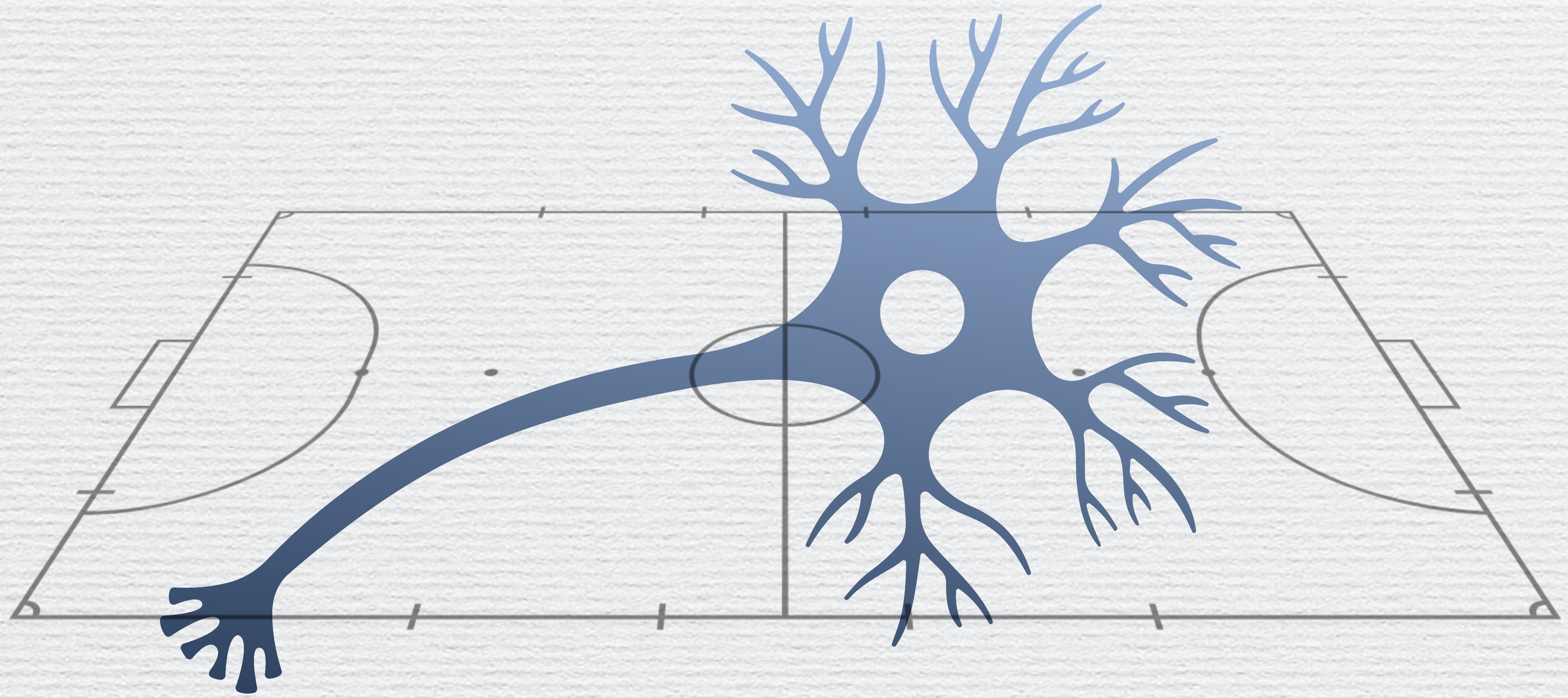
Brain and Physical Activity

From conceptual frameworks to the playground



Invited lecture at universität innsbruck
(April 2024)

Prof. Juanjo Pérez Soto, PhD

Adjunct Professor at Faculty of Education
(University of Murcia, Spain)

UNIVERSIDAD DE MURCIA

Co-funded by the Erasmus+ Programme of the European Union

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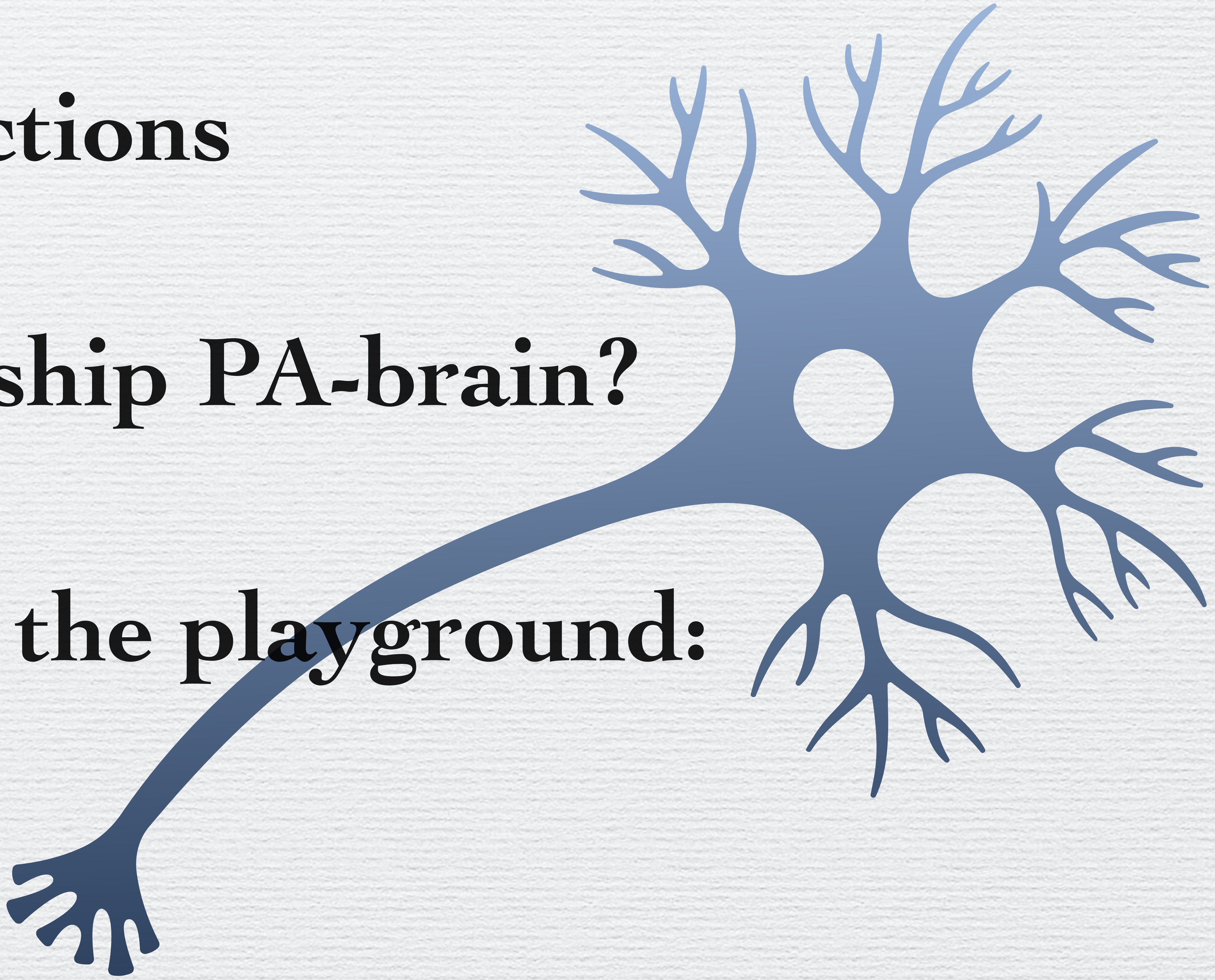
1. The human brain: parts and functions

2. What do we know in the relatioship PA-brain?

3. From conceptual frameworks to the playground: Physical Education



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1. The human brain: parts and functions

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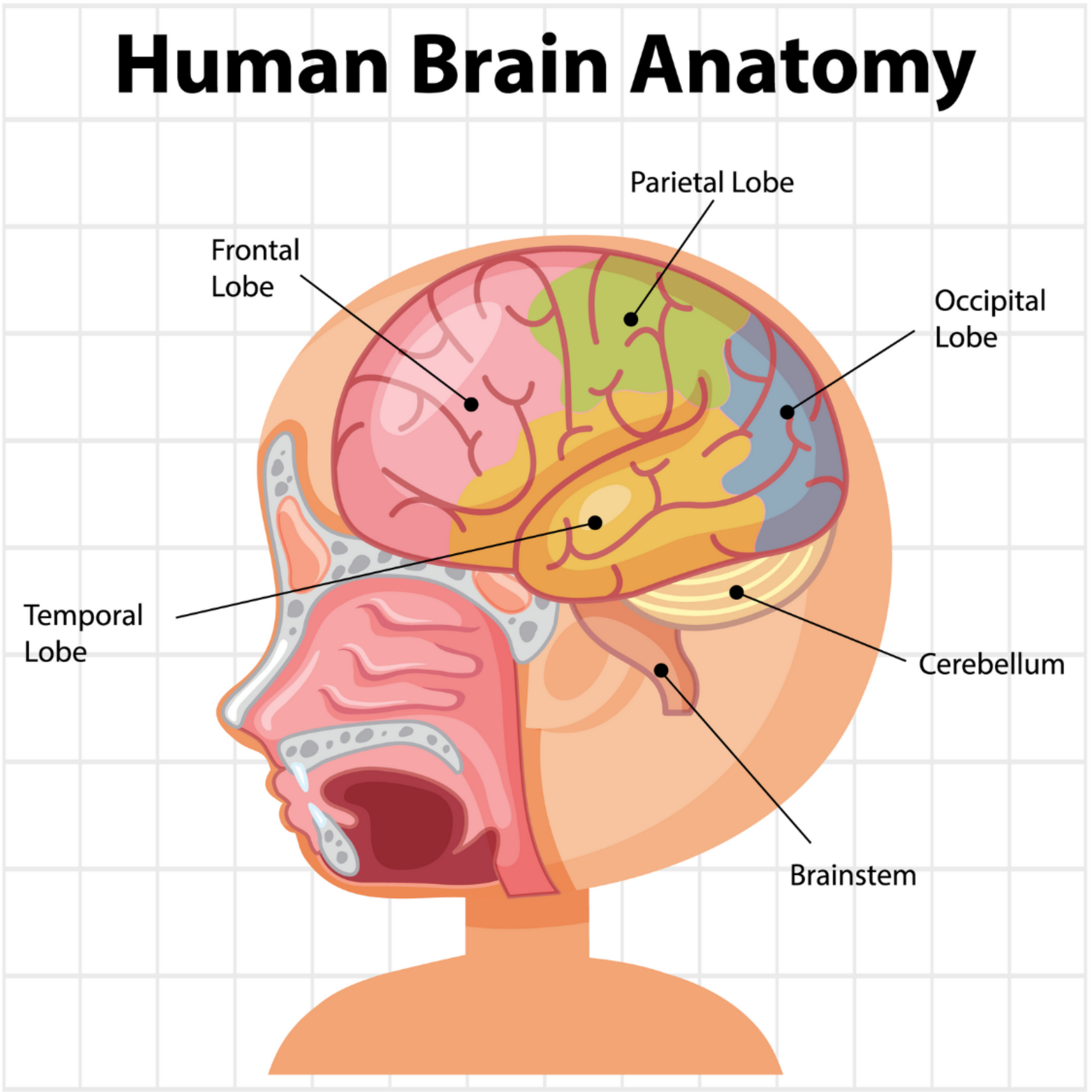
The brain

Parts and functions



Frontal Lobe

- Voluntary movements (motor cortex)
- Executive functions

Parietal Lobe

- Sensory perception
- Visuospatial Processing
- Proprioception

Occipital Lobe

- Visual Processing

Temporal Lobe

- Auditory processing
- Memory formation (hippocampus)
- Emotional Response (amygdala)

Brainstem

- Motor and Sensory Pathway Integration (signals).
- Coordination of movements (helps Cerebellum)

Cerebellum

- Coordination of movements (smooth execution)
- Balance and posture
- Encoding, storage, and refinement of motor skills

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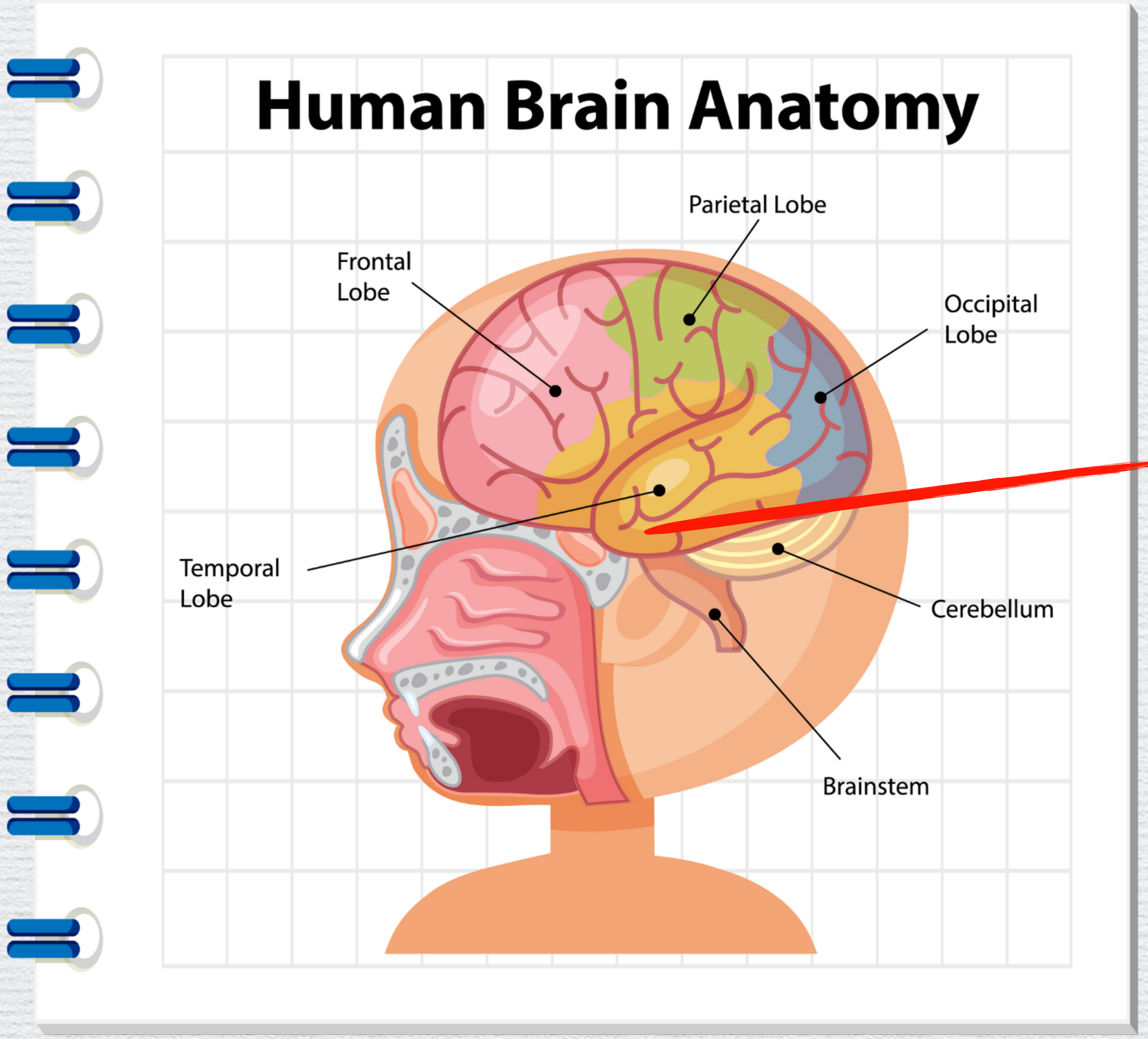
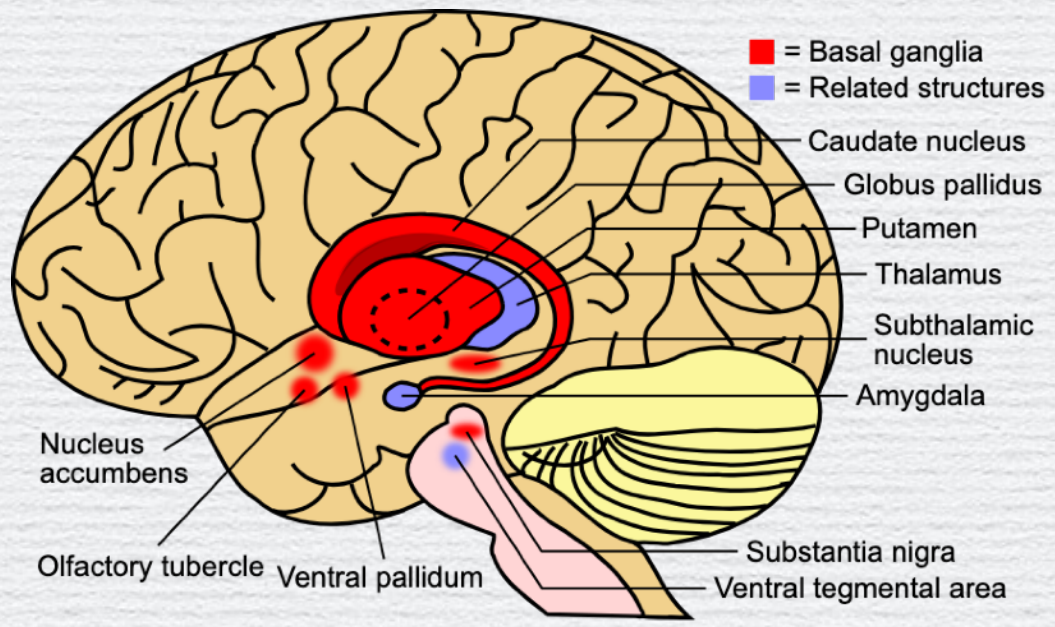
The brain

Parts of the limbic system





- **Basal Ganglia**: key role in movement control, learning, habit formation, and emotional processing. The basal ganglia receive inputs from the cerebral cortex and send output signals back to the cortex through the thalamus, forming the feedback loop that is critical for the regulation of voluntary movements.

- **Thalamus:** acts as the main relay station for sensory and motor signals to the cerebral cortex. Sensory signals coming from the body and external environment and motor control from basal ganglia and cerebellum.

- **Hypothalamus**: Plays a crucial role in maintaining the body's homeostasis, regulating a wide array of functions such as temperature, hunger, thirst, and the sleep-wake cycle. It also controls the pituitary gland, thus playing a significant role in the endocrine system.

- **Pituitary gland**: regulate vital body functions and general well-being by releasing a variety of hormones that control other endocrine glands throughout the body: growth hormone (GH), thyroid-stimulating hormone (TSH), adrenocorticotropic hormone (ACTH) that stimulates the production of cortisol by the adrenal glands…

- **Amygdala**: key structure within the limbic system. Process emotions, especially fear, anxiety, and aggression. It is connected to Thalamus (receives sensory input) to give quick response even before the cerebral cortex has fully processed them (survival mechanisms). Also connected to hypothalamus to initiate stress responses.

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The brain

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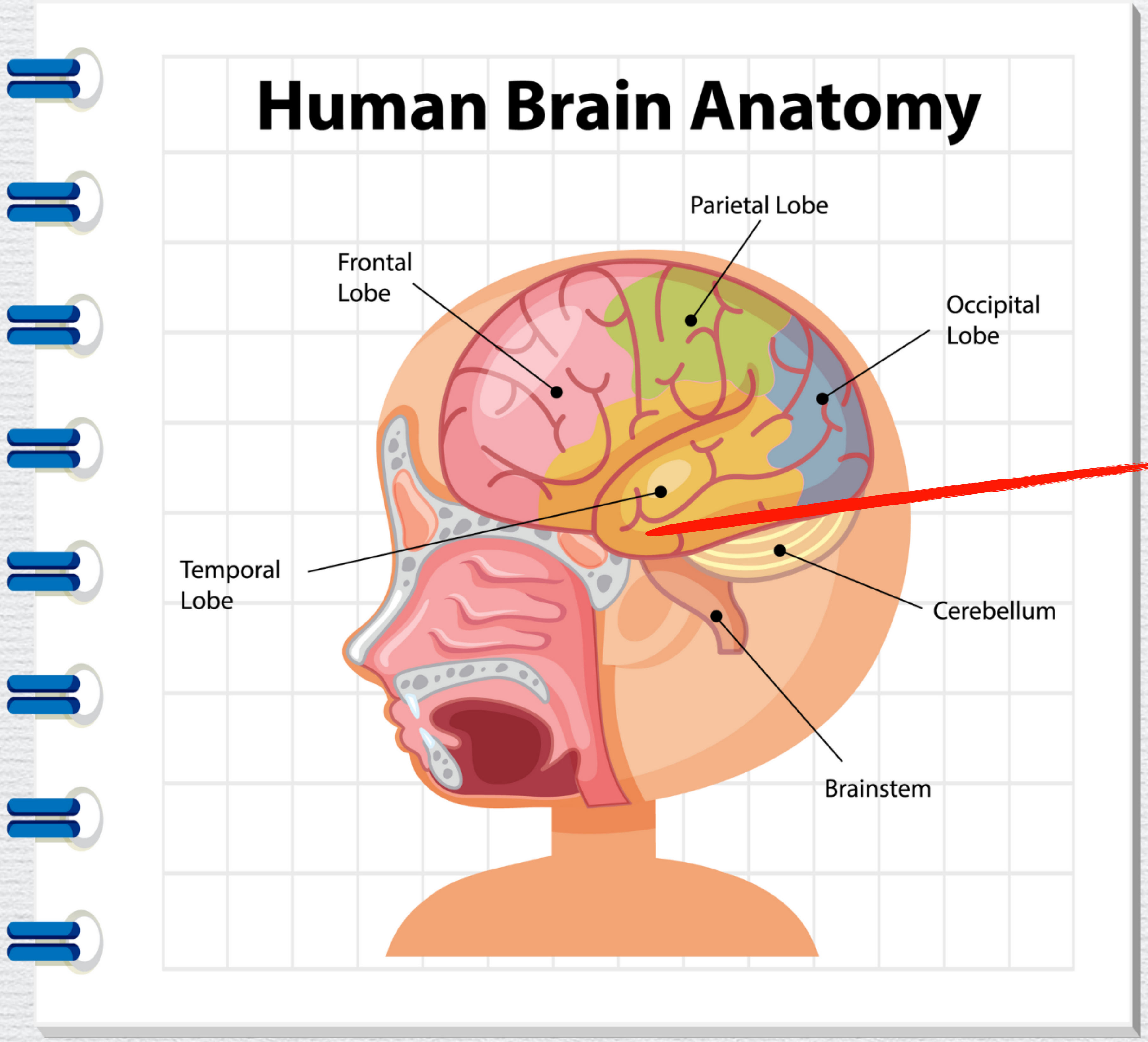

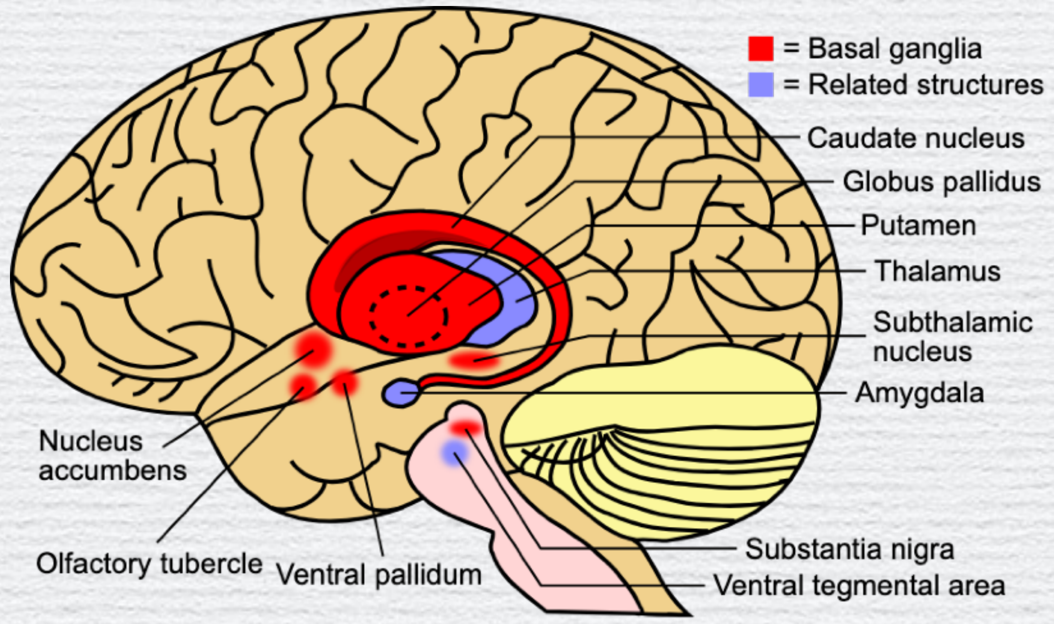

Memory Formation and Retrieval

New memories and linking emotions to these memories are formed in the **hippocampus**.

It helps encode information from short-term memory into long-term memory and is crucial for spatial navigation and memory.

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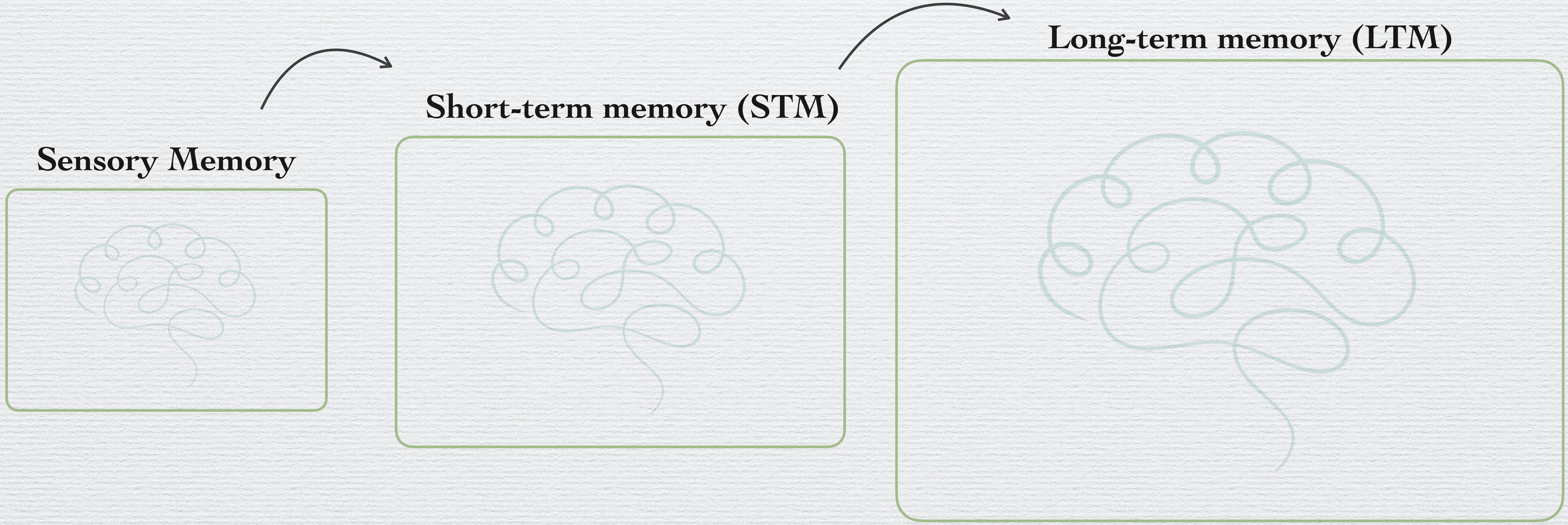
The brain

Memories: based on DURATION



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The brain

Memories: based on DURATION

Sensory Memory

- **Duration**: Very short (up to a few seconds)
- **Function**: Holds sensory information (e.g., sights, sounds).
- **Types**: Iconic memory (visual), echoic memory (auditory)…

Short-term memory (STM)

- **Duration**: Seconds to about 30 seconds.
- **Capacity**: Limited.
- **Function**: Temporary storage and manipulation of information for immediate tasks. It is the WORKING MEMORY.

Long-term memory (LTM)

- **Duration**: Can last from minutes to a lifetime.
- **Capacity**: Essentially unlimited.
- **Function**: Stores a vast amount of information for extended periods.
- **Types**: Explicit (declarative) and Implicit (non-declarative).

The brain

Memories: based on CONSCIOUSNESS

Implicit Memory (Non-declarative)

Explicit Memory (declarative)

Long-term memory (LTM)

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The brain

Memories: based on CONSCIOUSNESS

Implicit Memory (Non-declarative)

Memory without conscious awareness, influencing behaviors or thoughts.

Types:

- **Procedural Memory**: How to perform tasks or actions (e.g., riding a bike).
- **Priming**: Being more likely to use a piece of information after encountering it earlier.
- **Classical Conditioning**: Learning to link two stimuli together.

Explicit Memory (declarative)

Conscious recall of information.

Types:

- **Episodic Memory**: Personal experiences and events.
- **Semantic Memory**: Facts and general knowledge.

Long-term memory (LTM)

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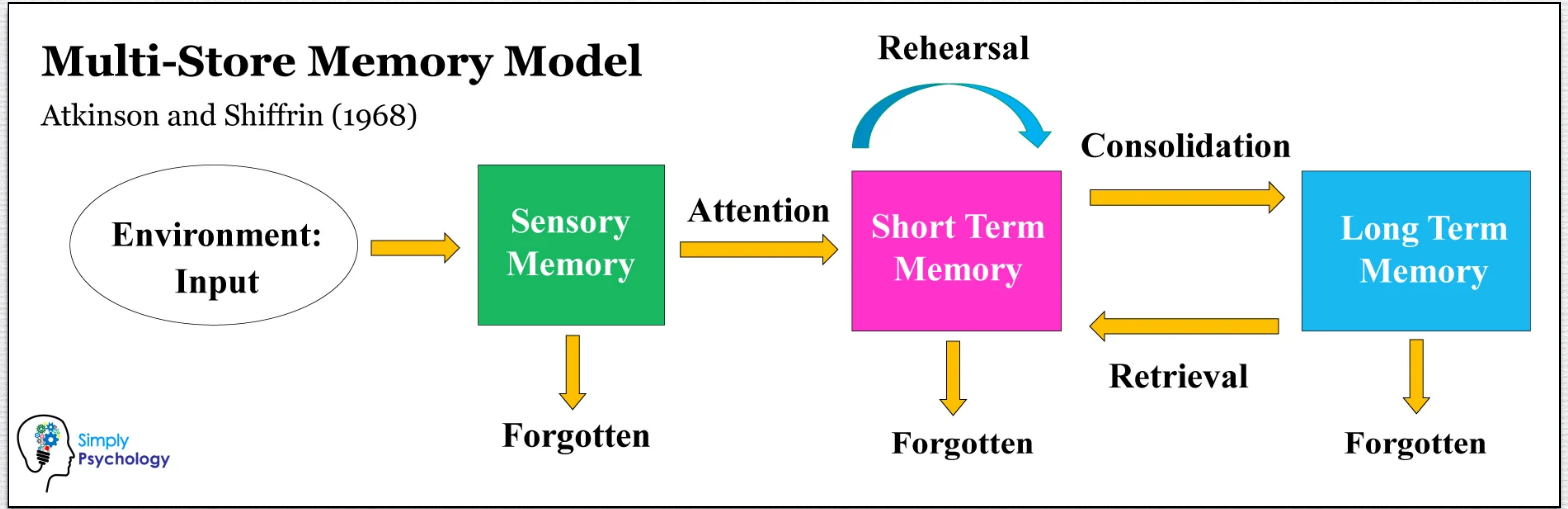
The brain

MEMORY PROCESSING MODEL



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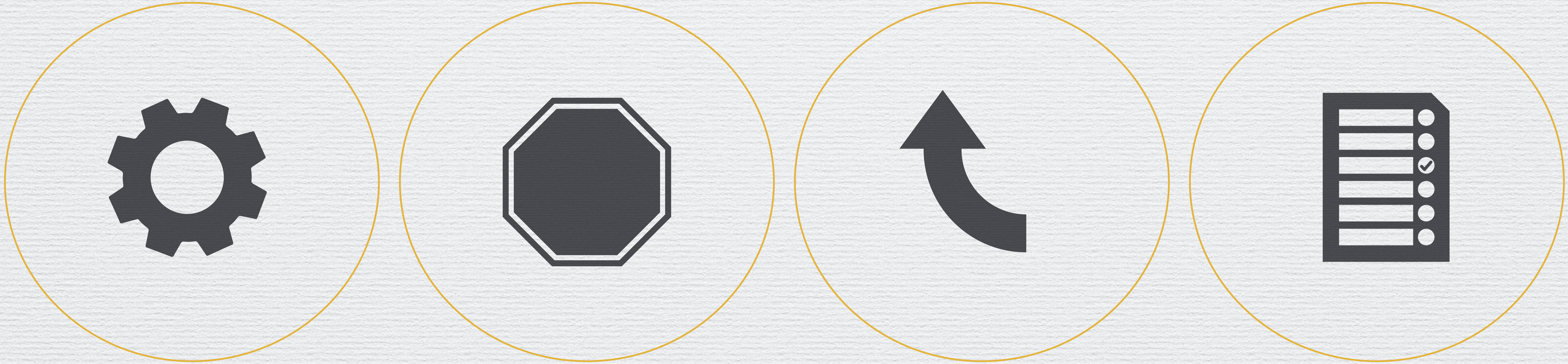
The brain

EXECUTIVE FUNCTIONS

(Prefrontal cortex)

Working Memory | **Inhibition (Self-Control)** | **Cognitive Flexibility** | **Planning**



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The brain

EXECUTIVE FUNCTIONS

(Prefrontal cortex)

Working Memory

About: holding and processing information in the mind over short periods of time.

Supports: reasoning, learning, understanding, and decision-making

Inhibition (Self-Control)

About: control and inhibit impulsive responses, both behavioral and emotional, enabling thoughtful decisions and actions.

Cognitive Flexibility

About: adapt to new information, switch tasks, and view problems from multiple perspectives.

Supports: innovation, problem-solving, and resilience.

Planning

The ability to foresee and sequence actions toward a goal, considering future events or consequences

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2. What do we know in the relatioship PA-brain?

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What do we know in the relatioship PA-Brain?

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Motor memories ara learnt by spacing practice sessions and are saved in long-term memory.

Extended video

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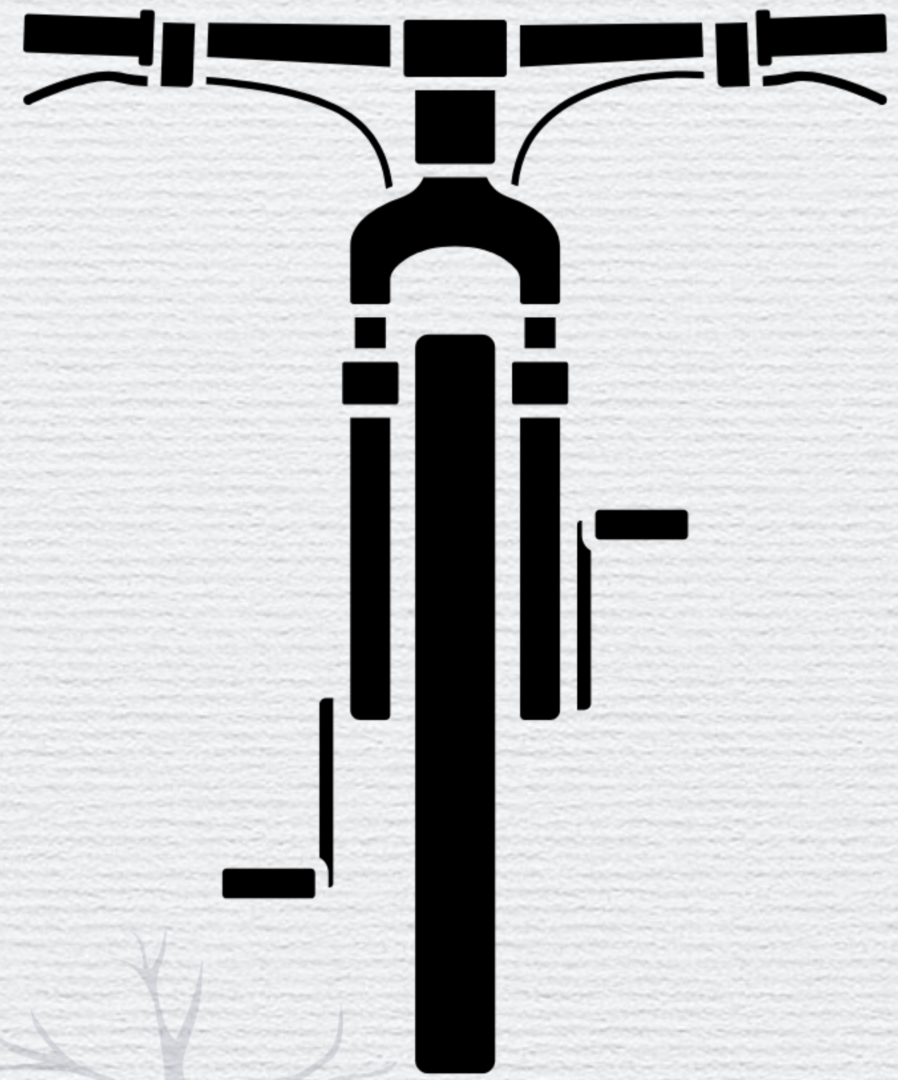
Motor memories ara learnt by spacing practice sessions and are saved in long-term memory.

From a brain perspective…



Prefrontal Cortex
When you decide to pedal, speed up, slow down…

Cerebellum and Vestibular System (inner ear)
For coordination, balance, spatial orientation

Basal Ganglia
Regulate movement initiation and muscle tone

Visual and Auditory Systems
The occipital lobe processes visual information, while the temporal lobe handles auditory input.

Sensory Cortex
Sensory feedback helps you adjust your balance

Motor memories ara learnt by spacing practice sessions and are saved in long-term memory.

Consolidated theories of motor learning

Fitts and Posner's 3-Stage Model:

Learning progresses from a cognitive stage of **understanding** the task (1), through an associative stage of **refining** the movement (2), to an autonomous stage where the skill is executed **effortlessly** (3).

Schmidt's Schema Theory:

This theory proposes the formation of generalized **motor programs and schemas** that enable adaptation and application of movements to new contexts through practice.

Ecological Approach by James Gibson:

Focuses on learning through direct interaction with the **environment**, emphasizing the role of perception in identifying and acting upon affordances.

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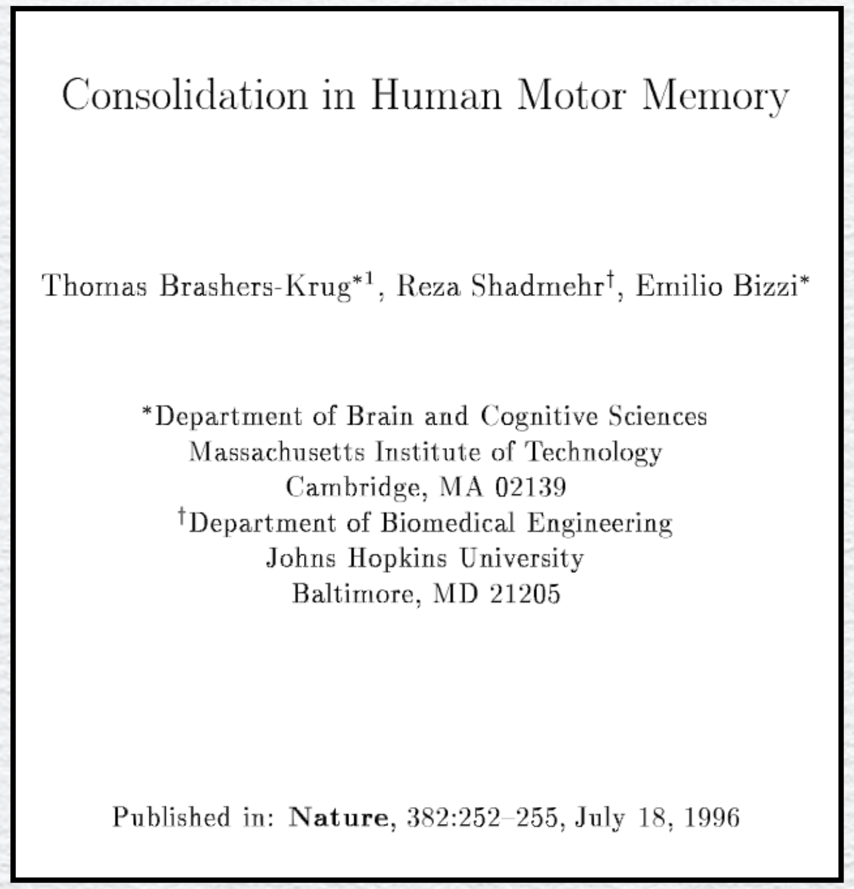


Consolidation in Human Motor Memory

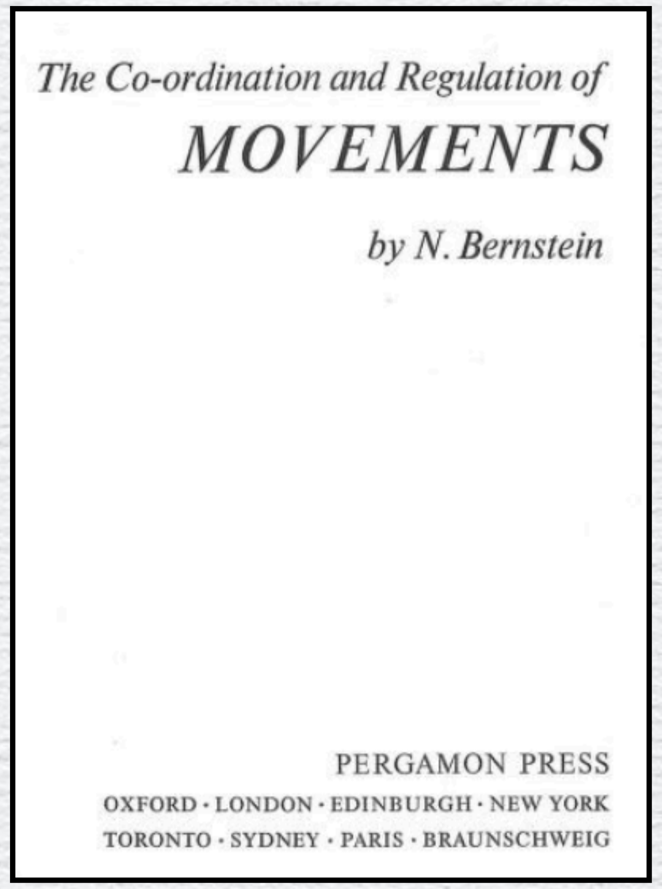
Thomas Brashers-Krug*[1], Reza Shadmehr[†], Emilio Bizzi*

*Department of Brain and Cognitive Sciences
Massachusetts Institute of Technology
Cambridge, MA 02139
[†]Department of Biomedical Engineering
Johns Hopkins University
Baltimore, MD 21205

Published in: **Nature**, 382:252–255, July 18, 1996

Brashers-Krug

- Two-Stage Consolidation Process
- Importance of Sleep
- Role of the Cerebellum and Striatum
- Interference and Facilitation
- Individual Differences in Consolidation
- Optimal Practice Schedules



The Co-ordination and Regulation of
MOVEMENTS
by N. Bernstein

PERGAMON PRESS
OXFORD · LONDON · EDINBURGH · NEW YORK
TORONTO · SYDNEY · PARIS · BRAUNSCHWEIG

Bernstein's theories

- Degrees of Freedom Problem (freezing degrees of freedom)
- Hierarchical Control
- Dynamic Systems Theory
- Repetition Without Repetition
- Motor Skill Learning as a Process of Discovery
- Sensory feedback for motor integration

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To wrap up…

Long-term memory	Spaced Practice	Sleep	Repetition in diverse environments

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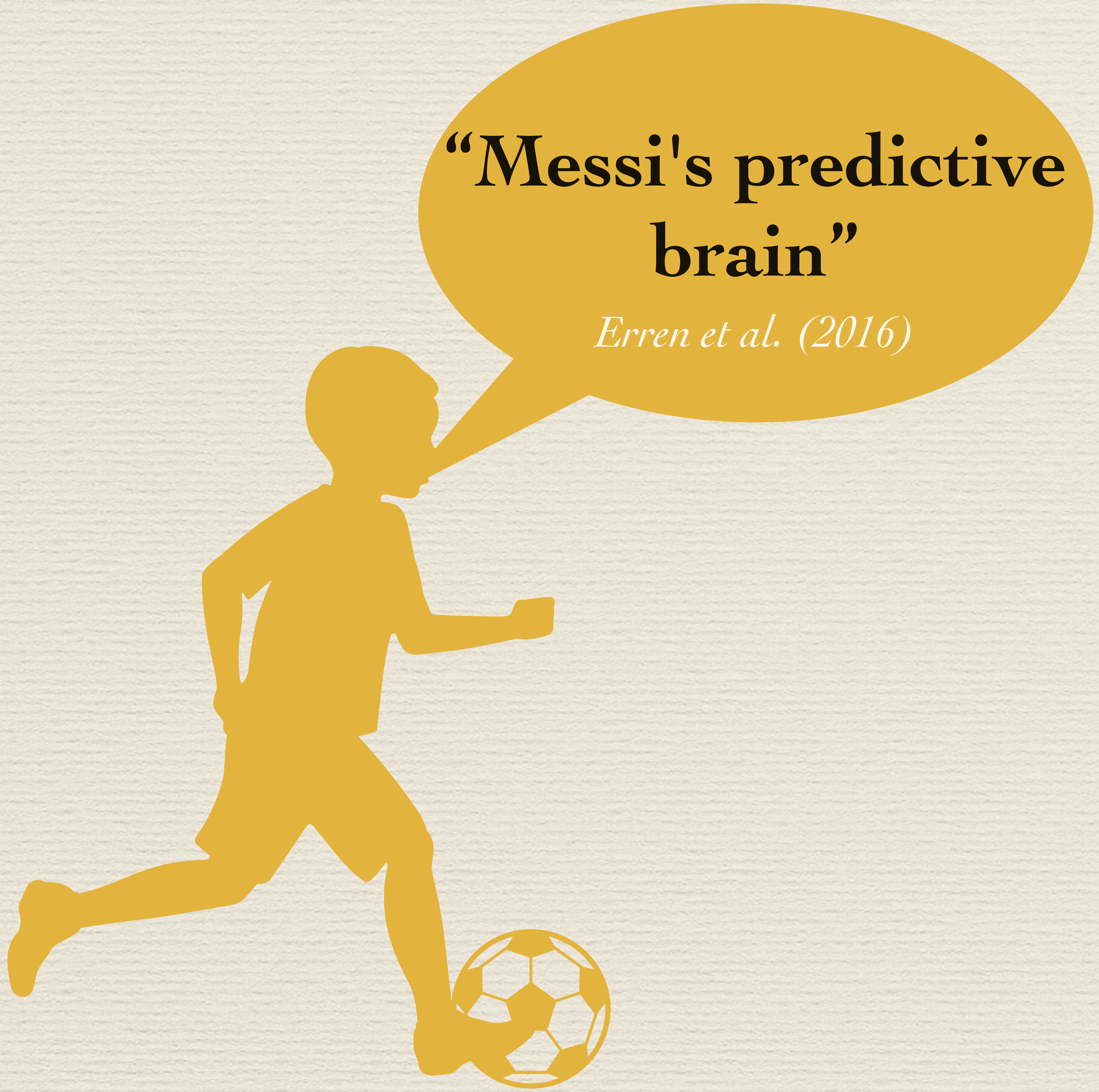
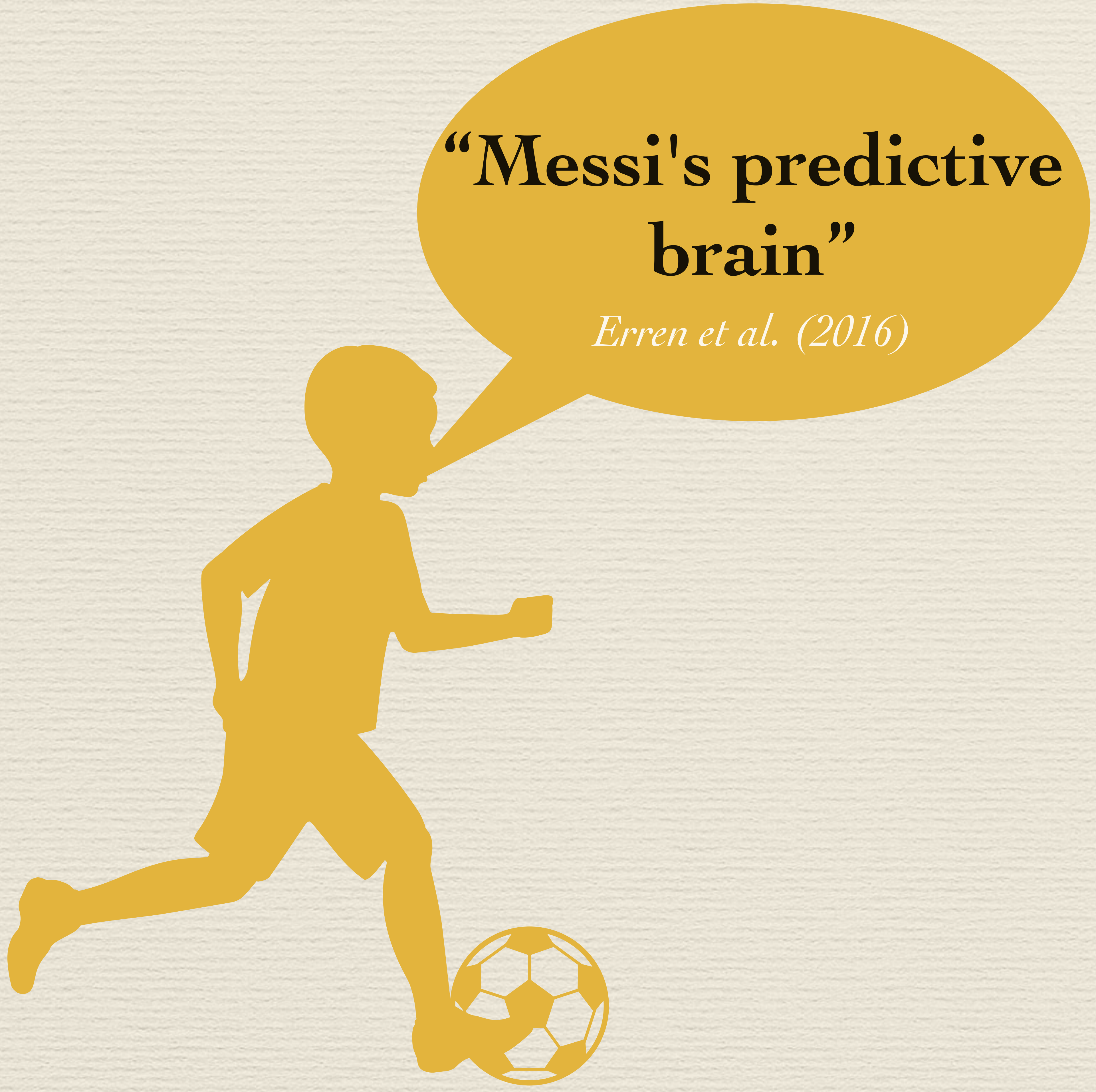


The involvement of perceptual-cognitive factors on sports

Selective attention test

A Double Dutch | Brain Games

Backpack - Situational Awareness Test



Automized motor skills may allow expertise player's brains to make better use of time to read the games and plan ahead

Meta-Analysis > J Sport Exerc Psychol. 2007 Aug;29(4):457-78. doi: 10.1123/jsep.29.4.457.

Perceptual-cognitive expertise in sport: a meta-analysis

Derek T Y Mann [1], A Mark Williams, Paul Ward, Christopher M Janelle

Affiliations + expand
PMID: 17968048 DOI: 10.1123/jsep.29.4.457

> Chronobiol Int. 2016;33(7):789-90. doi: 10.1080/07420528.2016.1178276. Epub 2016 May 9.

The discovery of slowness: Time to deconstruct Gretzky's and Messi's predictive brains

Thomas C Erren [1], Liz Kuffer [1], Andreas Pinger [1], J Valérie Groß [1]

Affiliations + expand
PMID: 27159282 DOI: 10.1080/07420528.2016.1178276

OPEN ACCESS Freely available online PLOS ONE

Executive Functioning in Highly Talented Soccer Players

Lot Verburgh[1]*, Erik J. A. Scherder[1], Paul A.M. van Lange[2], Jaap Oosterlaan[1]

1 Dept. of Clinical Neuropsychology, VU University Amsterdam, BT Amsterdam, The Netherlands, 2 Dept. of Social and Organizational Psychology, VU University Amsterdam, BT Amsterdam, The Netherlands

OPEN ACCESS Freely available online PLOS one

Executive Functions Predict the Success of Top-Soccer Players

Torbjörn Vestberg[1,2], Roland Gustafson[2], Liselotte Maurex[1], Martin Ingvar[1], Predrag Petrovic[1]*

1 Department of Clinical Neuroscience, Karolinska Institutet Stockholm, Stockholm, Sweden, 2 School of Law, Psychology and Social Work, Örebro University, Örebro, Sweden

AMERICAN PSYCHOLOGICAL ASSOCIATION
Psychological Bulletin

ISSN: 0033-2909
2021, Vol. 147, No. 12, 1290–1308
https://doi.org/10.1037/bul0000355

The Role of Domain-Specific and Domain-General Cognitive Functions and Skills in Sports Performance: A Meta-Analysis

Anton Kalén[1, 2], Elisa Bisagno[3], Lisa Musculus[4], Markus Raab[4, 5], Alexandra Pérez-Ferreirós[1, 6], A. Mark Williams[7], Duarte Araújo[8], Magnus Lindwall[9, 10], and Andreas Ivarsson[11, 12]

APPLIED COGNITIVE PSYCHOLOGY

RESEARCH ARTICLE

Measurement of cognitive functions in experts and elite athletes: A meta-analytic review

Hans-Erik Scharfen, Daniel Memmert

First published: 25 January 2019 | https://doi.org/10.1002/acp.3526 | Citations: 107

INTERNATIONAL REVIEW OF SPORT AND EXERCISE PSYCHOLOGY
https://doi.org/10.1080/1750984X.2023.2217437
Routledge Taylor & Francis Group
Check for updates

A critical review of research on executive functions in sport and exercise

Philip Furley[a], Lisa-Marie Schütz[b] and Greg Wood[c]

[a]German Sport University Cologne, Institute for Training and Computer Science in Sport, German Sport University, Cologne, Germany; [b]Heidelberg University, Institute of Sports and Sports Sciences, University of Heidelberg, Heidelberg, Germany; [c]Department of Sport and Exercise Sciences, Manchester Metropolitan University, Manchester, UK

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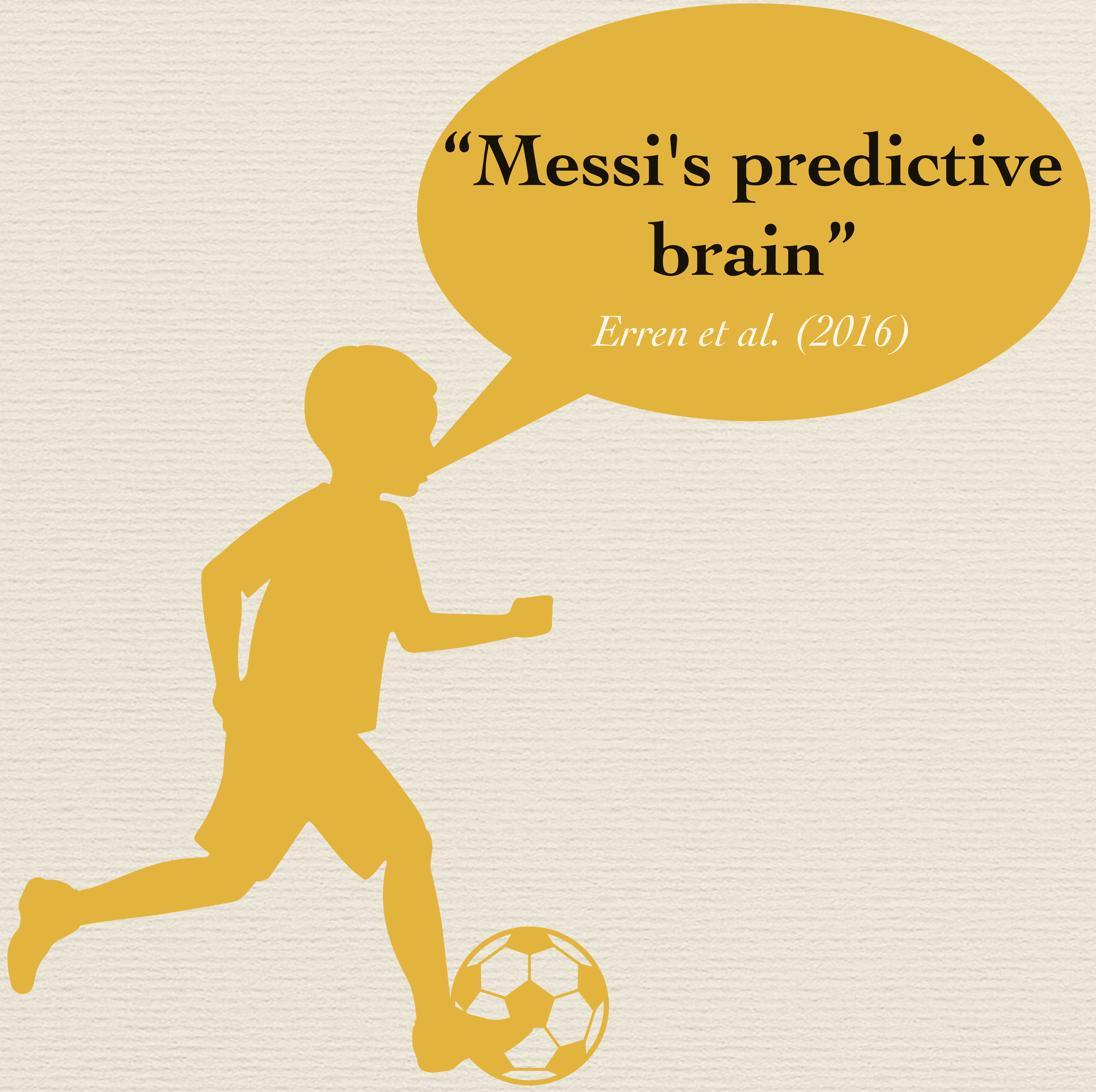

Automized motor skills may allow expertise player's brains to make better use of time to read the games and plan ahead

Mann et al. (2007)

Experts are better than nonexperts in picking up perceptual cues, as revealed by measures of response accuracy and response time.

Experts use fewer fixations of longer duration, including prolonged quiet eye periods, compared with nonexperts.

Verburgh et al. (2012)

Processing speed, cognitive inhibition, working memory

Verburgh et al. (2014)

Highly talented youth soccer players outperform youth amateur players on suppressing ongoing motor responses and on the ability to attain and maintain an alert state.

Kalén et al. (2021)

Higher skilled athletes perform better on cognitive function tests than lower skilled athletes.

There was insufficient evidence to determine whether cognitive functions and skills can predict future sport performance.

Scharfen and Memmert (2019)

Overall, the mean effect size was small to medium (r = 0.22), indicating superior cognitive functions in experts and elite athletes.

Furley, Schütz and Wood (2023)

Inconclusive empirical support.

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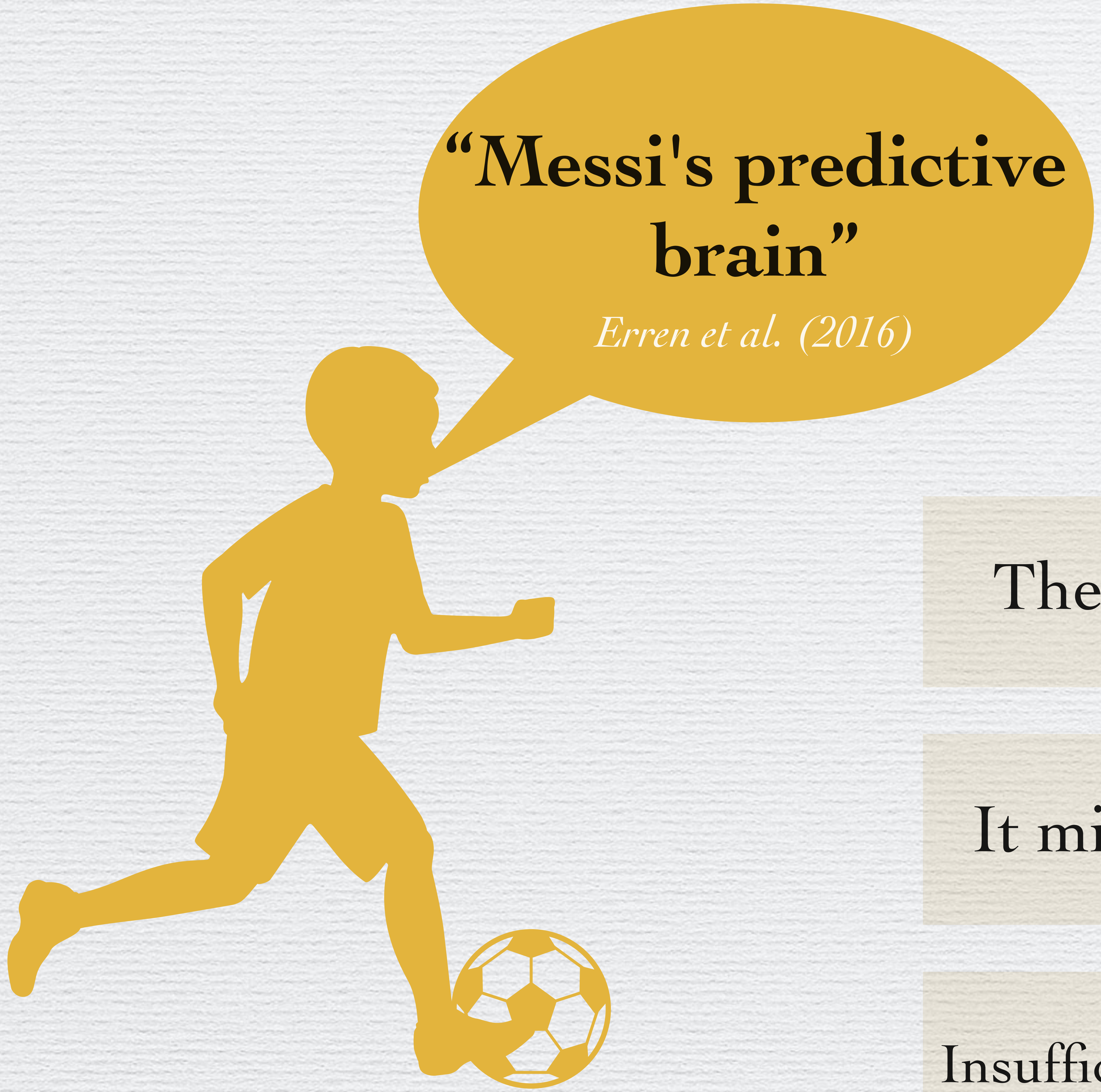

To wrap up...

There is a difference between expert and non-expert players

It might be due to enhanced cognitive functions

Insufficient evidence for cognitive functions to predict future sport performance.

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The euphoric state resulting from long-distance running and physical exercise and its possible effects on well-being and mental health.

JOURNAL ARTICLE

The Runner's High: Opioidergic Mechanisms in the Human Brain FREE

Henning Boecker, Till Sprenger, Mary E. Spilker, Gjermund Henriksen, Marcus Koppenhoefer, Klaus J. Wagner, Michael Valet, Achim Berthele, Thomas R. Tolle

Cerebral Cortex, Volume 18, Issue 11, November 2008, Pages 2523–2531, https://doi.org/10.1093/cercor/bhn013
Published: 21 February 2008

Randomized Controlled Trial > Eur J Appl Physiol. 2013 Apr;113(4):869-75.
doi: 10.1007/s00421-012-2495-5. Epub 2012 Sep 19.

Exercise-induced endocannabinoid signaling is modulated by intensity

David A Raichlen [1], Adam D Foster, Alexandre Seillier, Andrea Giuffrida, Gregory L Gerdeman

Affiliations + expand
PMID: 22990628 DOI: 10.1007/s00421-012-2495-5

Review > Int J Mol Sci. 2023 Jan 19;24(3):1989. doi: 10.3390/ijms24031989.

The Endocannabinoid System and Physical Exercise

Daniela Matei [1], Dan Trofin [1] [2], Daniel Andrei Iordan [3] [4], Ilie Onu [1] [5], Iustina Condurache [1], Catalin Ionite [1], Ioana Buculei [1] [2]

Journal Article

Front Psychol. 2022; 13: 1044988. PMCID: PMC9881726
Published online 2023 Jan 13. doi: 10.3389/fpsyg.2022.1044988 PMID: 36710801

Too much is too little: Estimating the optimal physical activity level for a healthy mental state

Akiyoshi Shimura,[1,*,†] Jiro Masuya,[1] Katsunori Yokoi,[2] Chihiro Morishita,[1] Masayuki Kikkawa,[1] Kazuki Nakajima,[1] Chong Chen,[3] Shin Nakagawa,[3] and Takeshi Inoue[1]

Sports Medicine (2019) 49:1383–1410
https://doi.org/10.1007/s40279-019-01099-5

SYSTEMATIC REVIEW

Check for updates

Role of Physical Activity and Sedentary Behavior in the Mental Health of Preschoolers, Children and Adolescents: A Systematic Review and Meta-Analysis

María Rodriguez-Ayllon[1] · Cristina Cadenas-Sánchez[1] · Fernando Estévez-López[2,3] · Nicolas E. Muñoz[1] · Jose Mora-Gonzalez[1] · Jairo H. Migueles[1] · Pablo Molina-García[1,4] · Hanna Henriksson[1,5] · Alejandra Mena-Molina[1] · Vicente Martínez-Vizcaíno[6,7] · Andrés Catena[8,9] · Marie Löf[5,10] · Kirk I. Erickson[11] · David R. Lubans[12] · Francisco B. Ortega[1,10] · Irene Esteban-Cornejo[1,13]

Meta-Analysis > BMJ. 2024 Feb 14:384:e075847. doi: 10.1136/bmj-2023-075847.

Effect of exercise for depression: systematic review and network meta-analysis of randomised controlled trials

Michael Noetel [1], Taren Sanders [2], Daniel Gallardo-Gómez [3], Paul Taylor [4], Borja Del Pozo Cruz [5] [6], Daniel van den Hoek [7], Jordan J Smith [8], John Mahoney [9], Jemima Spathis [9], Mark Moresi [4], Rebecca Pagano [10], Lisa Pagano [11], Roberta Vasconcellos [2], Hugh Arnott [2], Benjamin Varley [12], Philip Parker [13], Stuart Biddle [14] [15], Chris Lonsdale [13]

ELSEVIER
Psychology of Sport and Exercise
Volume 42, May 2019, Pages 146-155

Physical activity and mental health in children and adolescents: An updated review of reviews and an analysis of causality

Stuart J.H. Biddle, Simone Ciaccioni, George Thomas, Ineke Vergeer

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The euphoric state resulting from long-distance running and physical exercise and its possible effects on well-being and mental health.

Boecker et al. (2008)

The level of euphoria was significantly increased after running and was inversely correlated with opioid binding in prefrontal/orbitofrontal cortices, the anterior cingulate cortex, bilateral insula, parainsular cortex, and temporoparietal regions. These findings support the "opioid theory" of the runner's high and suggest region-specific effects in frontolimbic brain areas that are involved in the processing of affective states and mood.

Raichlen et al. (2013)

We show that eCB signaling is indeed intensity dependent, with significant changes in circulating eCBs observed following moderate intensities only (very high and very low intensity exercises do not significantly alter circulating eCB levels).

Matei et al. (2023)

The ECS has an important role in controlling motor activity, cognitive functions, nociception, emotions, memory, and synaptic plasticity. The close interaction of the ECS with dopamine shows that they have a function in the brain's reward system. Activation of the ECS also produces anxiolysis and a sense of wellbeing as well as mediates peripheral effects such as vasodilation and bronchodilation that may play a contributory role in the body's response to exercise.

Rodriguez-Ayllon et al. (2019)
Biddle et al. (2019)

There was a small but significant overall effect of physical activity on mental health in children and adolescents aged 6–18 years (effect size 0.17).

There are significant increases in research activity concerning physical activity and depression, self-esteem, and cognitive functioning in young people. The strongest evidence for a causal association appears to be for cognitive functioning, and there is partial evidence for depression.

Shimura et al. (2022)

Levels of physical activity per week optimized the mental health measurements values of the participants: 6,953 MET-minutes and 25.70 h for depression, 5,277 MET-minutes and 21.60 h for state anxiety, 5,678 MET-minutes and 22.58 h for trait anxiety, 25.41 h for resilience, and 9,152 MET-minutes and 31.17 h for insomnia vulnerability.

Noetel et al. (2024)

Exercise is an effective treatment for depression, with walking or jogging, yoga, and strength training more effective than other exercises, particularly when intense. Yoga and strength training were well tolerated compared with other treatments.

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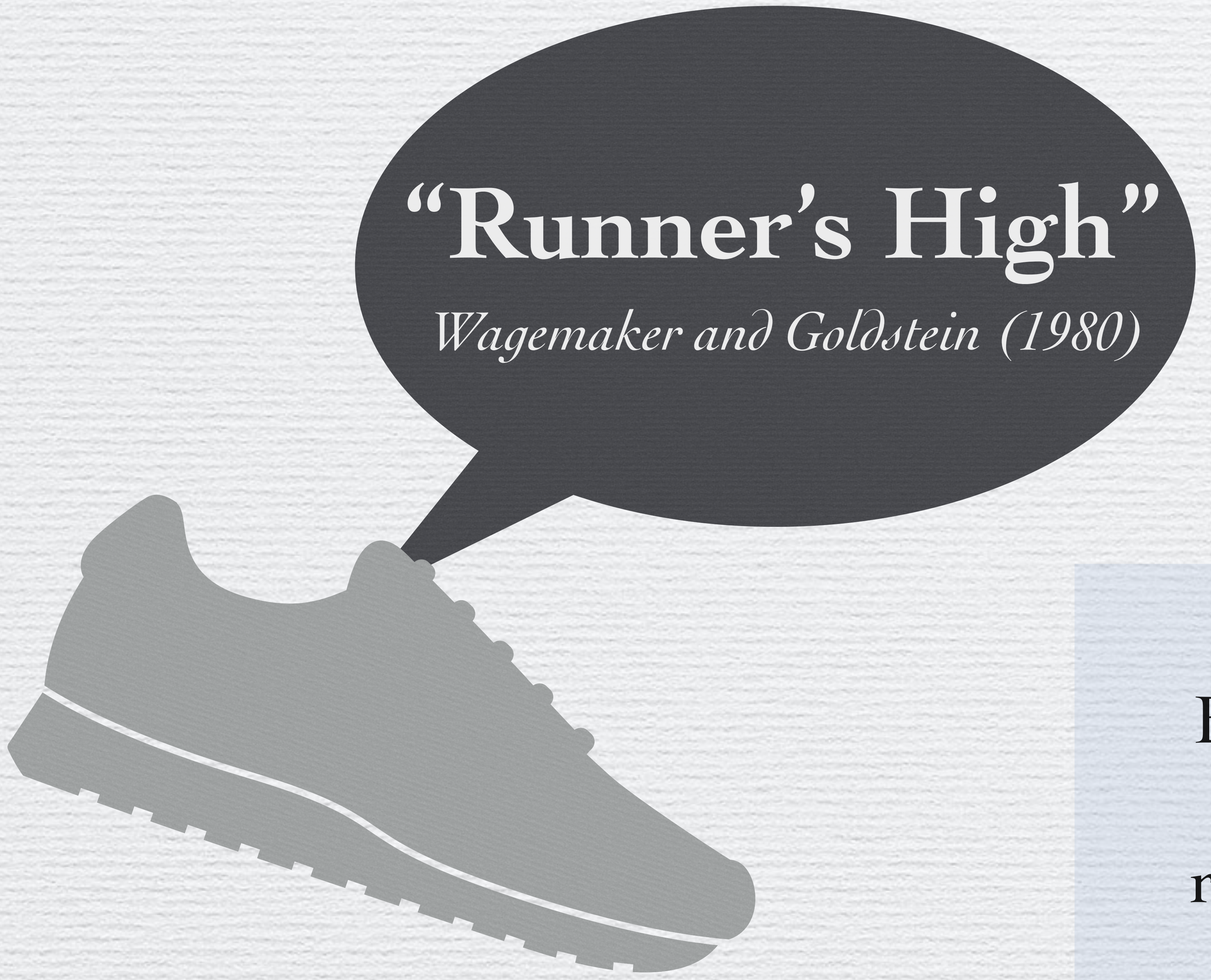


To wrap up…

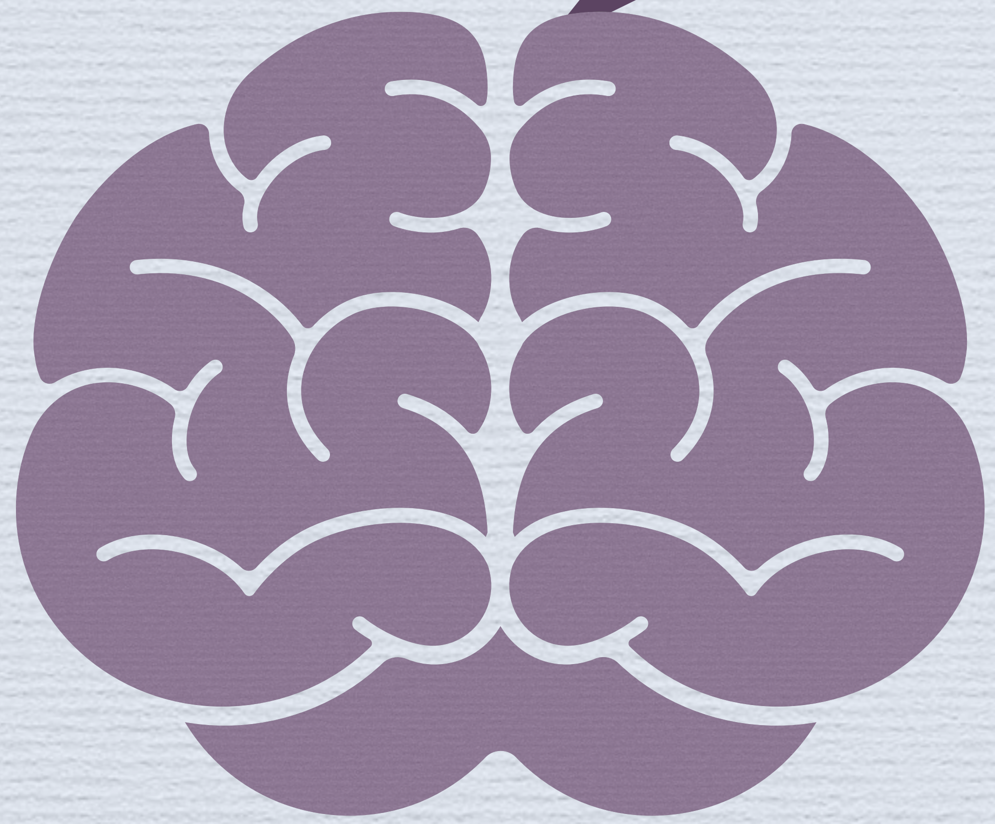
ECB has a function in the brain's reward system after physical exercise

Intensity and weekly time involved in exercise might be considered to observe eCB signaling

Walking or jogging, yoga, and strength training are effective for depression in adults. Insufficient evidence in adolescence.

"Miracle-Gro"

Dr. John Ratey



Science and Society | Published: January 2008

Be smart, exercise your heart: exercise effects on brain and cognition

Charles H. Hillman, Kirk I. Erickson & Arthur F. Kramer

Nature Reviews Neuroscience 9, 58–65 (2008) | Cite this article

Cognition

Original research

Timing of physical activity across adulthood on later-life cognition: 30 years follow-up in the 1946 British birth cohort

Sarah-Naomi James[1], Yu-Jie Chiou,[1,2,3] Nasri Fatih,[1] Louisa P Needham,[1] Jonathan M Schott[1,4] Marcus Richards[1]

PNAS

Exercise training increases size of hippocampus and improves memory

Kirk I. Erickson[a], Michelle W. Voss[b,c], Ruchika Shaurya Prakash[d], Chandramallika Basak[e], Amanda Szabo[f], Laura Chaddock[b,c], Jennifer S. Kim[b], Susie Heo[b,c], Heloisa Alves[b,c], Siobhan M. White[f], Thomas R. Wojcicki[f], Emily Mailey[f], Victoria J. Vieira[f], Stephen A. Martin[f], Brandt D. Pence[f], Jeffrey A. Woods[f], Edward McAuley[b,f], and Arthur F. Kramer[b,c,1]

[a]Department of Psychology, University of Pittsburgh, Pittsburgh, PA 15260; [b]Beckman Institute for Advanced Science and Technology, and [f]Department of Kinesiology and Community Health, University of Illinois, Champaign-Urbana, IL 61801; [c]Department of Psychology, University of Illinois, Champaign-Urbana, IL 61820; [d]Department of Psychology, Ohio State University, Columbus, OH 43210; and [e]Department of Psychology, Rice University, Houston, TX 77251

frontiers in Neuroscience

MINI REVIEW
published: 07 February 2018
doi: 10.3389/fnins.2018.00052

Exercise-Mediated Neurogenesis in the Hippocampus via BDNF

Patrick Z. Liu and Robin Nusslock*

Department of Psychology, Northwestern University, Evanston, IL, United States

Int J Environ Res Public Health. 2020 Aug; 17(16): 5972. PMCID: PMC7460146
Published online 2020 Aug 17. doi: 10.3390/ijerph17165972 PMID: 32824593

Physical Activity and Academic Achievement: An Umbrella Review

Ana Barbosa,[1] Stephen Whiting,[1,2,3] Philippa Simmonds,[3] Rodrigo Scotini Moreno,[3] Romeu Mendes,[1,2,3] and João Breda[2,3,*]

BMJ Open Sport Exerc Med. 2018 Mar 27;4(1):e000341. doi: 10.1136/bmjsem-2018-000341. eCollection 2018.

Systematic review of acute physically active learning and classroom movement breaks on children's physical activity, cognition, academic performance and classroom behaviour: understanding critical design features

Andy J Daly-Smith[1], Stephen Zwolinsky[1], Jim McKenna[1], Phillip D Tomporowski[2], Margaret Anne Defeyter[3], Andrew Manley[1]

Review | Brain Sci. 2021 May 21;11(6):675. doi: 10.3390/brainsci11060675.

Active School Breaks and Students' Attention: A Systematic Review with Meta-Analysis

Álvaro Infantes-Paniagua[1], Ana Filipa Silva[2,3], Rodrigo Ramirez-Campillo[4,5], Hugo Sarmento[6,7], Francisco Tomás González-Fernández[8], Sixto González-Víllora[9], Filipe Manuel Clemente[10,11]

J Public Health (Oxf). 2023 Nov 29;45(4):919-929. doi: 10.1093/pubmed/fdad102.

The effects of an active breaks intervention on physical and cognitive performance: results from the I-MOVE study

Alice Masini[1], Sofia Marini[2], Andrea Ceciliani[2], Giuseppe Barone[2], Marcello Lanari[3], Davide Gori[1], Laura Bragonzoni[2], Stefania Toselli[1], Rita Stagni[4], Maria Cristina Bisi[4], Alessandra Sansavini[5], Alessia Tessari[5], Laura Dallolio[1]

There's little known about the effects of exercise on brain functioning and neurogenesis but some structural changes happen in the brain when we exercise.

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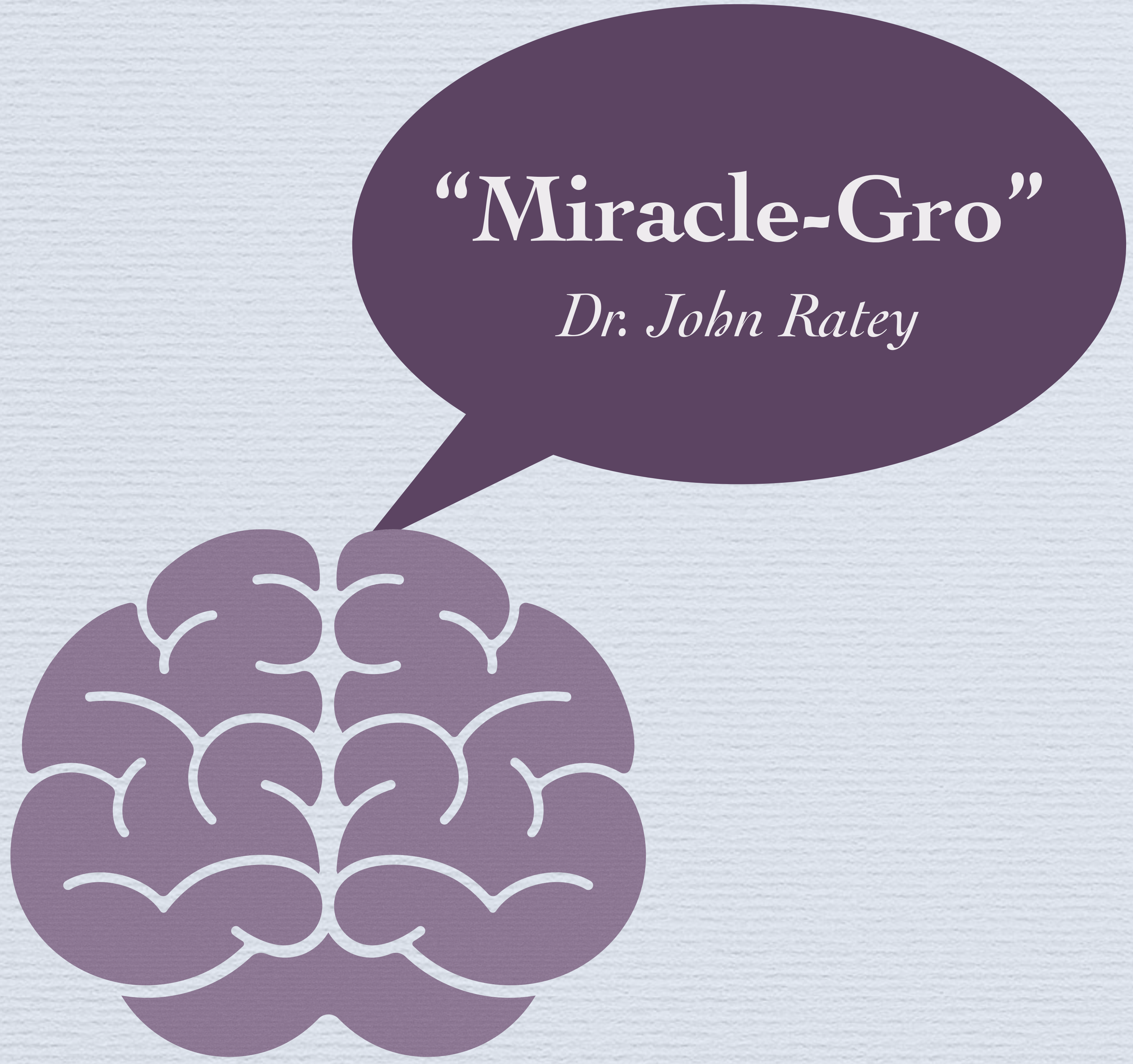

There's little known about the effects of exercise on brain functioning and neurogenesis but some structural changes happen in the brain when we exercise.

Hillman (2008)

This article examines the positive effects of aerobic physical activity on cognition and brain function, at the molecular, cellular, systems and behavioural levels.

James et al. (2023)

Sample of 1417 adults. Participation in leisure time physical activity was reported five times between ages 36 and 69. Being physically active, at all assessments in adulthood, was associated with higher cognition at age 69. The strongest association was between sustained cumulative physical activity and later-life cognitive state, in a dose-response manner.

Erickson et al. (2011)

These theoretically important findings indicate that aerobic exercise training is effective at reversing hippocampal volume loss in late adulthood, which is accompanied by improved memory function.

Liu and Nusslock (2018)

Although much more is known about the direct role that exercise and BDNF have on hippocampal neurogenesis in rodents, their corresponding cognitive benefits in humans will also be discussed.

Barbosa et al. (2020)

From meta-analyses, it was observed that physical activity had null or small-to-medium positive effects on academic achievement.

Daly-Smith et al. (2018)

Low-to-medium quality designs predominate in investigations of the acute impacts of active breaks on PA, cognition, academic performance and classroom behaviour. Evidence shows that increased PA and enhanced time on task.

Infantes-Paniagua et al. (2021)

Results showed some positive acute and chronic effects of active breaks on attentional outcomes (i.e., accuracy, concentration, inhibition, and sustained attention), especially on selective attention. However, most of the results were not significant.

Masini et al. (2023)

The active breaks group (ABsG) performed 10 min of ABs three times per school day and the control group (CG) did normal lessons. Working memory significantly increased in the ABsG than in CG. Children improved their time on task behaviors in ABsG.

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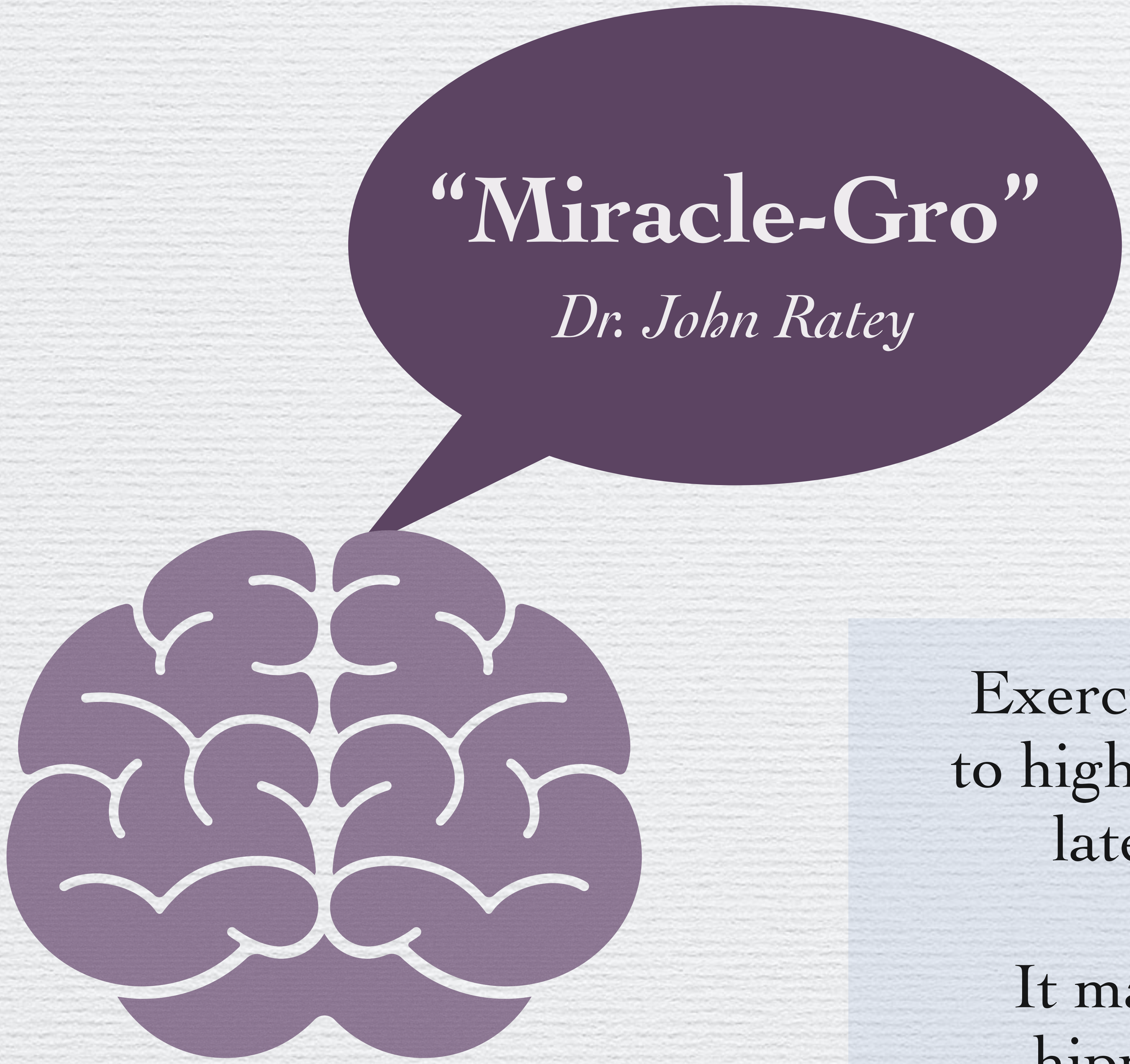

To wrap up…

Exercise is linked to higher cognition later in life.

It may reverse hippocampal volume loss.

BDNF production and blood flow are estimulated by exercise.

It may have implications for cognition and mental health.

Insufficient evidence linking exercise with academic performance

Active Breaks seem to enhance students' time on task

nature human behaviour

Article

https://doi.org/10.1038/s41562-023-01554-4

An umbrella review of randomized control trials on the effects of physical exercise on cognition

Received: 22 March 2022

Accepted: 9 February 2023

Published online: 27 March 2023

Check for updates

Luis F. Ciria [1,2], Rafael Román-Caballero [1,2], Miguel A. Vadillo [3], Darias Holgado [2,4], Antonio Luque-Casado [5], Pandelis Perakakis [6] & Daniel Sanabria [1,2]

Extensive research links regular physical exercise to an overall enhancement of cognitive function across the lifespan. Here we assess the causal evidence supporting this relationship in the healthy population, using an umbrella review of meta-analyses limited to randomized controlled trials (RCTs). Despite most of the 24 reviewed meta-analyses reporting a positive overall effect, our assessment reveals evidence of low statistical power in the primary RCTs, selective inclusion of studies, publication bias and large variation in combinations of pre-processing and analytic decisions. In addition, our meta-analysis of all the primary RCTs included in the revised meta-analyses shows small exercise-related benefits ($d = 0.22$, 95% confidence interval 0.16 to 0.28) that became substantially smaller after accounting for key moderators (that is, active control and baseline differences; $d = 0.13$, 95% confidence interval 0.07 to 0.20), and negligible after correcting for publication bias ($d = 0.05$, 95% confidence interval −0.09 to 0.14). These findings suggest caution in claims and recommendations linking regular physical exercise to cognitive benefits in the healthy human population until more reliable causal evidence accumulates.

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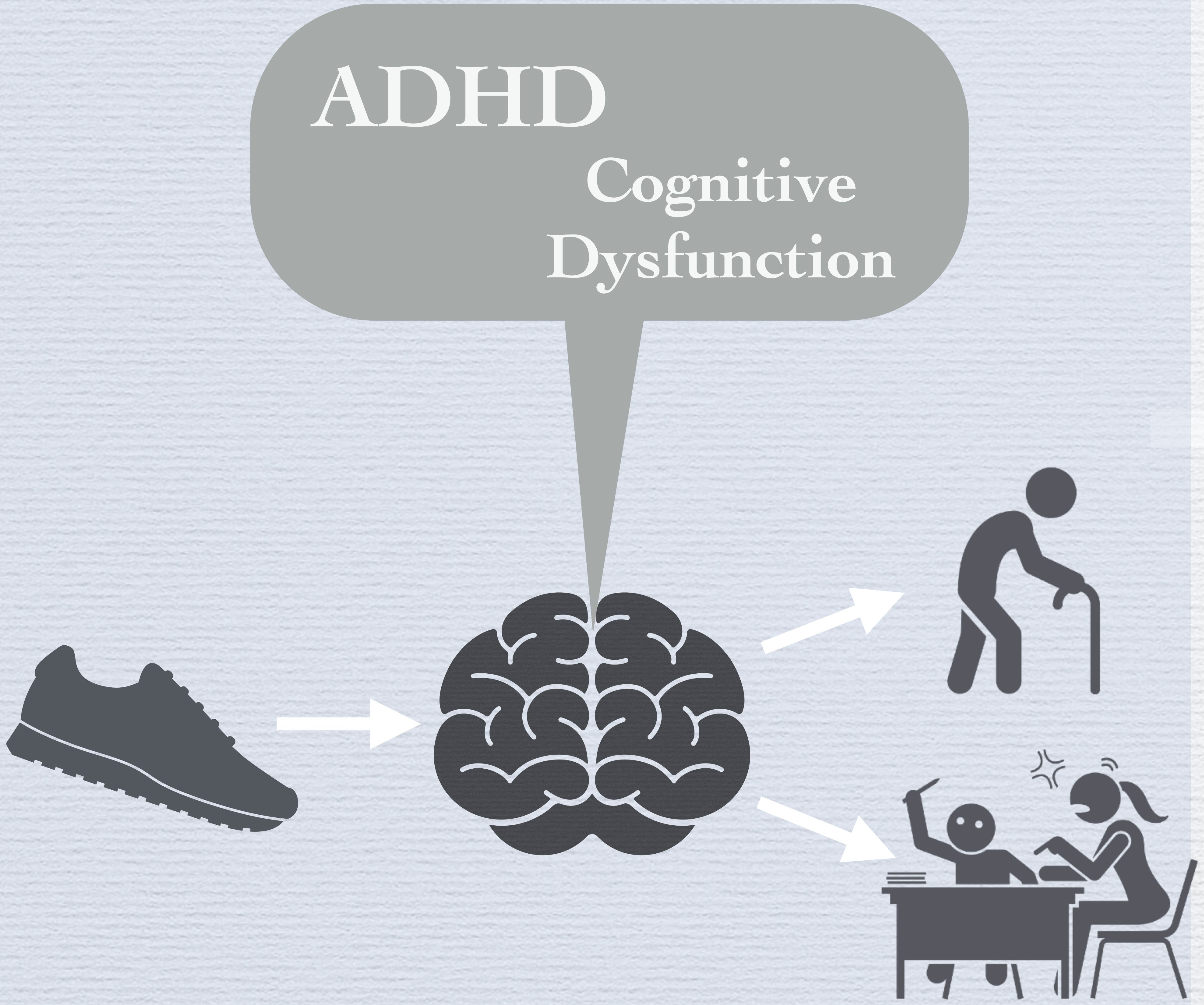

Meta-Analysis > J Am Geriatr Soc. 2018 Mar;66(3):487-495. doi: 10.1111/jgs.15241. Epub 2018 Jan 24.

Can Exercise Improve Cognitive Symptoms of Alzheimer's Disease?

Gregory A Panza [1,2], Beth A Taylor [1,2], Hayley V MacDonald [3], Blair T Johnson [4], Amanda L Zaleski [1,2], Jill Livingston [5], Paul D Thompson [2], Linda S Pescatello [1]

Affiliations + expand

PMID: 29363108 DOI: 10.1111/jgs.15241

Meta-Analysis > BMC Geriatr. 2022 Jul 25;22(1):617. doi: 10.1186/s12877-022-03302-1.

Effect of multicomponent exercise in cognitive impairment: a systematic review and meta-analysis

Luis Carlos Venegas-Sanabria [1,2,3], Iván Cavero-Redondo [4,5,6], Vicente Martínez-Vizcaino [1,7], Carlos Alberto Cano-Gutierrez [8,9], Celia Álvarez-Bueno [1,10]

Review | Open access | Published: 27 February 2023

Recent advances on the molecular mechanisms of exercise-induced improvements of cognitive dysfunction

Yi Lu, Fa-Qian Bu, Fang Wang, Li Liu, Shuai Zhang, Guan Wang & Xiu-Ying Hu

Translational Neurodegeneration 12, Article number: 9 (2023) | Cite this article

> J Alzheimers Dis. 2024;97(2):829-839. doi: 10.3233/JAD-230740.

Exercise-Related Physical Activity Relates to Brain Volumes in 10,125 Individuals

Cyrus A Raji [1,2], Somayeh Meysami [3,4], Sam Hashemi [5,6], Saurabh Garg [2,6], Nasrin Akbari [5,6], Gouda Ahmed [5,6], Yosef Gavriel Chodakiewitz [5], Thanh Duc Nguyen [5,6], Kellyann Niotis [7,8], David A Merrill [3,4,9], Rajpaul Attariwala [5,6,10]

Review > Psychiatry Res. 2022 May:311:114509. doi: 10.1016/j.psychres.2022.114509. Epub 2022 Mar 14.

Effects of physical exercise on attention deficit and other major symptoms in children with ADHD: A meta-analysis

Wenxin Sun [1], Mingxuan Yu [2], Xiaojing Zhou [3]

Review > Child Care Health Dev. 2015 Nov;41(6):779-88. doi: 10.1111/cch.12255. Epub 2015 May 18.

The effects of physical exercise in children with attention deficit hyperactivity disorder: a systematic review and meta-analysis of randomized control trials

A J Cerrillo-Urbina [1], A García-Hermoso [2], M Sánchez-López [1,3], M J Pardo-Guijarro [1,3], J L Santos Gómez [4], V Martínez-Vizcaíno [1]

Meta-Analysis > Front Public Health. 2023 Mar 24:11:1133727. doi: 10.3389/fpubh.2023.1133727. eCollection 2023.

Comparative effectiveness of various physical exercise interventions on executive functions and related symptoms in children and adolescents with attention deficit hyperactivity disorder: A systematic review and network meta-analysis

Feilong Zhu [1], Xiaotong Zhu [1], Xiaoyu Bi [1], Dongqing Kuang [1], Boya Liu [2], Jingyi Zhou [1], Yiming Yang [1], Yuanchun Ren [1]

> Front Behav Neurosci. 2020 Oct 22:14:564886. doi: 10.3389/fnbeh.2020.564886. eCollection 2020.

Chronic Physical Activity for Attention Deficit Hyperactivity Disorder and/or Autism Spectrum Disorder in Children: A Meta-Analysis of Randomized Controlled Trials

Meiqi Zhang [1], Zhan Liu [1], Hongtao Ma [2], Daniel M Smith [1]

Meta-Analysis > PLoS One. 2023 Aug 17;18(8):e0289732. doi: 10.1371/journal.pone.0289732. eCollection 2023.

Meta-analysis of the effects of physical activity on executive function in children and adolescents with attention deficit hyperactivity disorder

Yiling Song [1], Biyao Fan [2], Chunshun Wang [1], Hongjun Yu [1]

Some trials try to identify potencial benefits for those illness

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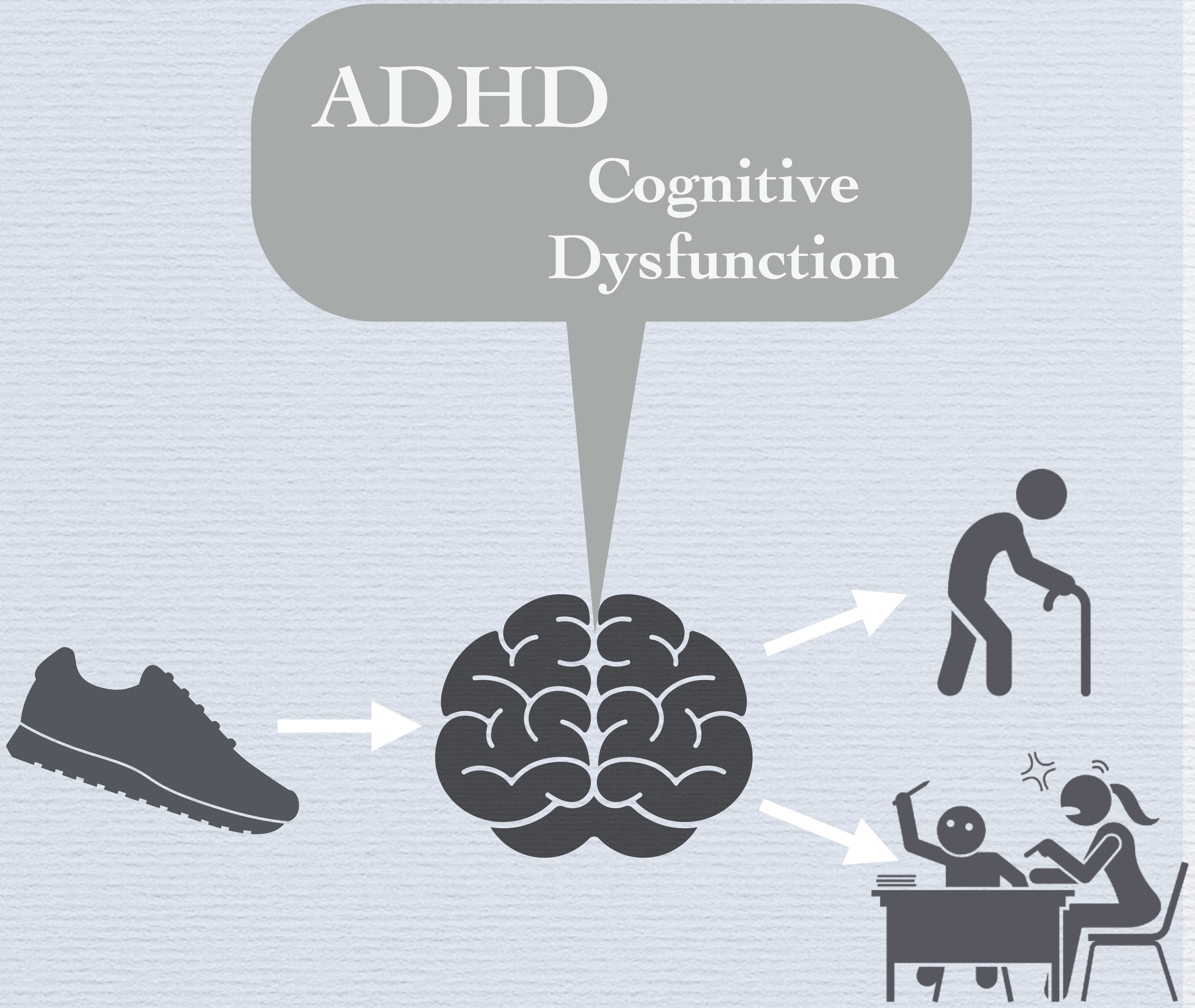

Some trials try to identify potencial benefits of exercise for different brain disorders or dysfunctions.

Panza et al. (2018)

Aerobic exercise had a moderate favorable effect on cognitive function (d_{+w} = 0.65, 95% CI = 0.35-0.95), but other exercise types did not.

Raji et al. (2023)

10,125 healthy participants underwent whole-body MRI scans. Exercise-related physical activity is associated with increased brain volumes, indicating potential neuroprotective effects. Increased days of MVPA correlated with larger brain volumes.

Venegas-Sanabria et al. (2022)

This study suggests that multicomponent physical exercise could have an effect on global cognition in people with mild cognitive impairment or dementia only when aerobic exercise is included in the intervention.

Lu et al. (2023)

BDNF is the key modulator between exercise and cognitive function. Exercise improves cognitive function by promoting cytokine release. There's a key factor of skeletal muscle-brain axis: irisin.

Cerrillo-Urbina et al. (2015)

Aerobic exercise had a moderate to large effect on core symptoms such as attention (SMD = 0.84), hyperactivity (SMD = 0.56) and impulsivity (SMD = 0.56) and related symptoms such as anxiety (SMD = 0.66), executive function (SMD = 0.58) and social disorders (SMD = 0.59) in children with ADHD.

Zhang et al. (2020)

Chronic PA interventions may promote EF and MS in children with ADHD/ASD, especially in inhibitory control, cognitive flexibility, and gross motor skills. However, PA interventions seemed to have insignificant effects on working memory and fine motor skills to children with ADHD/ASD

Sun et al. (2022)

Physical exercise can help alleviate the symptoms of ADHD in children. Specifically, it can improve attention, executive function, and motor skills. There were no significant effects on hyperactivity, depression, social problems or aggressive behavior. Intervention duration and frequency might be the source of heterogeneity.

Zhu et al. (2023)

The results from this network meta-analysis reconfirmed the beneficial effects of various physical exercise interventions on executive functions and ADHD-related symptoms and provide evidence that open-skill activities which require participants to react in a dynamically changing and externally paced environment (e.g. football or racket sports) had the highest probability of being the most promising physical exercise treatment for improving executive functions, particularly in inhibitory control. While closed-skill activities dominated by aerobic exercises (e.g. swimming, running, cycle ergometer, rope skipping) tended to be the most effective in helping working memory.
The multicomponent physical exercise tended to be the most effective in helping cognitive flexibility.
Closed-skill activities dominated by aerobic exercises possessed the greatest likelihood of being the best intervention for ADHD-related symptoms.

Song et al. (2023)

PA interventions had positive effects on improvements in core executive functions in children and adolescents with ADHD and were influenced by intervention intensity, type of motor skill, sessions of PA, and amount of exercise.

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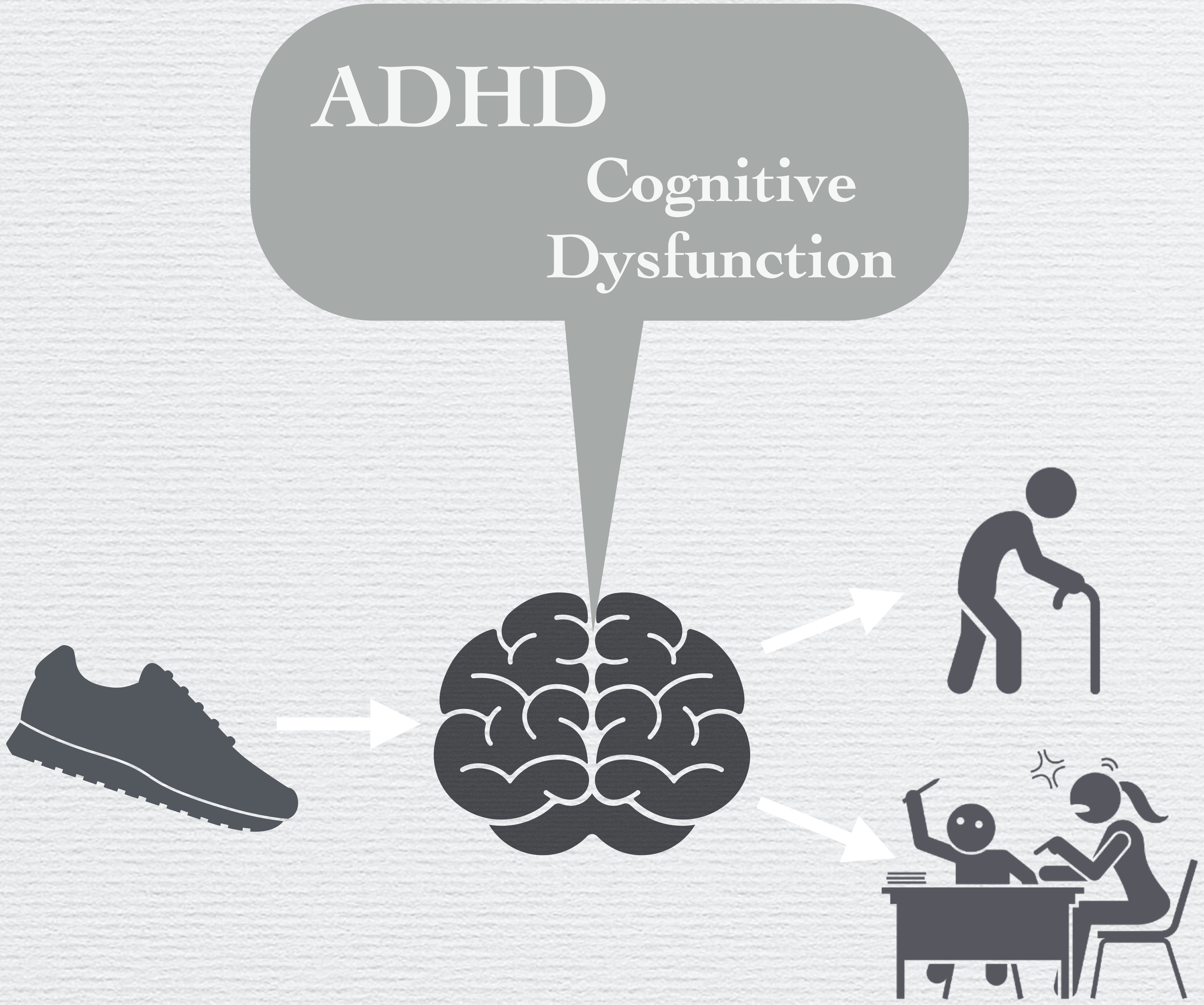

To wrap up…

Aerobic exercise but no other type.

Days involved in MVPA correlated with larger brain volumes.

Physical exercise can help alleviate the symptoms of ADHD in children.

Insufficient evidence to set up a standardized protocol. Although, a meta-analysis point to aerobic exercise as the most effective.

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3. From conceptual frameworks to the playground: PE

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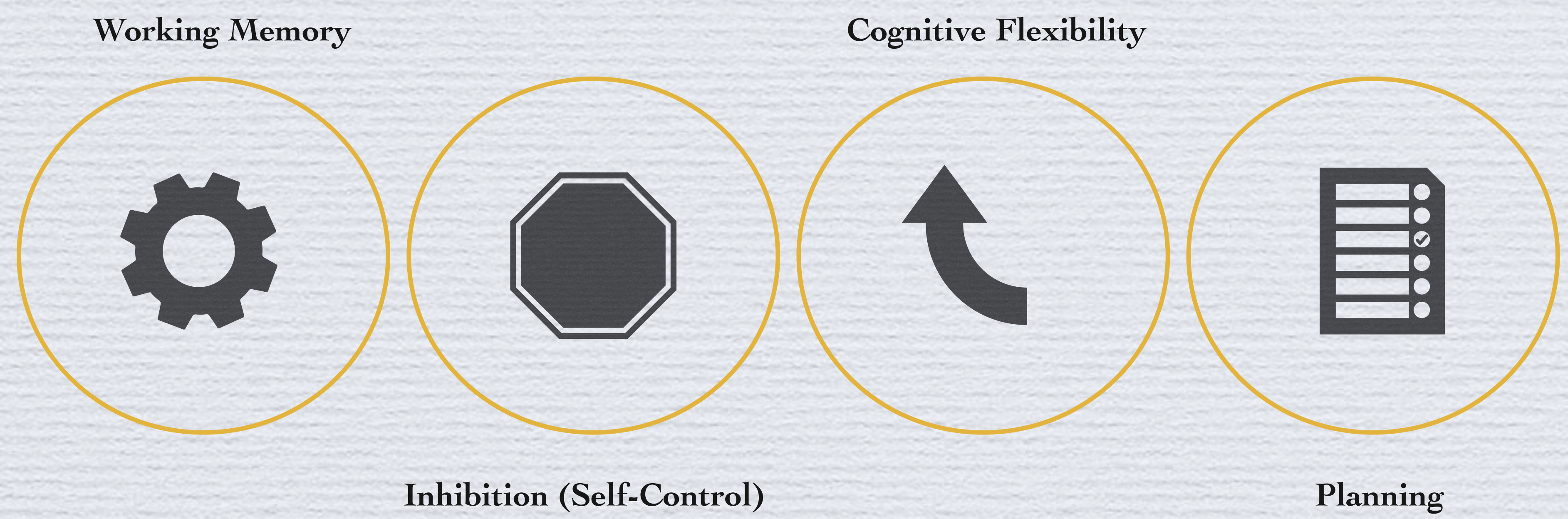
PE games focused on Executive Functions



Physically active breaks between lessons to enhance students' attention and time on task

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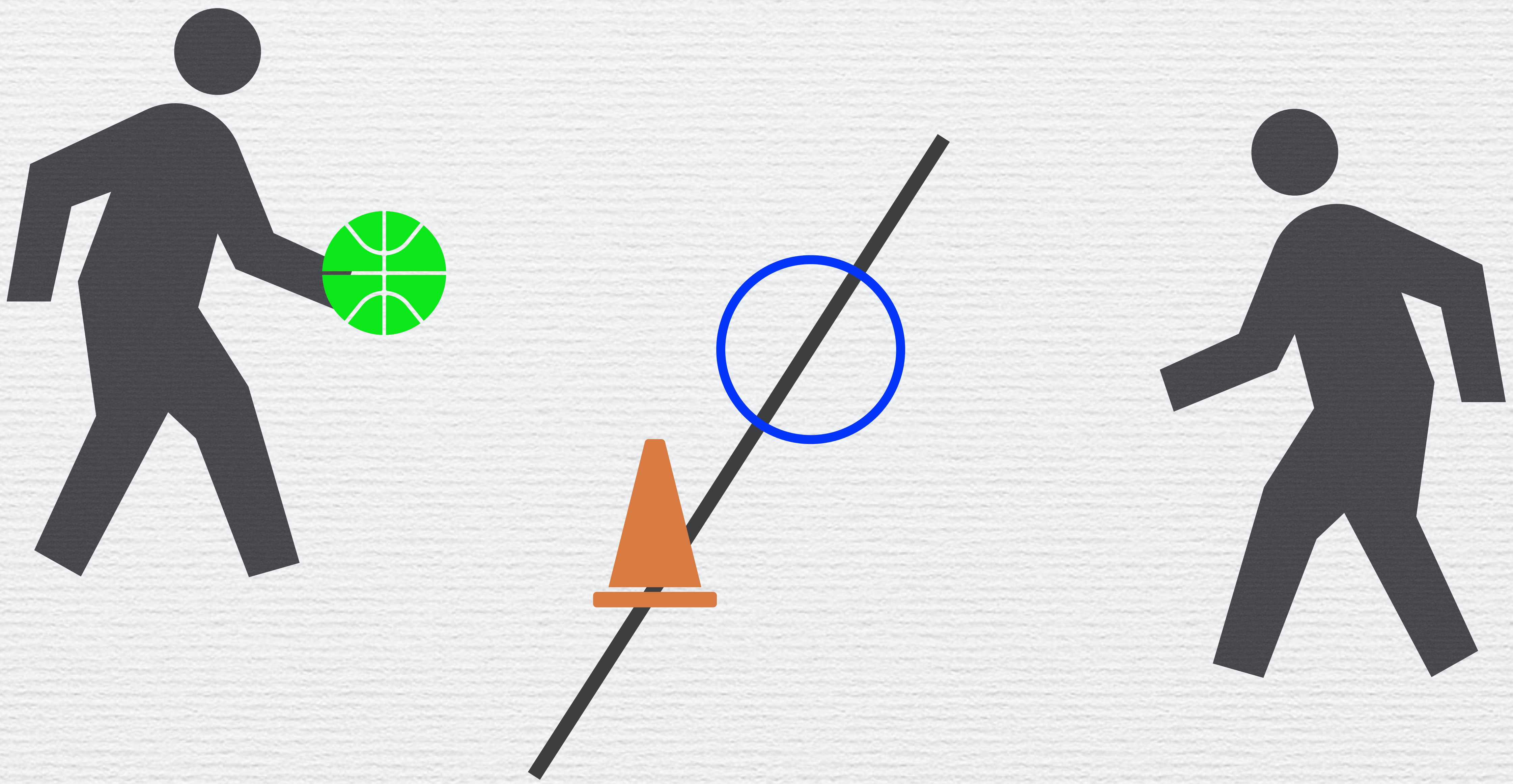
Game: "Cone, hoop, ball"



1) Ball (hit the opponent), Cone (knock down) or Hoop (step in).
2) Ball (know down cone), Cone (step in the hoop) or Hoop (hot the opponent).
3) …

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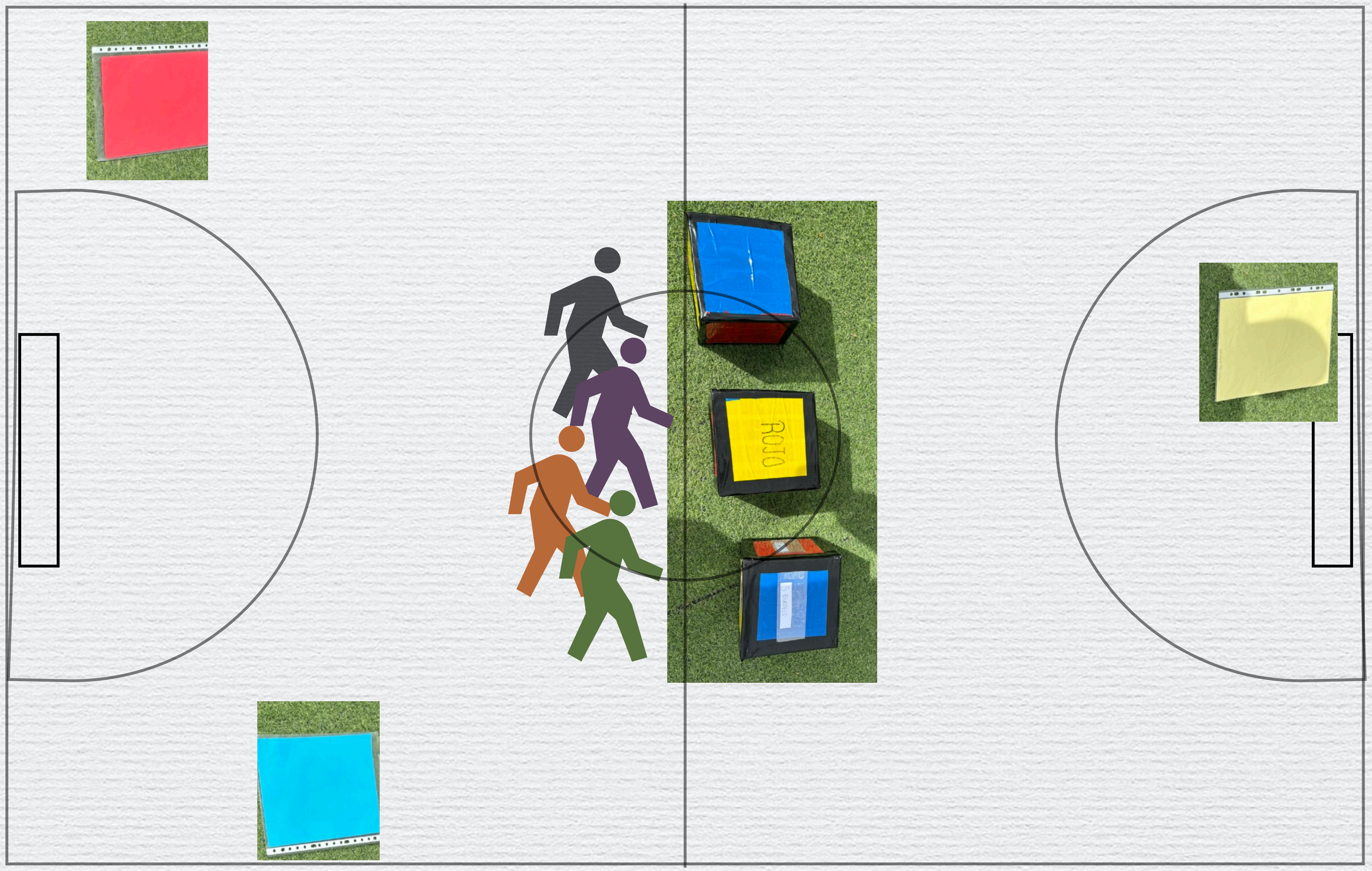
Game: "Fitness Confusion"



Roll the 3 dice at the same time and react faster than the opponents

Fetch the missing color (blue, red, yellow) or performe the fitness activity

1) **Dice 1:** Colours
2) **Dice 2:** Words with misleading background colour.
3) **Dice 3:** Fitness activities (only performed when dice 1 and 2 match).

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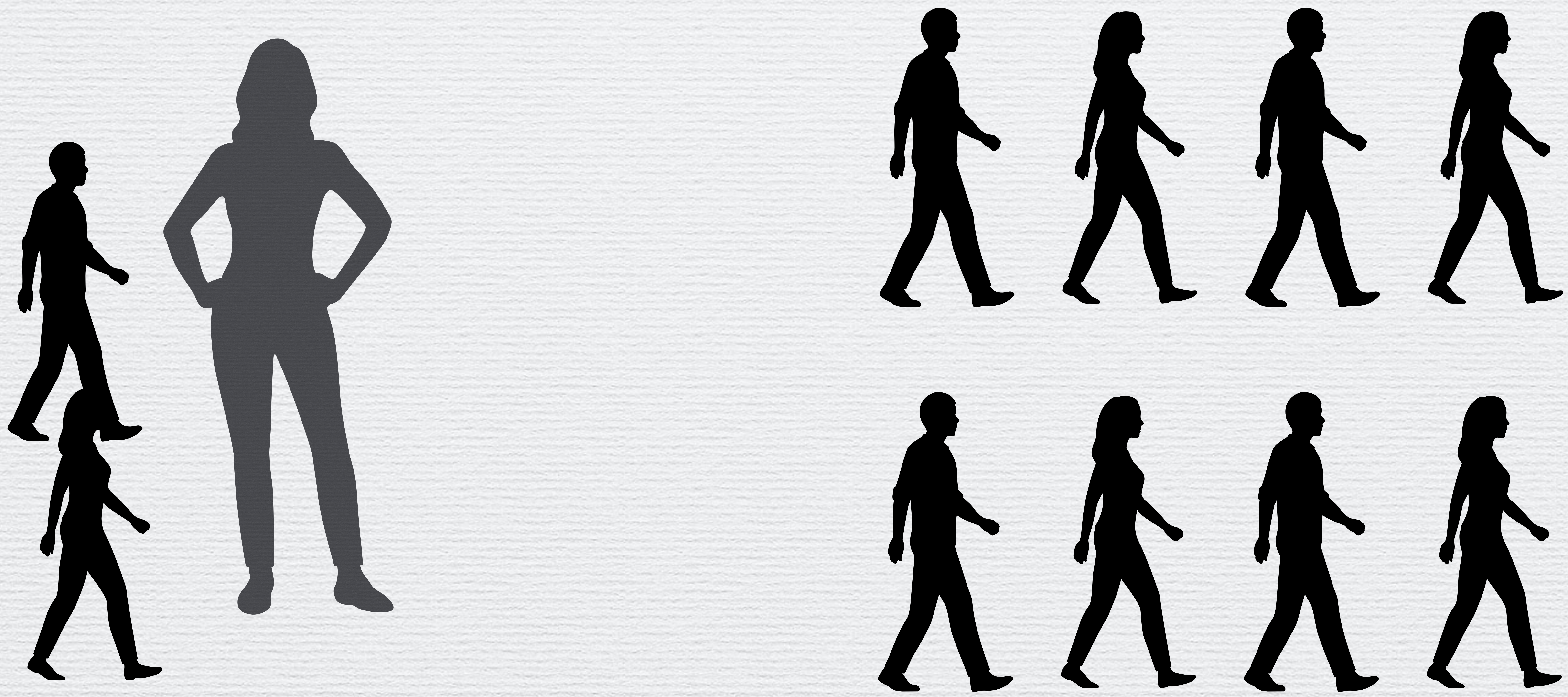
Game: "Mimic broken telephone"



1) Choreography
2) Choreography + sentence
3) Choreography + sentence + shape

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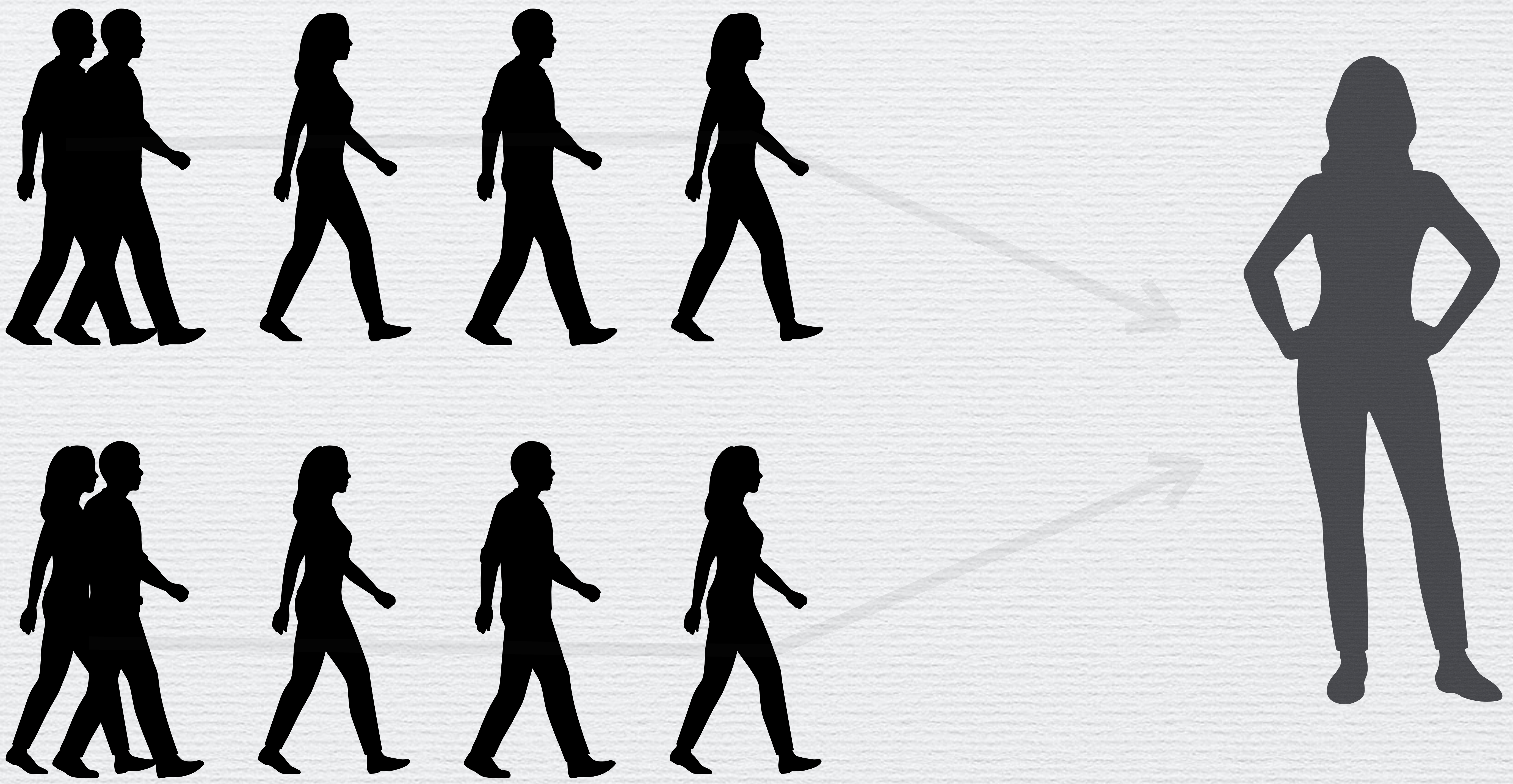
Game: "Mimic broken telephone"



1) Choreography
2) Choreography + sentence
3) Choreography + sentence + shape

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AI apps

Home court

Active Arcade

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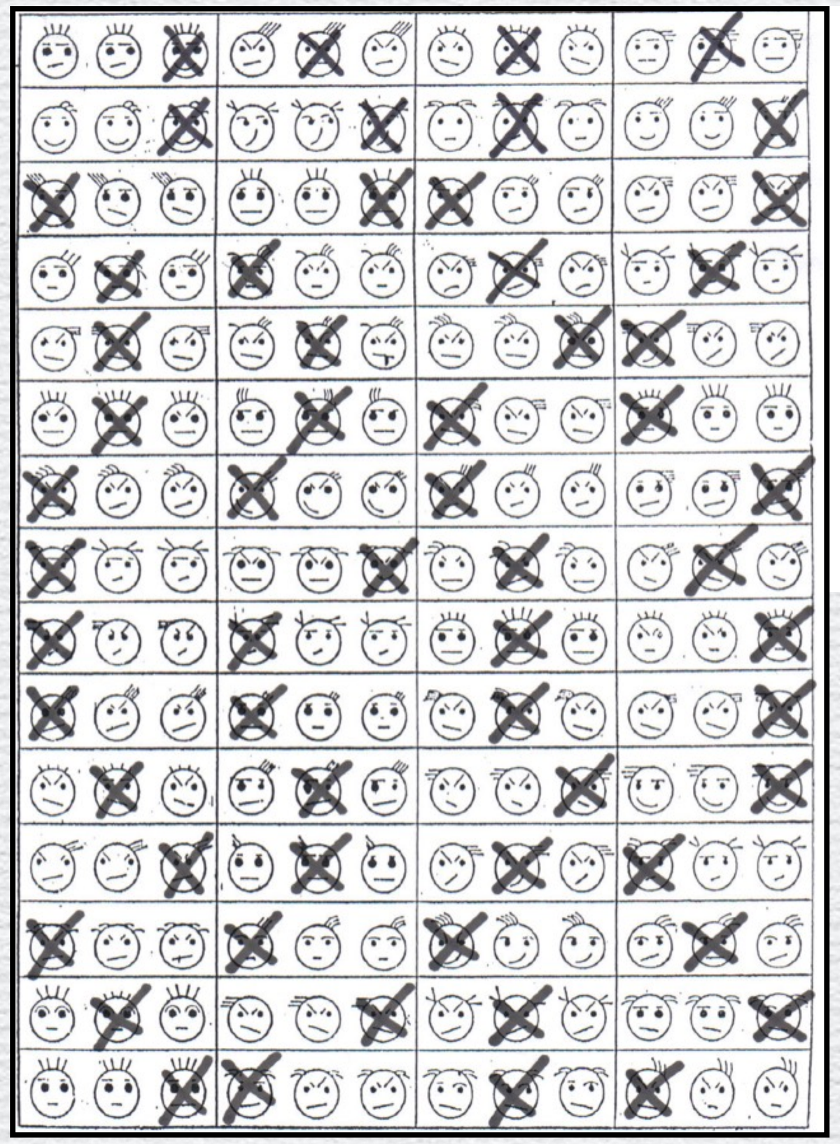
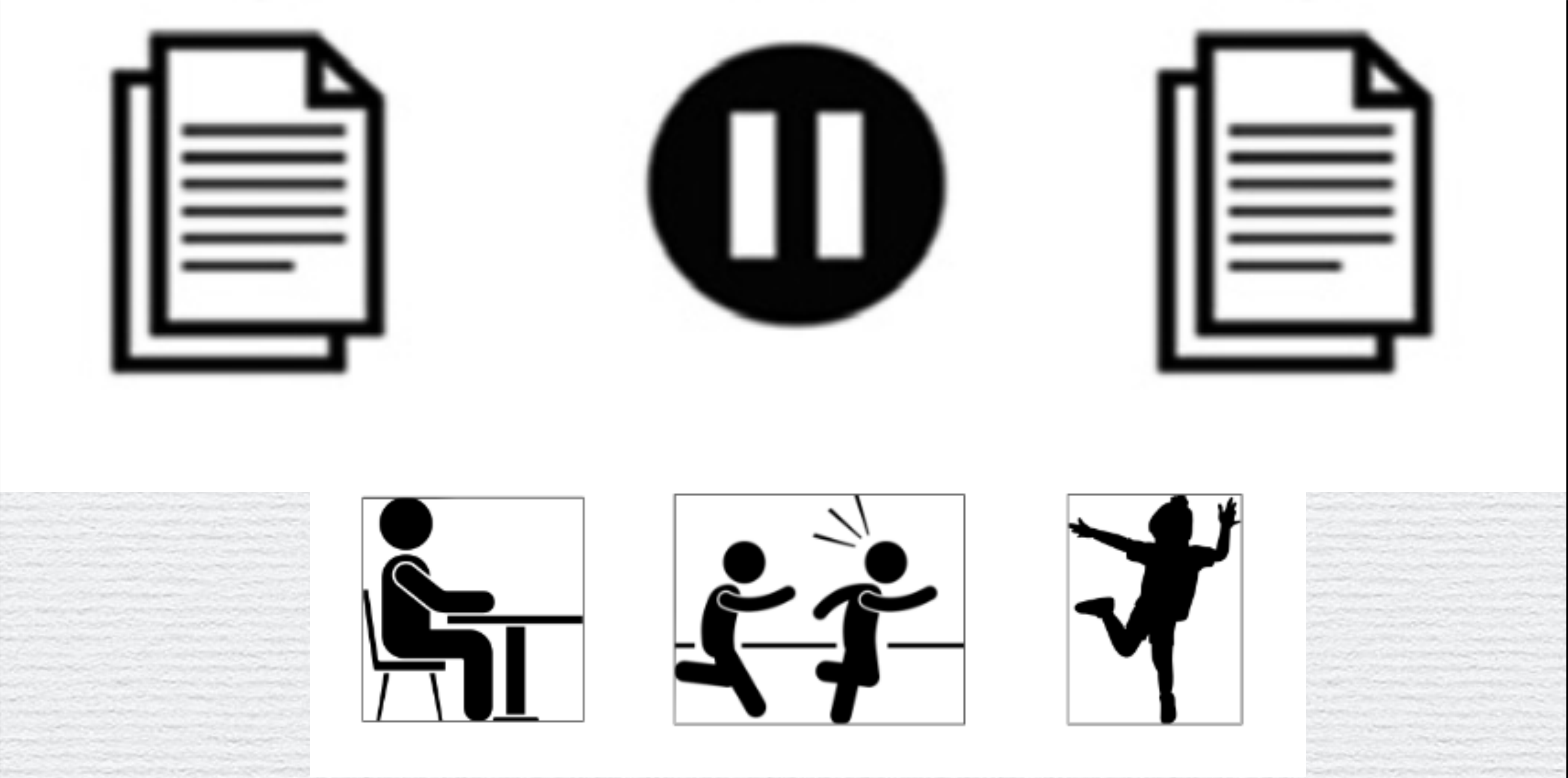
Cross-sectional Quasi-experimental design

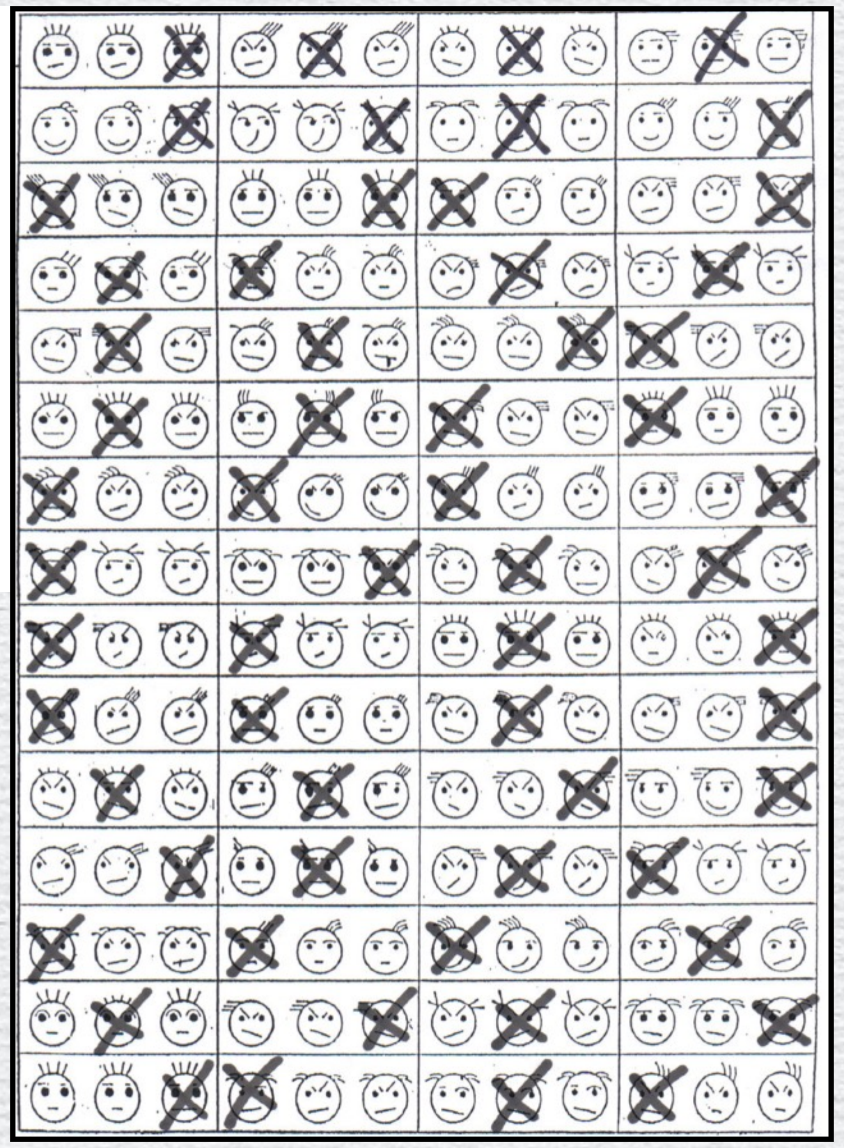
Test (3')

Active Break (10')

Test (3')







Rest no PA

Outdoor tag-games

Indoor fitness and dance with video

Perception Test Similarities and Differences or FACES.

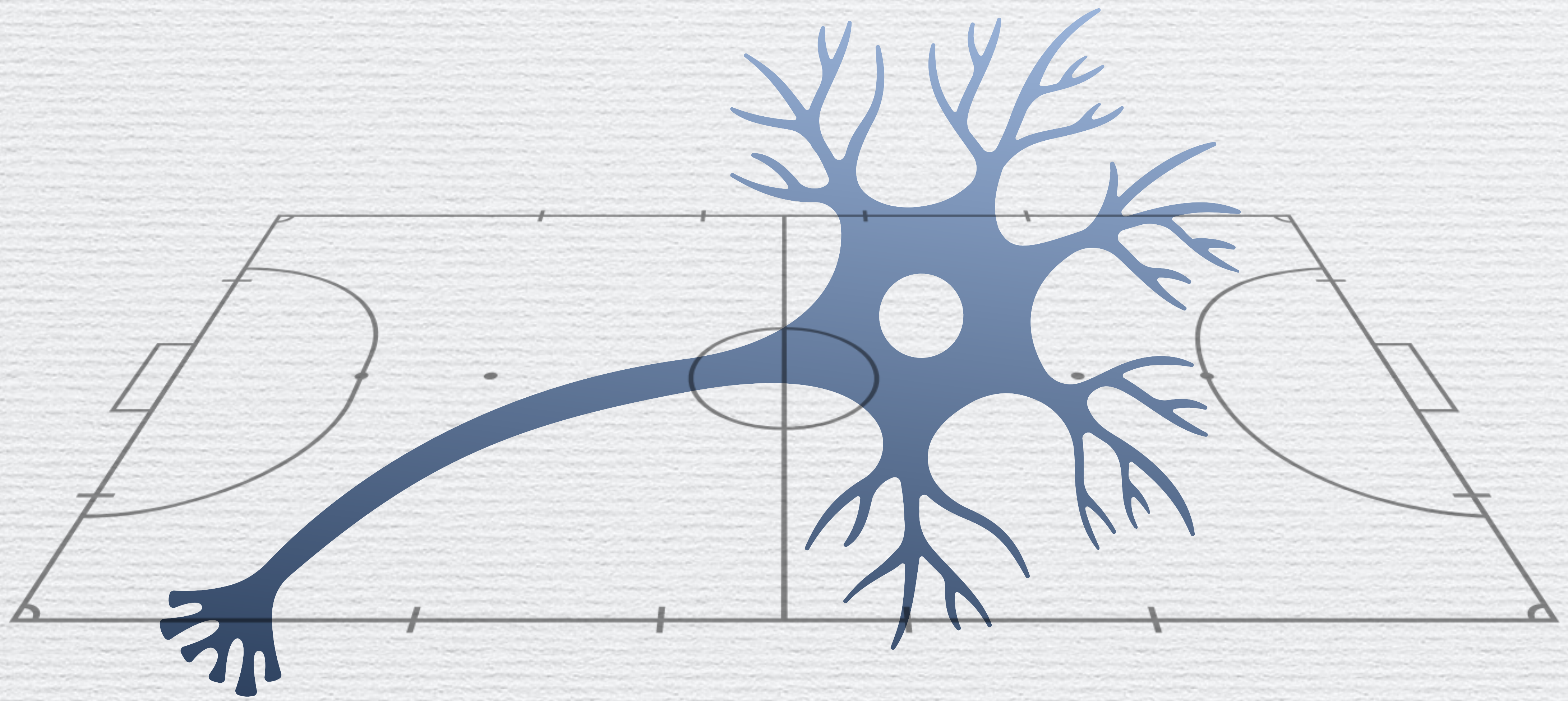
Thurstone y Yela, 2012

What's for?

FACES test assesses cognitive flexibility and visual perception by requiring test-takers to identify similarities and differences between various facial features presented to them. This ability is crucial for effective problem-solving and adaptive thinking in everyday life.

Brain and Physical Activity

From conceptual frameworks to the playground



Invited lecture at
(April 2024)

universität
innsbruck

Prof. Juanjo Pérez Soto, PhD

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