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Examining the effects of long-term high-intensity aerobic training on behaviors associated with the prefrontal cortex, hippocampus and striatum

NYU

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Introduction

Long-term voluntary exercise in rodents causes brain-region specific anatomical, physiological and behavioral changes, with these effects being seen primarily in the hippocampus, striatum, and prefrontal cortex (Voss et al., 2013). Investigations of exercise-induced cognitive improvements in humans have focused on the prefrontal cortex, and few studies have collectively examined changes in mood, cognition and exercise physiology. In this randomized controlled study, we examined the effects of altering cardiovascular fitness through long-term aerobic exercise on mood and behaviors associated with the hippocampus, striatum, and prefrontal cortex.

Methods

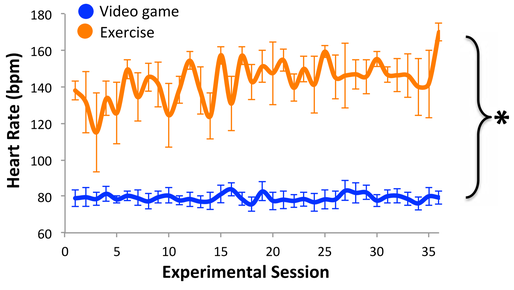
- Randomized controlled design
- Healthy subjects, 35-59 years of age, who are sedentary (i.e., exercising less than twice per week in the past three months)
- Randomly assigned to 3 months of non-spatial video games or high-intensity aerobic cycling exercise
- Pre- and post-intervention testing: mood questionnaires, cognitive tasks, VO2 max testing
- Repeated measures analysis of variance (ANOVA); Pearson's correlation; significance level of p<0.05

Video Game Group n=9

vs.

Exercise Group n = 11

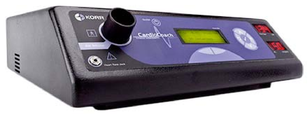
Physiological Data



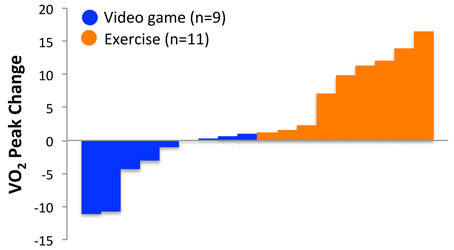
VO2 Measure	Group	Average Scores: Pre-intervention	Average Scores: Post-intervention	P value	Effect size
Starting	Video Game	5.09 (±1.57)	3.55 (±0.76)	0.415	0.042
	Exercise	2.86 (±0.98)	3.10 (±0.65)		
Aerobic Threshold	Video Game	13.63 (±2.11)	11.31 (±2.48)	0.001	0.502
	Exercise	10.76 (±1.62)	16.85 (±1.39)		
Anaerobic Threshold	Video Game	16.64 (±2.84)	14.96 (±3.77)	0.008	0.383
	Exercise	12.53 (±2.17)	19.79 (±1.50)		
Peak	Video Game	20.66 (±4.04)	17.09 (±4.00)	0.001	0.534
	Exercise	15.01 (±2.13)	22.64(±1.05)		

- Values represent millileters of oxygen used in one minute per kilogram of body weight (ml O_2/kg/min)
- p values represent the interaction of group*time

WOMEN							
Age (years)	Very poor	Poor	Fair	Average	Good	Very good	Excellent
35-39	<24	24-27	28-31	32-35	36-40	41-44	>44
40-44	<22	22-25	26-29	30-33	34-37	38-41	>41
45-49	<21	21-23	24-27	28-31	32-35	36-38	>38
40-54	<19	19-22	23-25	26-29	30-32	33-36	>36
55-59	<18	18-20	21-23	24-27	28-30	31-33	>33
MEN							
35-39	<28	28-32	33-38	39-43	44-48	49-54	>54
40-44	<26	26-31	32-35	36-41	42-46	47-51	>51
45-49	<25	25-29	30-34	35-39	40-43	44-48	>48
40-54	<24	24-27	28-32	33-36	37-41	42-46	>46
55-59	<22	22-26	27-30	31-34	35-39	40-43	>43

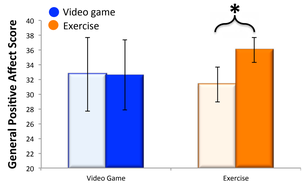


Exercise Significantly Increased VO_2 Max Levels

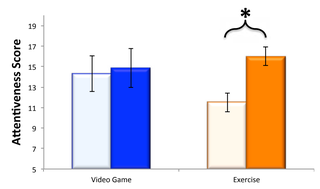


Mood Data

Exercise improves general positive affect and attentiveness in previously sedentary adults.

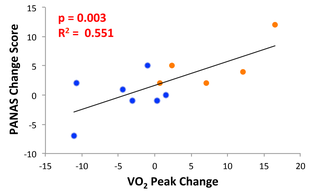


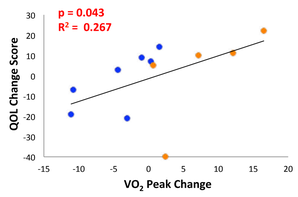
* F(1,11)=5.402, p=0.040, partial η2 = 0.329



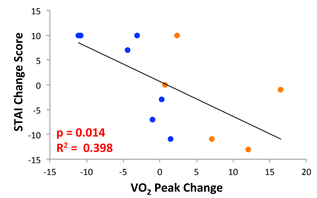
* F(1,11)=7.103, p=0.022, partial η2 = 0.392

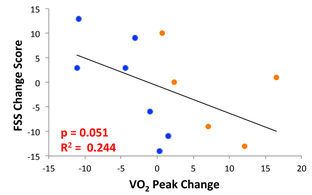
The greater the improvement in fitness, the greater the increase in general positive affect and quality of life.





The greater the impovement in fitness, the greater the decrease in anxiety and fatigue.

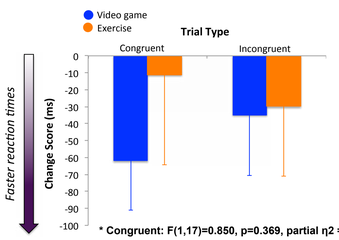




Prefrontal-dependent cognition

ATTENTION
Stroop Task

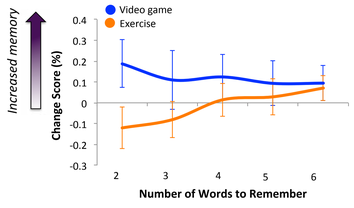
Red Blue
Yellow Green
Blue Yellow
Green Red
Green Green
Yellow Blue
Blue Red



* Congruent: F(1,17)=0.850, p=0.369, partial η2 = 0.048
* Incongruent: F(1,14)=0.005, p=0.942, partial η2 = 0.000

WORKING MEMORY
Reading Span Task

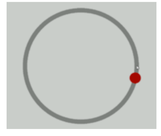
"The rabbit took off with the carrot. BOOK"

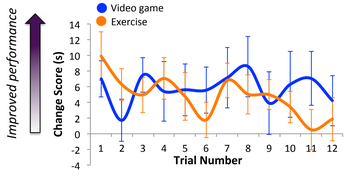


* F(4,64)=1.374, p=0.253, partial η2 = 0.079

Striatal-dependent cognition

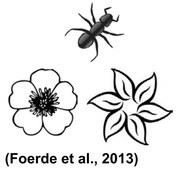
PROCEDURAL LEARNING
Pursuit Rotor Task



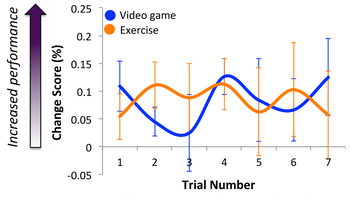


* F(11,198)=1.335, p=0.207, partial η2 = 0.069

PROBABILISTIC LEARNING



(Foerde et al., 2013)

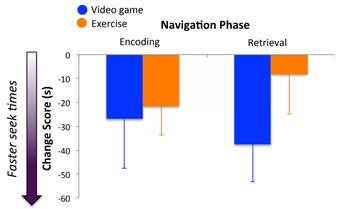


* F(6,96)=1.512, p=0.182, partial η2 = 0.086

Hippocampal-dependent cognition

SPATIAL NAVIGATION AND EPISODIC MEMORY

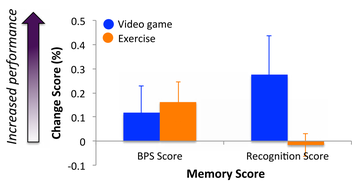
(Miller et al., 2013)



* Encoding: F(1,15)=0.058, p=0.813, partial η2 = 0.004
* Retrieval: F(1,14)=1.357, p=0.264, partial η2 = 0.088

PATTERN SEPARATION
Mnemonic Similarity Task

(Stark et al., 2013)



* BPS Score: F(1,18)=0.117, p=0.737, partial η2 = 0.006
* Recognition Score: F(1,18)=3.493, p=0.078, partial η2 = 0.163

Conclusions

1. This pilot data suggests that of all the variables we measured, a wide range of positive mood measures show the most robust improvements with increased fitness.
2. We have not yet found significant differences between the exercise and video game groups on our measures of prefrontal, striatal or hippocampal functions. A larger N may be needed to see any effects of these tasks.
3. Future analyses will focus on a group of n=66 (33 per group) and examine differences in responders versus non-responders in terms of VO_2 max changes.

References

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