special-purpose productions has been developed into empirical studies on chess masters who can recognise an immense number of configurations of chess pieces.

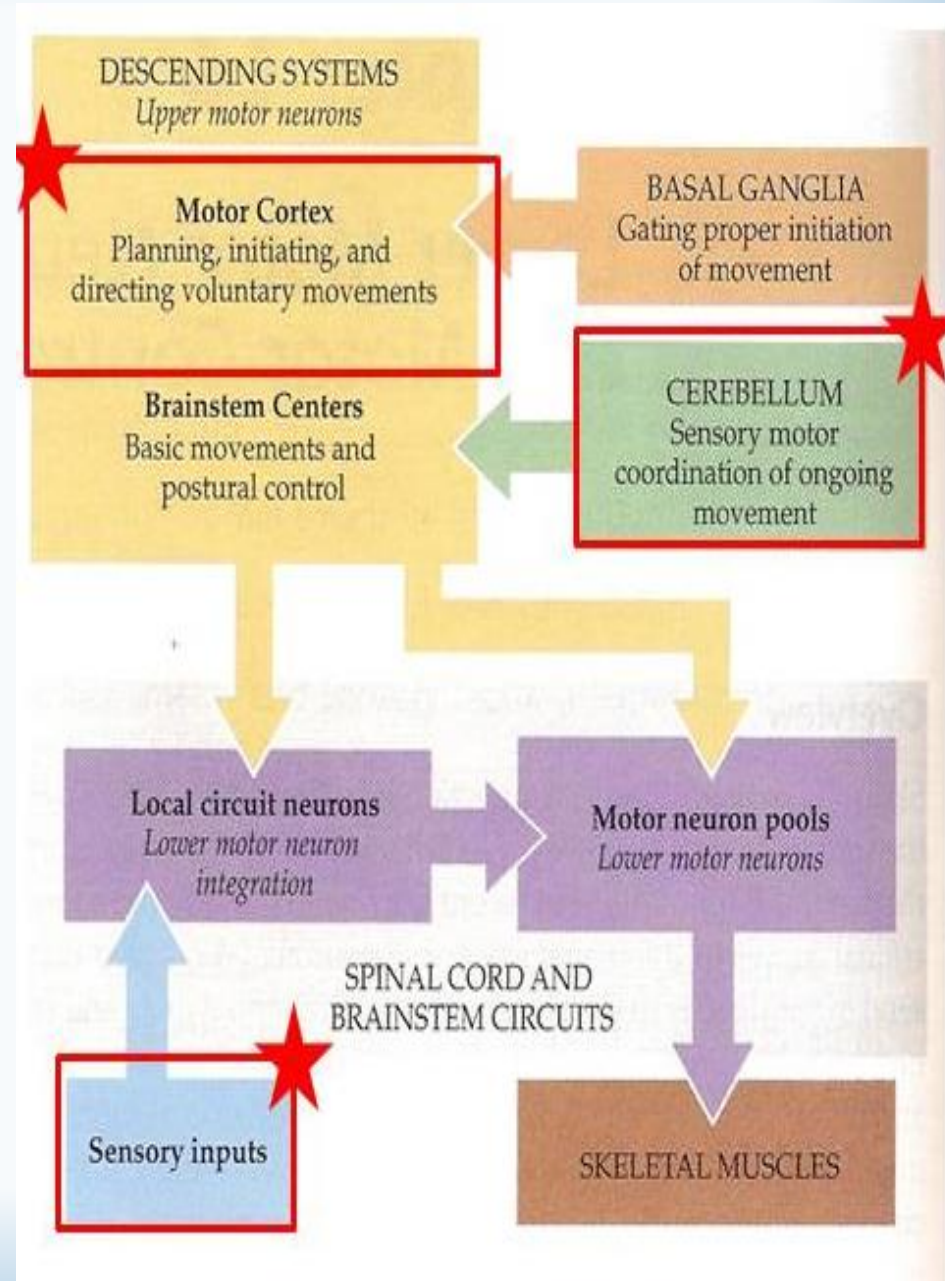


MODELLING SKILL ACQUISITION

- In skilled performance: expert relies on highly detailed elaborate memories in form of procedural knowledge.
- Novices must decide from actions with limited guidance from general-purpose & weak-method productions
- Many production systems developed to explain skill interaction:
 - The Goals, Operators, Methods, and selection model (Card et al., 1983), which has led to changes in the displays of computers.
 - Cognitive complexity theory (Bovair et al., 1990), which represents WM demands imposed by task performance.

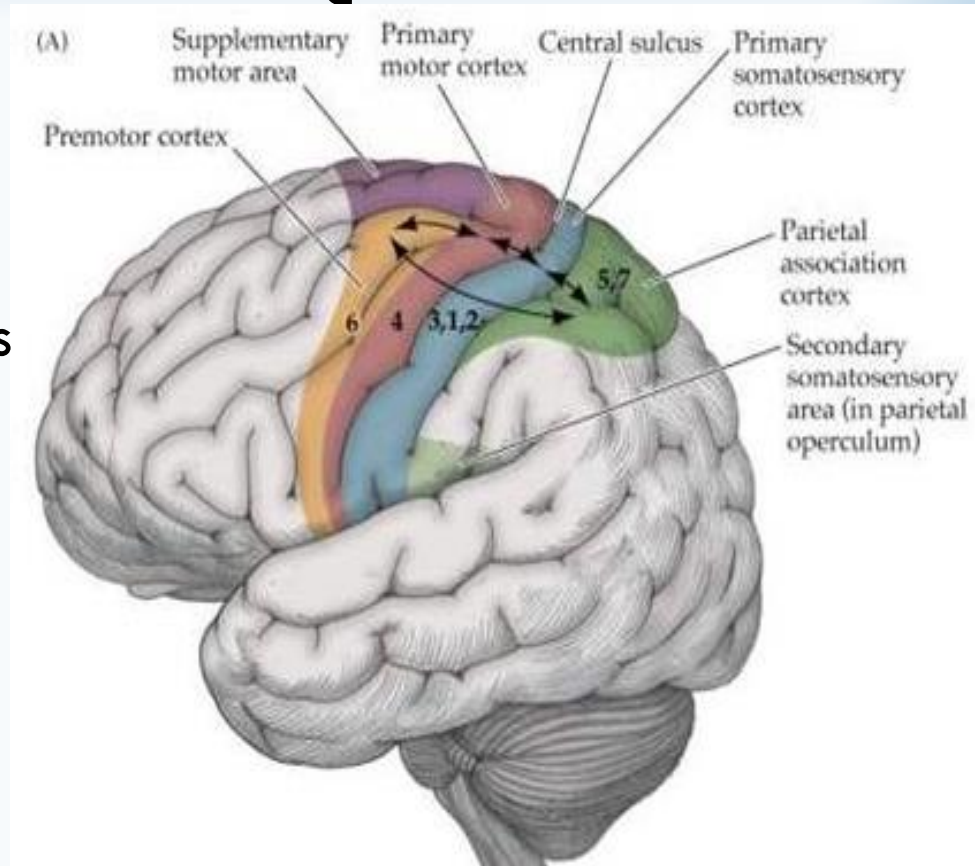
MODELLING SKILL ACQUISITION

- Cognitive & motor skills may be governed by same principles.
- But motor skills are differentiated by inaccessibility of process involved.
- Difficulty in learning how to ride a bike is that it is difficult for an instructor to verbalise how it should be achieved.
- Neurological evidence suggests motor behaviour is controlled by the sensorimotor cortex, basal ganglia, and cerebellum.



MODELLING SKILL ACQUISITION

- Inability to verbalise procedural actions is due to those motor systems in the brain not sending feedback about their operations to the neocortical system, which supports verbal representation.



- Main issue in researching motor skills concerns nature of the memory trace or motor programme which preserves acquired skills.
- But evidence suggests there exists some form of internal programme for motor skills and that complex movements might sometimes be executed without sensory feedback.

MOTOR SKILLS

- Evidence comes from **deafferented movement** (Lashley, 1971):-
 - Where movement continues in limbs despite (through injury), there not being proprioceptive feedback loops sending signals from muscles through afferent neurons to the spinal cord and motor centres of the brain.
 - <https://www.youtube.com/watch?v=FKxyJfE831Q>
- Secondly, actions can be performed so rapidly (milliseconds) that any feedback and correction would be too slow.

MOTOR SKILLS

- These arguments suggest movement is controlled by pre-existing programmes.
- By us making movement mistakes, although not ideal, it's indicative of no feedback loop.
- Theories of Cognitive skill emphasise control of behaviour by mental structures.
 - They also propose shift of control from high-level decision making structures to more specialised routines during skill acquisition.

MOTOR SCHEMA

- Similar account applied to motor skills:
 - Keele (1986): complex skills are acquired by integrating motor programmes for simple movements into more complex integrated programme in same way knowledge compilation operates for cognitive skills.
 - But control process is not understood as there is no protocol for movement like cognitive skills which can be verbalised.

MOTOR SCHEMA

- Schmidt (1975, 1976) put forward a motor schema theory:
 - It incorporates idea of a motor program but.....
 - Includes flexible system based on schematic representations....
 - This enables us to put together varying patterns of responses to changing circumstances
 - Some under feedback control and others not.
- The theory also predicts ***invariant relative timing***:
 - Overall sequence of movement can be made faster or slower as a unit while the constant phasing in the sequence is maintained.

MOTOR SCHEMA

- Info about a particular motor skill is stored in 2 schemas:
 - 1. Recall schema:** shows how movement outcome depends on both parameters of the generalised motor programme and initial environmental conditions.
 - Recall schema controls motor program used for rapid movement
 - 2. Recognition schema:** describes how movement outcomes depend on initial conditions and sensory consequences of movement
 - Recognition schema used to evaluate the movement-produced feedback.

COGNITIVE-MOTOR SKILLS

- Schmidt & Lee (1999) provide supportive evidence from empirical work but also highlighting issues....
 - E.g., vague account of how the learning process takes place.
- A good account of skill learning needs to encompass
 - Cognitive and....
 - Motor skills
 - This is what many skills use in the real world.
 - Driving, playing sports, operating machinery, etc.
- Important cognitive-motor skill: interaction with technology.
- Specifically, how we use keyboards to type out a passage of text.
 - This may give us an understanding of how cognitive and motor processes integrate.
 - It can also give us further insight into the skill theories previously discussed.

COGNITIVE-MOTOR SKILLS

- Someone new to using a keyboard will show **qualitative** and **quantitative** changes in performance with practice.
- Performance speed is measured by how many words a person can type in a minute (wpm).
 - The aim is examine whether wpm increases and errors decrease over time.
- The actual response speed is measured by the median time that elapses or inter-key interval between each key stroke.
- In experts this can average to 100ms which is incredibly fast.
- This finding is important because it provides support for the idea that there is pre-programming of motor responses as discussed earlier.

COGNITIVE-MOTOR SKILLS

- Speed is how experts & non-experts differ in a quantitative way
 - but they also differ qualitatively by performance being more variable in non-experts,
 - e.g., being slower when having to type letters rarely used.
- Non-skilled typist need to finish pressing the previous key before starting to think about processing the next key, let alone actually pressing it....
 - whereas processing for skilled typist is automatic.
- Typing is a useful skill to build a model as it is constrained enough, with component processes that can be linked to an overall architecture.

COGNITIVE-MOTOR MODEL

- Rumelhart and Norman's (1982) schema activation model
 - Describes 4 component processes:
 1. Perceptual process: text input is perceived and coded as an individual word schema
 2. Parsing: codes are computed & activated for each letter in the word.
 3. A key press schemata is activated by the parser
 4. Response activation: key press schemata activates the appropriate finger and hand muscles to press the key.

COGNITIVE-MOTOR MODEL

- The researchers programmed a simulation which specified in detail how activation was transmitted between different schemata.
 - E.g., the most activated key press schemata tends to inhibit other activated schemata, so we don't end up pressing several keys at once – only the key we want to press.
- Once the target is pressed the schema is deactivated
 - This allows the next schema in the sequence to be disinhibited
 - Subsequently it becomes activated in order to make a response, with the schemata and response units operate in parallel.

COGNITIVE-MOTOR MODEL

- Processing becomes more parallel in nature as a typist gains expertise.
 - Typists usually look ahead in the text of something they are copying so that the keypress for a given letter is being selected and executed.
 - Words and letters further on in the text are being parsed.
 - So the response system is already prepared for moving onto the next letter in the sequence.
- The number of characters a person is looking ahead to is called the **hand-eye span**
 - It can be measured either by watching eye movements and keypress at the same time or by experimental studies of preview.

COGNITIVE-MOTOR MODEL

- In preview studies the number of letters the typist is looking ahead to is controlled artificially by presenting the text to be copied on a visual display unit
 - With a preview of 5, only the next 5 letters are visible
 - Then as each character is typed the next letter in the sequence becomes visible.
- So, the hand-eye span is measured by reducing preview to a point at which performance is slowed.
- A component skill acquired by expert typists is the ability to look ahead in the text so their reliance on parallel processing is far more substantial.

DO BRAINS OF EXPERTS DIFFER?

- Radiologists knowledge of x-ray is visual and engaged brain areas involved in dealing with visual info.
- There is no difference between experienced radiologist and medical students in the early visual areas of the occipital cortex.
 - Which processes info for basic characteristics (size, shape).
- However, later visual areas that deal with complex patterns – e.g., fusiform gyrus, is more activated in radiologists when viewing x-rays.
 - This area is responsible for holistic processing.
- For chess experts the neighbouring Para hippocampal gyrus (important for scene perception) and retrosplenial cortex (important for navigation) is also more activated.
 - It allows them to mentally manipulate & simulate a situation of moves in the future.

DO BRAINS OF EXPERTS DIFFER?

- The brain has different specialist neural mechanisms for dealing with different information.
- Some researchers suggest that neural activity is reduced in experts performing a task in their domain because it is taken as an index of neural efficiency (i.e., performance is effortless to an expert).
- However, complex cognitive process require the support of many brain areas.
 - Activation and manipulation of knowledge leads to neural expansion in areas associated with that knowledge.
- Also, the same areas in the opposite hemisphere are thought to be engaged with experts – termed the ‘double-take of expertise’.
 - The sharing across hemispheres may support parallel processing.

DO BRAINS OF EXPERTS DIFFER?

- Although the performance of a tennis player, chess player, and radiologist are different (physically, cognitively, and with the brain regions involved).....
 - They all employ numerous patterns of activity from their domain to circumvent cognitive and neural limitations.
- This is also why there is limited transfer between domains.
 - Also, limited transfer within domains
 - E.g., an expert tennis player is not likely to be an expert in another type of sport.

SUMMARY

- Skilled actions are highly complex but critical in order to understand performance in the real-world.
- Being an expert in a given skill means performance becomes more flexible, fluent, and efficient.
- Special-purpose routines are learned for encoding and responding to the task/stimuli.
- Verbal declarative knowledge is replaced with nonverbal procedural knowledge.
- Models have been developed for simple skills:
Anderson's ACT* model: "IF-THEN" rules.
- Principles of cognitive skills used to understand motor skills.
 - Pre-existing motor programmes.
 - Motor-schema theory
- But real-world tasks involve **both** cognitive and motor skills.

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