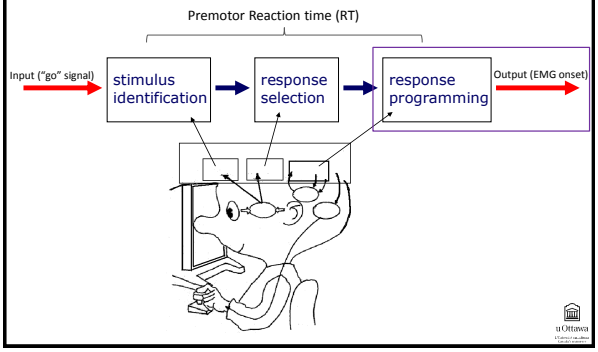
APA 2120

Lecture 8: Motor Programs
Oct 1, 2012

u Ottawa

3-stage model



Curiosity Video

- http://www.youtube.com/watch?v=ISmWAyQxqqs

Central (as opposed to peripheral) Control

- What is a Motor Program?
  - a *pre-structured* set of neural commands, *organized in advance*, that allow the entire movement sequence to be carried out.
    - (Keele, 1968)
  - Produces movement with a minimal role for sensory information
  - Movement is carried out essentially *open-loop* until enough time has passed to allow feedback processes to operate

Do Motor Programs Exist?

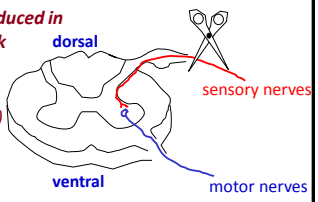
- What is the rationale for a motor program?
- Or what observations support the concept of a motor program and its features?

Do Motor Programs Exist?

Support for existence of Motor Programs:

1. ***Movements can be produced in the absence of feedback***

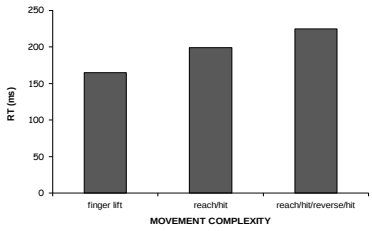
e.g. Deafferentation or Fast Movements (Boxing jab)



Do Motor Programs Exist?

Support for Motor Programs:

2. ***Reaction time increases with the complexity of movements***

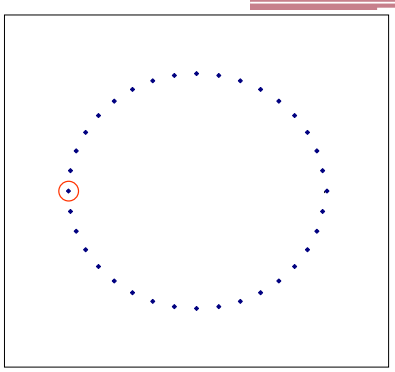


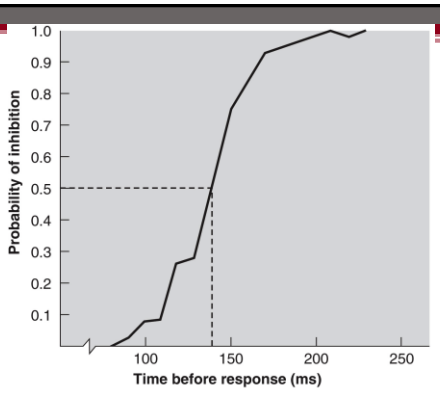
Henry & Rogers, 1960

Do Motor Programs Exist?

Support for existence of Motor Programs:

3. **Stopping a response requires <u>sufficient time</u> prior to response initiation**
   - Difficult to stop the initiation of a response once it has been preplanned and initiated internally and the point of no return has passed – suggests "release" of motor program
   - e.g., Slater-Hammel (1960) Experiment





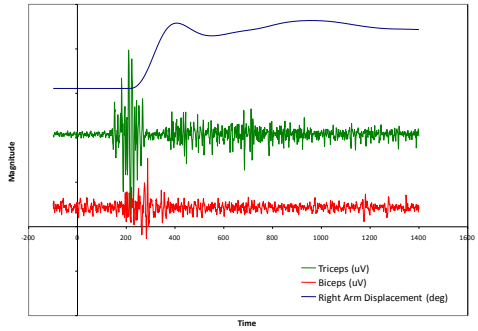
Do Motor Programs Exist?

Support for the existence of Motor Programs:

4. **Muscle activation patterns indicate that responses are executed as a unit**
   - Movement "blocking" study by Wadman (1969)
     - Performed rapid arm extension movement in "blocked" and "unblocked" condition
     - Examined tri-phasic EMG activity of triceps (agonist) & biceps (antagonist)

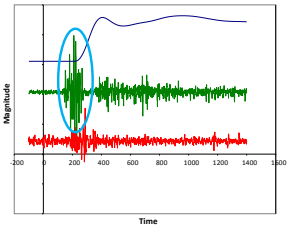
"Extend your arm quickly"

tri-phasic EMG - normal



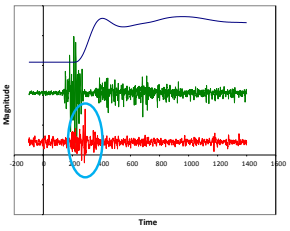
Muscle Activation Patterns

- tri-phasic muscle activation pattern
  - first agonist burst (AG1)
    - Accelerates limb
    - Burst amplitude and duration are dependent on movement amplitude (reflects force)



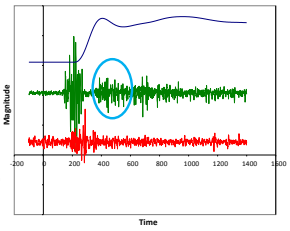
Muscle Activation Patterns

- tri-phasic muscle activation pattern
  - antagonist burst (ANT)
    - burst amplitude and timing influenced by movement extent and velocity
      - e.g. earlier onsets with small, fast movements
    - represents 'braking'



Muscle Activation Patterns

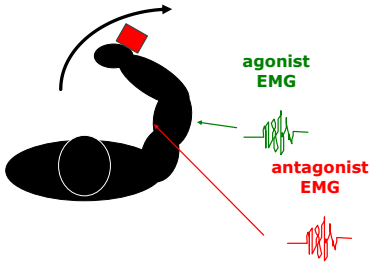
- tri-phasic muscle activation pattern
  - second agonist burst (AG2)
    - influenced by strategy
      - helps to "clamp" limb at target position



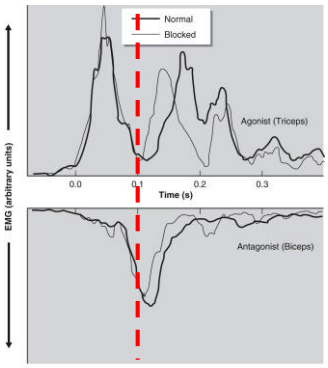
Triphasic EMG pattern

1. 1st Agonist burst
   Central origin
2. Antagonist burst
   Comes from mixed central and peripheral contributions
   - can be present without feedback
   - can also be influenced by feedback
3. 2nd Agonist burst
   Comes from central and peripheral contributions

Wadman et al. (1979) Movement "Blocking"



Wadman et al.'s Data

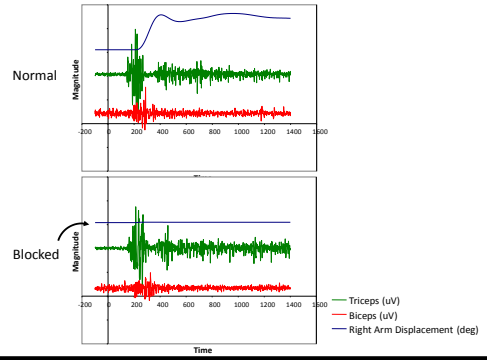


Blocking study conclusions

- Motor program is sent to the muscles via an open loop operation
  - Commands for movement organized in advance and executed as a unit
  - Carried out open-loop (without feedback) until enough time for feedback processing has passed
    - How much time is needed for feedback processes
  - Similar EMG for normal and blocked movements for first 100 msec, even though limb does not move if blocked

GL – deafferented patient

GL's EMG – Normal vs Blocked



The Problem with Programs – How Many Motor Programs do We Have?

- Some problems with the motor program concept:
  - ***Degrees of freedom*** – how are all the independent states of the various muscles & joints all controlled at the same time
  - ***Novelty*** – how do we know how to program new movements
  - ***Storage*** - Where are all the motor programs stored?
- Is a specific "motor program" required for each movement that can be performed?

One Solution: Generalized Motor Program (GMP)

- a "Generalized Motor Program" (GMP) was proposed as a construct that allows a central representation for a class of movements
- GMP - motor program for a class or family of actions rather than specific actions
  - Action Class - a set of different actions with a common but unique set of features

Generalized Motor Program

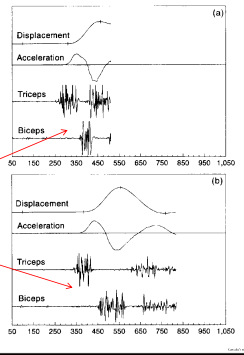
- Allow performer to adapt the generalized program to produce pattern variations to meet the needs of the situation or environment
  - Helps solve storage & novelty problems
- *what might a motor program specify*?
  - … muscles recruited
  - … onset and offset of muscle contractions
  - … details of timing
  - … force of contractions

GMP's

- GMP's are thought to have invariants & parameters
  - **Invariants - "deep structures"**
    - Components that remain constant - ("signature" of the program)
    - Fundamental features of the GMP that do not change from one execution to the next
  - **Parameters – "surface features"**
    - The modifiable features of a GMP
    - Input specifications for the GMP that define how it is executed

Invariant Features

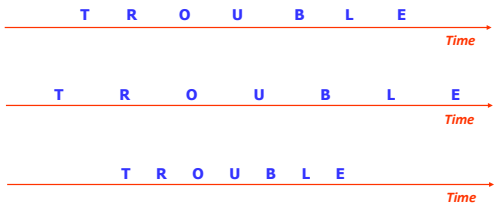
1. Order of Elements
   - Order of events or actions is invariant or fixed
     - e.g. Agonist and antagonist have specific order that determines the outcome.
   - Simple extension movement has a different pattern to a reversal



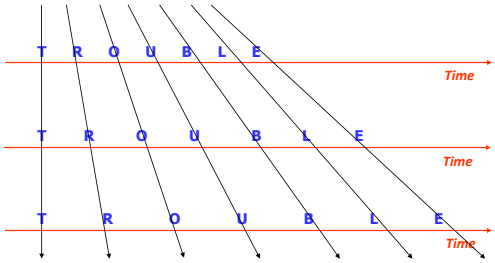
Invariant Features

2. Relative Timing
   - *Relative* timing of events or actions is invariant and remains in constant
   - Relative timing involves *proportion* of each component to the total time
   - If relative timing is the same = same GMP
   - If relative timing is different = different GMP
   - Can be relative timing of EMG, limb movement, force produced, etc.

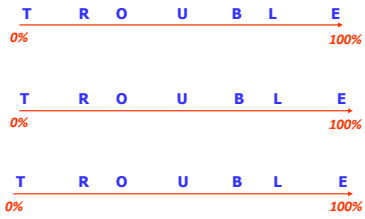
Relative Timing

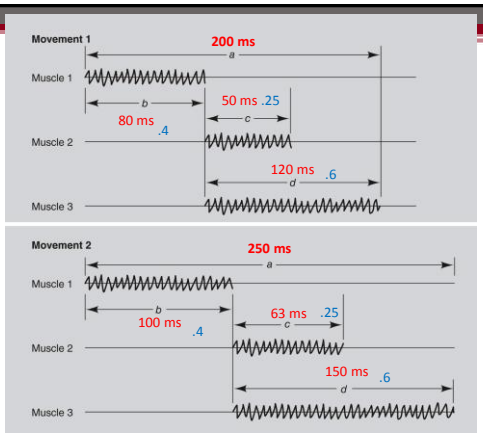


Phasing/Relative Timing



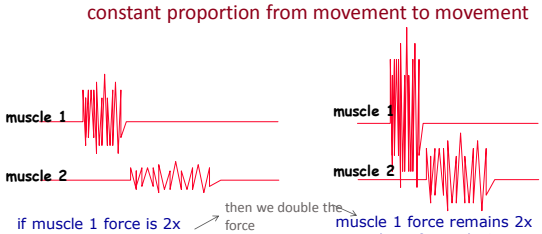
Phasing/Relative Timing



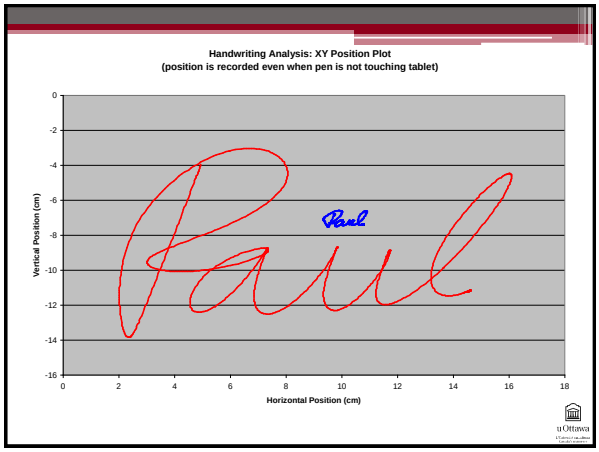


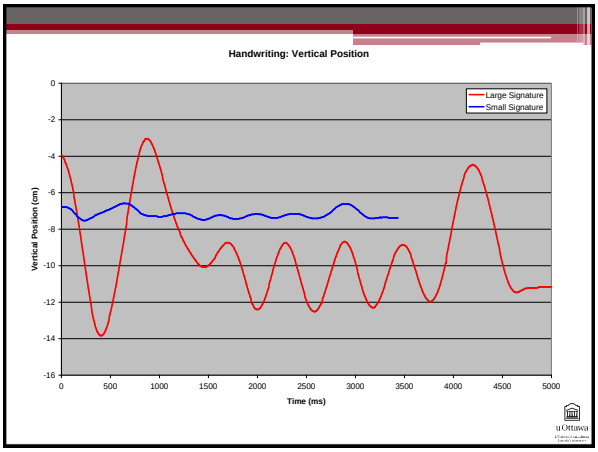
Invariant Features

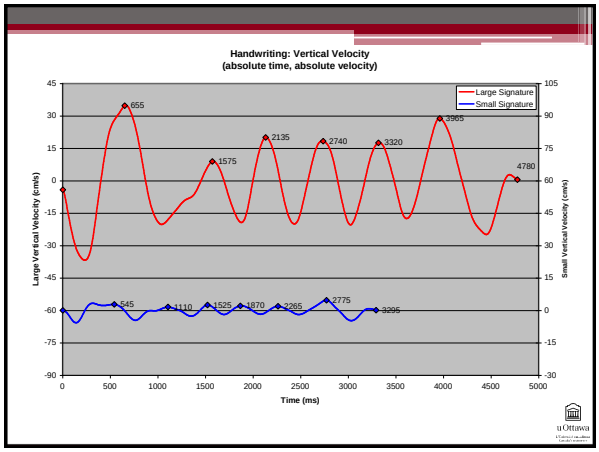
3. Relative Force
   - Amount of force produced by muscles remains in constant proportion from movement to movement

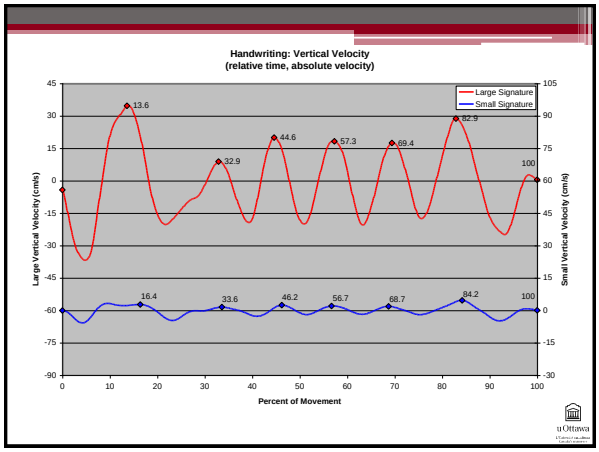


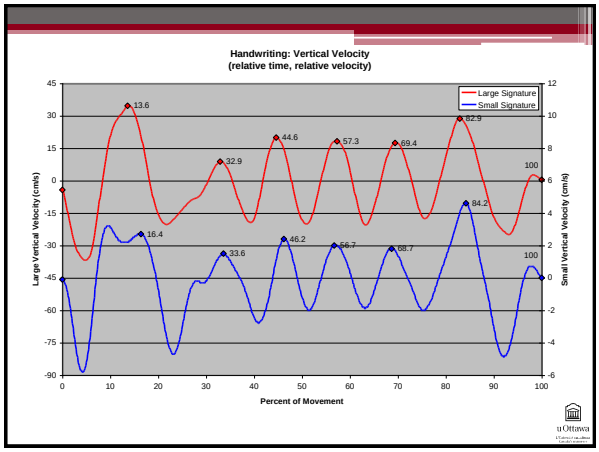
if muscle 1 force is 2x that of muscle 2 ... → then we double the force → muscle 1 force remains 2x that of muscle 2

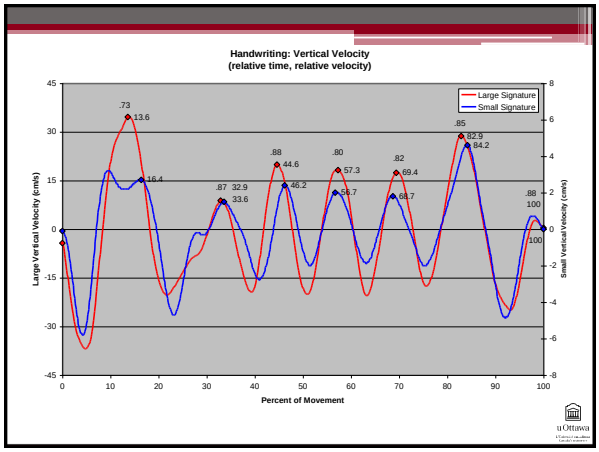










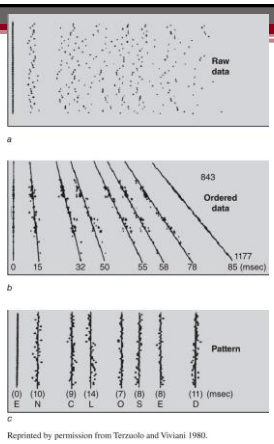


Parameters

1. Absolute Duration
   - overall speed at which program is executed can change
2. Absolute Force
   - overall force produced by muscles can change
3. Effectors
   - muscles used can change
   - same GMP can be executed by different muscles
   - motor equivalence = different effectors can be used to achieve the same goal

Absolute Duration

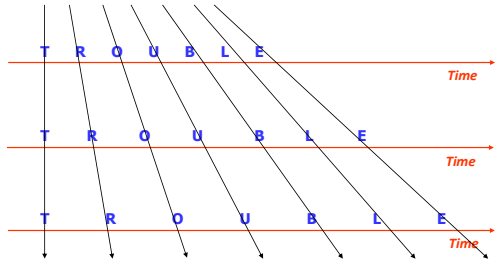
Movements can be performed in different total times (ie. faster or slower) but relative timing must stay the same.



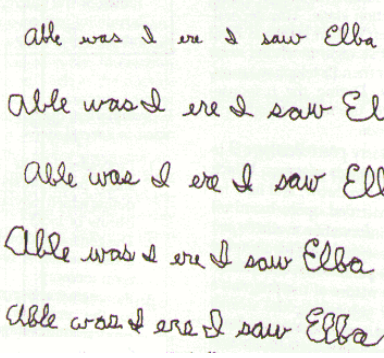
Reprinted by permission from Terzuolo and Viviani 1980.

Absolute Timing Differences

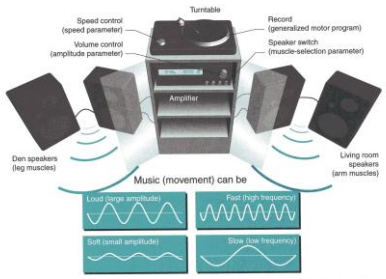
Relative timing preserved



Effectors



Record player Analogy for GMP

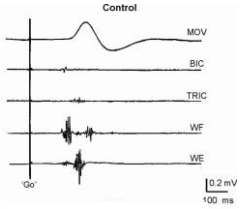


Summary of Motor Programs

- Motor program theory assumes all aspects of movement planning and execution are done in the CNS via "programs" which are stored in memory
  - Although we have not been able to prove motor programs exist, there is research to support their existence
  - GMP's solves some of the storage & new movement problems associated with programs

Startle

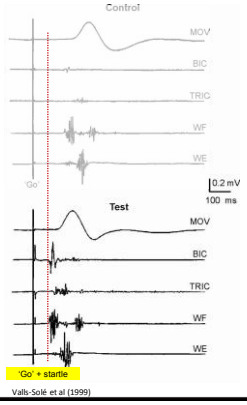
177 ms



Valls-Solé et al (1999)

177 ms

77 ms



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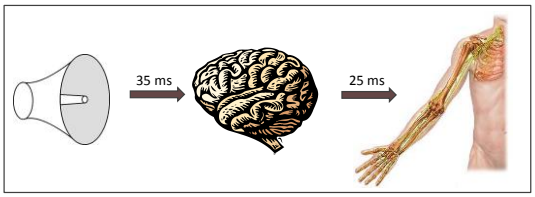
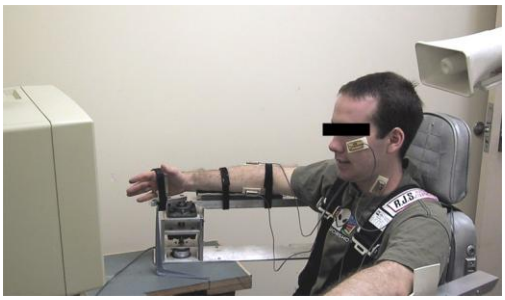
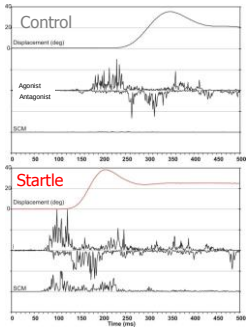
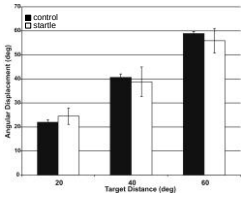




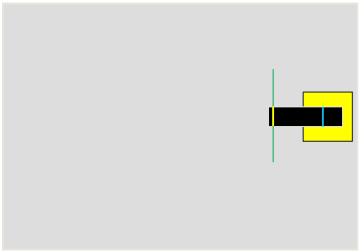
RT + Startle (targeted extension)



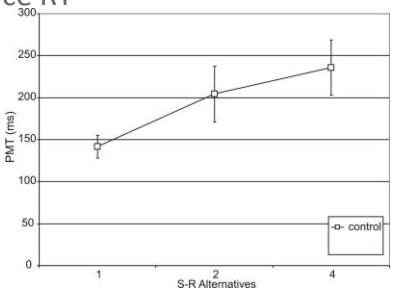


Carlsen AN, et al. (2004) Prepared movements are elicited early by startle. *J Motor Behav* 36:253-264

Trial Types

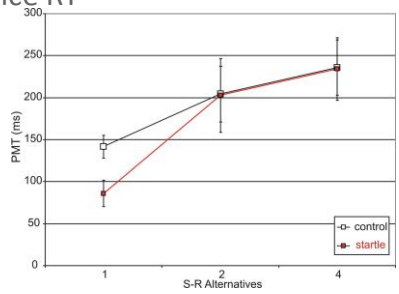


Choice RT



Carlsen AN, et al. (2004) Can prepared movements be stored subcortically? *Exp Brain Res 159*:301-309

Choice RT



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Conclusions

- Simple RT was facilitated by Startle
- Choice RT was not facilitated by startle

- **Pre**-programmed movement is triggered by Startle
- No **Pre**-programming = no triggering