Effects of Exercise on Brain

- Promote and maintain brain function
- Decrease depression
- Resist stress
- Enhance learning
- Improve cognition
- Decrease sleepiness
- Subside neurodegeneration disease
- Increase hippocampal neuron number

(Kems, 2004)

Effects of exercise

↑neurogenesis ↑learning ↑synaptic plasticity

Non-Run Run (Fabel et al., 2003) (Anderson et al., 2000) (Farmer et al., 2004)

NMNDA-dependent synaptic plasticity
The difficulty to record electrophysiological signals during exercise

- Motion artifact
- Behavior interference
- Resist (in rodent)

Changes in electroencephalogram and heart rate during treadmill exercise in the rat

Jia-Yi Li, Terry B. J. Kuo, Sandy S. Y. Hsieh, Cheryl C. H. Yang

Specific aim

To determine whether and how the rat’s brain responds to exercise.

Methods

- Animal preparation
  - 6-7 wks old male WKY (n=10)
  - implantation of electrode
- Recorded for 80 min (AM 6:00 to 7:30)
  - during dark period

![Running or resting](image)

![neocortex EEG](image)
Summary

- To provide an efficient way to observe the interaction of brain and heart activities during strenuous exercise.

- Alpha & beta - vigilance, alertness and attention
- Theta during running - related to memory and cognitive functions

- The order of the changes during exercise
  provide the useful hints as to the cause/effect relationship between cerebral activity and autonomic functioning

Effect of aging on treadmill exercise induced theta power in the rat

Terry B. J. Kuo, Jia-Yi Li, Sandy Shen-Yu Hsieh, Jin-Jong Chen, Ching-Yao Tsai, Cheryl C. H. Yang

Theta wave of EEG

- Sleep propensity (Torraval & Akerstedt, 1987; Vyazovskiy & Tobler, 2005)
- Cognition and memory (Czeisler et al., 1997; Klimnach 1999)
- Attention and motivation (Bennett et al., 1973)
- Integration of motor programming (Morris and Hagan, 1983)
- Hippocampal theta in rats: locomotion, orienting, spatial learning, memory, REM sleep (Winson, 1978; Bland, 1985)
  Type 1: large movement
  Type 2: REM sleep & anesthesia
Characteristic of theta rhythms

- Theta amplitude
  - sleep propensity
  - locomotion magnitude
  - environment
  - spatial learning
- Theta frequency
  - speed of locomotion
  - motivation

Effect of aging on locomotion induced theta

- amplitude in rat’s hippocampus (Barnes, 1979)
- amplitude, $\&$ frequency in rat’s hippocampus (Markowska et al., 1995)
- amplitude, $\&$ frequency (subtle) in rat’s hippocampus (Zhong et al., 1997)
- amplitude, $\&$ frequency in rat’s hippocampus (Abe and Toyosawa, 1999)
- amplitude, $\&$ frequency in human’s fronto-central midline scalp (Cummins and Finnigan, 2007)
- “The theta rhythm does not differ between adult and old rats.” (Orr et al., 2001)

Specific aims

- To confirm whether brains of awake young rats showed a significantly response to treadmill exercise when compared to before exercise.
- To determine whether older rats have a lower baseline level and/or show a lower response to exercise than young rats.
- To determine whether treadmill exercise is still able to evoke brain activity in the older rats.

Methods

- Animal preparation
  - 8 and 60 wks old male WKY (n=8)
  - implantation of electrode
- Recorded for 80 min (AM 6:00 to 7:30)
  - during dark period
Summary

- Aging in rats may lower theta power EEG spectra during waking and produce a lower response to running stimuli.
- We offered electrophysiological evidence for aging-related changes in exercise-evoked theta power.

Change of hippocampal theta activity during initiation and maintenance of running in the rat

Terry B. J. Kuo, Jia-Yi Li, Cheryl C. H. Yang
in preparation

- Exercise alters state of consciousness has been found in athletes. (Dietrich, 2003)
- Theta rhythm ⇔ cortical arousal in rodents (Vinogradova, 1995; Kahana et al, 2001)
- Free running = running + resting ⇔ running

rare electrophysiological evidence
Running exercise is not homogeneous

- Metabolism
  - aerobics vs. anaerobic
- Fatigue
  - high EMG activity vs. low EMG activity
- Personal perception
  - smooth vs. uneven

Specific aims

- To determine whether a running exercise can be classified into different stages according to EEG responses.
- To understand the electrophysiological characteristics of the initiation of exercise.
- To determine the contribution factor for hippocampal theta activity during maintenance of exercise.

Methods

- Animal preparation
  - 8 wks old male WKY (n=15)
  - implantation of the electric sensors
- Wireless recording system
  - EEG, EMG and ECG

* $p < 0.05$ vs. mean value of before running (open circle)
† $p < 0.05$ vs. the first point during exercise
Frq, Amp and HR

\[ \text{different slopes in two stages} \]

\[ *p < 0.05 \text{ from zero by 95\% confidence interval analysis} \]

\[ \dagger p < 0.05 \text{ vs. the initiation of exercise} \]

Quantitative analyses of time constants in hippocampal theta frequency (Frq) and power (Amp) of electroencephalogram, electromyogram power (EMG), heart rate (HR), and physical activity (PA) in rats

\[ *p < 0.05 \text{ vs. EMG, } \dagger p < 0.05 \text{ vs. PA, } \ddagger p < 0.05 \text{ vs. Frq, } \# p < 0.05 \text{ vs. Amp.} \]

A typical example of time constants (TC) in hippocampal theta frequency (Frq) and power (Amp) of electroencephalogram, electromyogram power (EMG), heart rate (HR), and physical activity (PA) as initiation of exercise in one rat are shown.

Two-dimensional scattergram showing the relationship between hippocampal theta components (frequency, Frq; amplitude, Amp) and corresponding parameters of body movement (electromyogram power, EMG; heart rate, HR; physical activity, PA)

\[ *p < 0.05 \text{ vs. EMG, } \dagger p < 0.05 \text{ vs. PA, } \ddagger p < 0.05 \text{ vs. Frq, } \# p < 0.05 \text{ vs. Amp.} \]

The correlation coefficients between hippocampal theta components (frequency, Frq; amplitude, Amp) and parameters of body movement (electromyogram power, EMG; heart rate, HR; physical activity, PA) in rats

\[ *p < 0.05 \text{ from zero by 95\% confidence interval analysis.} \]
Summary

- The running exercise is heterogenous and can be classified into initiation and maintenance according to EEG responses.
- A switch for theta amplitude during initial movement: theta frequency.
- Maintenance: positive correlation between theta component and physical activity.
- Our finding may provide electrophysiological evidences for psychologists with exercise treatments on patients.