The role of the brain in motor performance in young and old adults

Vianney Rozand
Planning

Preparation

Motor command
Motor cortex

Spinal cord

Muscles

Afferent feedback
- Measure brain activity
- Stimulate the brain
  - compare to voluntary contraction
  - measure EMG
- Fatigue the brain (cognitive task)
- Train the brain (motor imagery)
- Measure brain activity
- Stimulate the brain
  - compare to voluntary contraction
  - measure EMG
- Fatigue the brain (cognitive task)
- Train the brain (motor imagery)
Part I.

Effects of mental exertion on physical performance
- Maximal voluntary contraction
- Motor control
Mental exertion and physical performance

How inducing mental exertion?

Cognitive task
- Mental math
- Stroop task

- AX-CP test

1251 13 = ... 13 = ...

Stroop task
RED  YELLOW  GREEN
ORANGE  BLUE  GREEN
YELLOW  BLUE  RED
ORANGE  RED  GREEN

AX = Right clue
AY, BX, BY = Wrong clue
**Mental exertion and physical performance**

**Marcora et al. (2009)**

- Cognitive task: 1h30 AX-CP test
- Until exhaustion: 80% MAP
- Stop when <60 rpm

**Time to exhaustion**

- 12%; p < 0.01

- No physiological adjustment

- Higher perception of effort

**Graphs**

**A**

- Heart Rate (beats·min⁻¹)
- Control vs. Mental fatigue

**E**

- Oxygen Consumption (l·min⁻¹)
- Rate of Perceived Exertion

**Bar Graph**

- Control vs. Mental fatigue

- Duration (s)
Mental exertion and physical performance

- **Perception of effort**  
  *Williamson et al., 2001*

- **Motivation**  
  *Walton et al., 2003*

- **Motor control**  
  *Paus, 2001*

- **Motor planning**  
  *van der Linden et al., 2003*

Reduced activity during subsequent physical exercise (Tanaka et al., 2014)
Mental exertion and maximal force production (Rozand et al. 2014, Front Hum Neurosci)

**Question:** Does mental exertion alter maximal force production?

- High mental exertion: Stroop task
- Moderate mental exertion: congruent Stroop task
- Control task: watching a movie

MVC knee extension

Cognitive task

Nerve stimulation

Stroop task

RED  YELLOW  GREEN

ORANGE  BLUE  GREEN

YELLOW  BLUE  RED

ORANGE  RED  GREEN
Voluntary activation level

Mental exertion and maximal force production \((\text{Rozand et al. 2014, Front Hum Neurosci})\)

\[\text{Voluntary activation (\%)} = (1 - \text{SIT/RT}) \times 100\]
Mental exertion and maximal force production (Rozand et al. 2014, Front Hum Neurosci)

- No difference in MVC torque
Mental exertion and maximal force production \cite{Rozand2014, FrontHumNeurosci}

- No difference in MVC torque
- No difference in voluntary activation level

**Conclusion:** Mental exertion $\Rightarrow$ No alteration of maximal force production and voluntary activation level
Mental exertion and speed-accuracy trade-off (Rozand et al. 2015, Neuroscience)

Speed-accuracy trade-off (Fitts law)

![Graph showing speed-accuracy trade-off](image)

- After muscle fatigue
- Before muscle fatigue

Muscle fatigue => Adaptated strategy of the CNS to preserve task success

(Missenard et al., 2009)
Mental exertion and speed-accuracy trade-off (Rozand et al. 2015, Neuroscience)

**Question:** Does mental exertion alter the speed-accuracy trade-off?

5 difficulties
Mental exertion and speed-accuracy trade-off \textit{(Rozand et al. 2015, Neuroscience)}

\begin{itemize}
\item\textbf{Actual movements} => Increased actual movement duration
\item\textbf{Imagined movements} => Increased imagined movement duration
\end{itemize}

\textbf{Conclusion:} Mental exertion alters the speed-accuracy trade-off

- Adapted strategy to conserve task success
- Changes in the preparatory/planning phases
Mental exertion and physical performance

**Motor control**
Slowed movement

**Maximal force**
Maximal activation preserved

**Endurance**
Shorter time to exhaustion

Mental exertion

Primary Motor Cortex

ACC

quadriceps
Mental exertion

- **Endurance** (Marcora et al., 2009)
- **Force** (Rozand et al., 2014)
- **Motor control** (Rozand et al., 2015)
Part II.

Effects of age on voluntary activation during dynamic contractions
Aging and voluntary activation

**Force** is reduced with advancing age (Doherty et al., 2003)

- Decrease in **muscle mass** (Frontera et al., 1991)
- Decrease in **voluntary activation?** (Stevens et al., 2003)
  - Conflicting results
  - Most studies analyzed isometric contractions
How measuring voluntary activation during dynamic contractions?

Superimposed twitch (%) = MVC torque/(MVC torque + SIT) x 100
Voluntary activation during dynamic contractions

Voluntary activation similar (maximal) during isometric, concentric and eccentric contractions in young and old adults

- Electrical stimulation/Ankle dorsiflexors (Klass et al., 2005)
- Electrical stimulation/Knee extensors (Wilder & Cannon, 2009)

Only the best trials (maximal activation) were presented

Only on lower limb muscles (locomotor muscles)
**Question:** Is there an age difference in voluntary activation during maximal dynamic contractions with elbow flexor muscles?

3 contraction types:
- Isometric
- Concentric at 60°/s
- Eccentric at 60°/s

2 stimulation methods:
- Electrical stimulation
- Transcranial Magnetic Stimulation

2 trials per condition
Old adults are weaker in the three contraction types.
Voluntary activation assessed with electrical stimulation is similar in young and old adults.
Voluntary activation assessed with TMS is similar in young and old adults.
Greater variability in voluntary activation during isometric contractions in old adults
Age-related decrease in MVC torque during isometric, concentric and eccentric contractions

No age-related decrease in voluntary activation

Greater variability in voluntary activation during isometric contractions in older adults

Decrease in MVC torque more likely to be due to impairments within the muscles
Part III.

Effects of physical activity level on corticospinal excitability and neuromuscular function in young and old adults
How measuring corticospinal excitability?

EMG response
Motor evoked potential (MEP)

Transcranial magnetic stimulation
How measuring corticospinal excitability?

Pitcher et al. (2003)
Is corticospinal excitability influenced by the level of physical activity?

Corticospinal excitability differs between active (>10,000 steps/day) and inactive (<10,000 steps/day) young and old adults on the knee extensor muscles.

Hassanlouei et al. (2017)
Physical activity and corticospinal excitability

=> Is the difference between active and inactive people specific to locomotor muscles, or is it a global effect in the brain?

63 subjects
- 30 Young
- 33 Old
Decreased corticospinal excitability in old adults
Physical activity and corticospinal excitability

Physical activity level does not affect corticospinal excitability of upper limb muscles in both young and old adults
**Question:** Does physical activity level affect neuromuscular function and fatigability in very old adults?

- **29 very old adults** (>80 years)
  - 13 inactive
  - 16 active
Physical activity and neuromuscular function

No difference in 6min Walk Test, MVC and fatigue between active and inactive
The capacity to activate the muscles is correlated with the physical activity level.
Physical activity affects corticospinal excitability of the lower but not upper limb muscles.

Voluntary activation level is correlated with physical activity.

Physical activity does not affect maximal force, fatigue and functional performance.

Physical activity is one but not the main determinant of the decrease in functional performance in older adults.
What’s next?

- Testing young and old (60-80 years) adults
- Link to biological data (muscle composition)
- Testing dynamic contractions
- Testing the effectiveness of training in active and inactive adults
The role of the brain in motor performance in young and old adults

Vianney Rozand