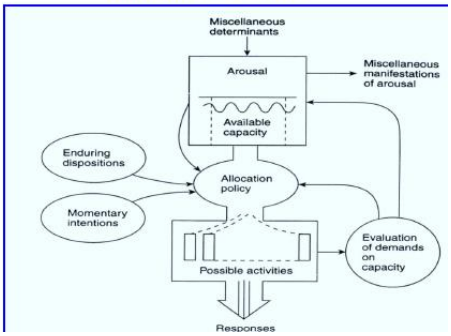
EXSS2025: MOTOR CONTROL AND LEARNING

- **Motor control**: the underlying neuro-physiological mechanisms that permit posture or movement coordination and control.
- **Motor learning**: the ability to optimally learn perceptual, cognitive and movement skills considering factors like acquisition, retention, transfer, performance as well as interactions- individual, task and learning environment.

INDIVIDUAL FACTORS THAT INFLUENCE MOTOR PERFORMANCE AND LEARNING

Information processing

Kahneman's Model

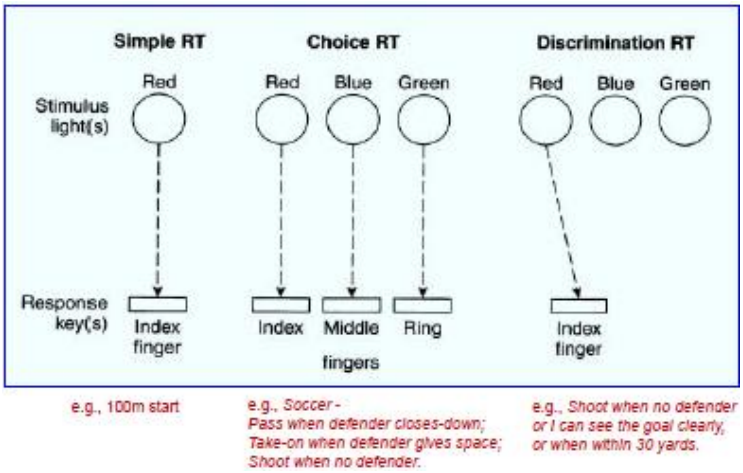


- Information processing: the mechanisms through which learning occurs.
- Reaction time
  - Time between the presentation of a stimulus and first sign of movement.
  - For example a sprint start is an example of information processing. Interestingly, a legal start is 100ms, as any faster than this is deemed to be involuntary (false start).
  - Reaction time could also be considered the first signs of neural (EMG) activity within the muscle or motor unit associated with the movement task (unobservable).

FACTORS AFFECTING VOLUNTARY REACTION TIME	
Performer	▪ Readiness and activation state ▪ Motivation ▪ Age and health
Stimulus Factors	▪ Modality of Presentation: visual, auditory, tactile, proprioceptive - Auditory and tactile signals are quicker to respond to than visual (less neural processing) ▪ Intensity: loudness or brightness of the stimulus ▪ Complexity: the amount of information to process (no. of stimuli or responses) ▪ Predictability: expectation of what the stimulus will be - Decreased reaction time with more probable outcomes, and increased RT with low expectancy outcome. Eg. rugby defenders vs sprinters. - When there is no advance warning: Stimulus identification → response selection→ response programming - When there is advance information available, skip response selection in the process of… - Perception-Action Coupling: the interaction between the performer and the physical environment, which influences open motor skills. - Also note, experienced learners can know what cues (advance warning) to look for, so better performances will be those that don't give off pre-movement cues.
Response Factors	▪ Number of Response Choices ▪ Stimulus-Response Compatibility ▪ Response Complexity ▪ Required Accuracy of Response ▪ Time Between Responses (psychological refractory period PRP) - Second stimulus is slowed if within 160ms of 1st stimulus, due to serial processing - For example, faking left then running right, causes delay in opponent
Task Experience	▪ Experience in the task results in superior: - Perceptual learning: acquisition of information (know where, when and what to look for - Motor learning: muscle activation, sequencing and joint coordination - Familiarity with the task: enables more efficient planning and coordination

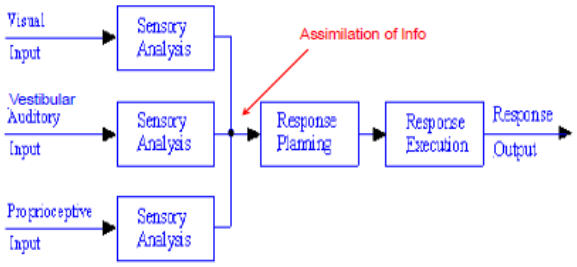
- Valls-Sole et al (1999) examined wrist flexion task to a stimulus without or with a loud unexpected noise.

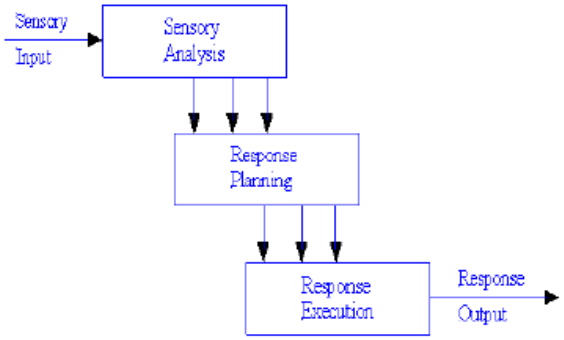
- Found movement, timing and EMG response time reduced with the startle stimulus as bypass the stage of voluntary control of movement initiation (that associated with the motor cortex).
- Hick's Law (1952): RT= a + b ($\log_2$N) where a and b are constants, N is number of stimulus-response alternatives.
- Choice RT increases by around 150ms every time the number of S-R alternatives doubles. Therefore, texting and driving very dangerous as delays RT.



- Stages of Information Processing
  - The stages between stimulus onset and response output.
    Sensory input → sensory analysis→ response planning → response execution
  - Studies of RT and movement response indicate stages, i.e time required and serial processing (which is preceded by parallel processing of information from sensory systems).
  - Cascade Processing: an overlap of processing between stages, for example response planning begins when information is still being gathered.
  - The time taken for information processing indicates whether it is an involuntary (reflex) or voluntary (planned) response, where 30-50ms are myotatic, automatic reflexes, and >120ms are voluntary.

Response type	Loop time(ms)	Structures involved	Modified by instruction	Affected by no. of choices	Example
Myotatic reflexes (autogenetic)	30-50	Spindles, golgi-tendons of same muscles	No	No	Stretch reflex
Long-loop reflexes (autogenetic)	50-80	Spindles, cortex or cerebellum, same muscles	Yes	No	Walking (sub-cortical control)
Triggered reactions (not autogenetic)	80+	Various sensory receptors, higher centres, associated musculature	Yes	Yes	Wineglass effect
Voluntary RT (not autogenetic)	>120	Various sensory receptors, higher centres, any musculature	Yes	yes	Running





  - Triggered responses: a coordinated reaction to a particular stimulus. Too fast to be voluntary, but can be modified through conscious processes, for example lift wineglass and begins to slip- then w increase grip force.

Movement decision-making and planning

- There are limits in modifying movements
  - Slater-Hamell 1960 Anticipation-Timing Task, in which participants had to stop the sweeper arrow on a certain number when it was moving.

- Found that the closer the movement was to being executed, the less likely subjects could stop the movement (despite the arrow having stopped moving).
- i.e once the movement had been committed to, difficult to suppress within 140ms, despite situation change.

- Motor equivalence
  - Motor Equivalence (Bernstein, 1967): the capability of the motor control system to enable a person to achieve an action goal in a variety of situations and conditions.
  - For example, writing with different context, size, force, direction, muscle involvement.
  - Lashley (1942) examined a writing task with different effectors (different limbs, or different muscles). Found that despite use of different effectors, the subjects still retaining their own distinctive writing pattern.
  - Thus, the pattern developed in memory structure, recalled and planned in advance, is used when required.
- Overlearning
  - The continuation of practice beyond the amount needed to achieve a certain performance criterion, with the purpose of making the skill last longer. Works for procedural skills and dynamic balance.
  - Found there was a point of diminishing returns, whereby increasing beyond a certain amount of extra practice was not proportionally more beneficial to retention performance.
  - Procedural skills:
  - Skills not performed until some time after initial training, saw large decrements in performance.
  - Eg. Schendel & Hagman (1982) examined soldiers assembling machine guns, and found that immediate overtraining group and refresher overtraining (at 4 weeks after) performed better than controls.
  - So, additional practice is required after the skill appears to have been learnt to ensure consolidation and retention when skill is not likely to be used again soon after training.
  - Dynamic balance:
  - Melnick (1971) studied dynamic balance on stabilometer until success of 28 seconds out of 50 was reached. Found 50% overtraining performed as well as 100% and 200%, so point of diminishing returns.

<u>Attention, attention capacity and memory</u>

- Attention is the portal to your memory, so to retain info, must focus attention. However, attention is limited (receive more stimuli than can process).
- Must use selective focusing: prioritising amongst multiple stimuli. Attention is also modulated so selection inhibits processing of other stimuli.
- Kahneman's Model: states that attentional resources are allocated based on 3 rules:
  - Allocate to ensure that we can complete an activity
  - Allocate according to our enduring dispositions (disposed to do as a priority)
  - Allocate according to the novelty of the situation (don't notice it normally unless it's different).
- Cocktail Party Phenomenon (Cherry, 1953): when hear name, draws attention as name is meaningful, like athletes only hearing coach in performance because coach is meaningful to them.
- Thus, when teaching give limited things to attend to (eg. technique, breathing) and eliminate distractions.
- There are a number of conceptual explanations of attention as a capacity:

Bottleneck Perspective (single filter)	▪ We have a sensory buffer which makes us serially process incoming sensory info, and attention is the result of the buffer and is required for subsequent selection of movement response. ▪ i.e can only analyse 1 info at a time, and we prioritise the order which we'll attend to them. ▪ Later versions of the explanation moved location of the single channel to later on in the sequence, stating that parallel processing is possible without attention, but the bottleneck occurs in the response selection stages (deciding what to do).
Flexible Central Resource Capacity	▪ Driven by Kahneman (1973), proposing that a fixed capacity for attention exists but you can allocate (change the spotlight of attention) as required. ▪ The amount of available attention in the capacity changes according to: - Individual: activation level (fatigue, rewards) - Task: precision, accuracy and complexity required - Situation: threats, novelty, meaningfulness vs selective goal directed ▪ Available attention= pool of effort. Parallel processing is possible but with some cost.

Multiple Resource Capacity	▪ Navon & Gopher (1979), proposes there are 3 sources of information-processing capacity: - Input and output modalities: vision, hearing, limbs, speech - Stages of information processing: perception, memory encoding, output responses - Codes of information processing: spatial codes, verbal codes ▪ Performance of simultaneous multiple tasks depends on competition for attention resources within and between multiple sources, eg. driving and conversation. ▪ Tasks requiring similar modalities, codes and responses will interfere, affecting attention. ▪ Tasks requiring different modalities, codes and responses won't interfere so attention and performance on the secondary task can be maintained.
Action Selection Approach	▪ Criticised the idea of capacity as it is difficult to measure capacity of attentional resource. ▪ Ultimately the blockage comes from planning a movement, as we can only execute one movement at a time. Allocation is the most basic process of attention, not capacity. ▪ Prioritised according to importance, and other actions are prevented at least until primary task has run its course, otherwise selected actions would not be complete ▪ Tipper (1992) examined RT to lights on a board and found interference was large when a distractor was located between the start and endpoint of movement, but not when located beyond the target. ▪ This shows that interference was due to intention or goal outcome of the movement, not capacity, and also found interference was dependent on the nature of the action. ▪ PRP is both a problem for the motor system, but also protective such as when preparing movements to dangerous stimuli, subjects are successful only if they can process information and produce movement without interference from conflicting signals. ▪ Consistent with Neumann's Action Selection view of attention, where interference can be the result of an action that has been selected.