Innovations in technology and IT solutions for cognition in relation to falls

"Harnessing the Power of Neural Networks"

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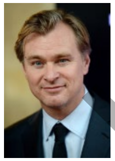
Swiss Federal Institute of Technology Zurich

"When you play a videogame, you could be a completely different person than you are in the real world, certain aspects of the way your brain works can be leveraged for something you could never do in the real world."

Christopher Nolan

https://de.wikipedia.org/wiki/Christopher_Nolan



[1] Theoretical relevance of VR approaches / «why would we care for neuromuscular control & healthy aging in an aging society?»

– *Focus on **brain, gait & falls***

[2] Important mobility components of aging populations

– *Muscle Strength, Gait Speed, Gait Variability & Executive Function*

[3] How should/could interventions be designed?

– *Exergames and physical and cognitive functioning*

➢ *understand the relation between cognitive and physical functions*
➢ *understand why we should train the brain to improve gait and prevent falls*
➢ *understand the rationale to use VR/Exergaming in aging populations*

HEALTHY AGING (WHO)

"*the process of developing and maintaining functional ability that enables well-being in older age*."[1]

TWO MAIN CONCEPTS[2]

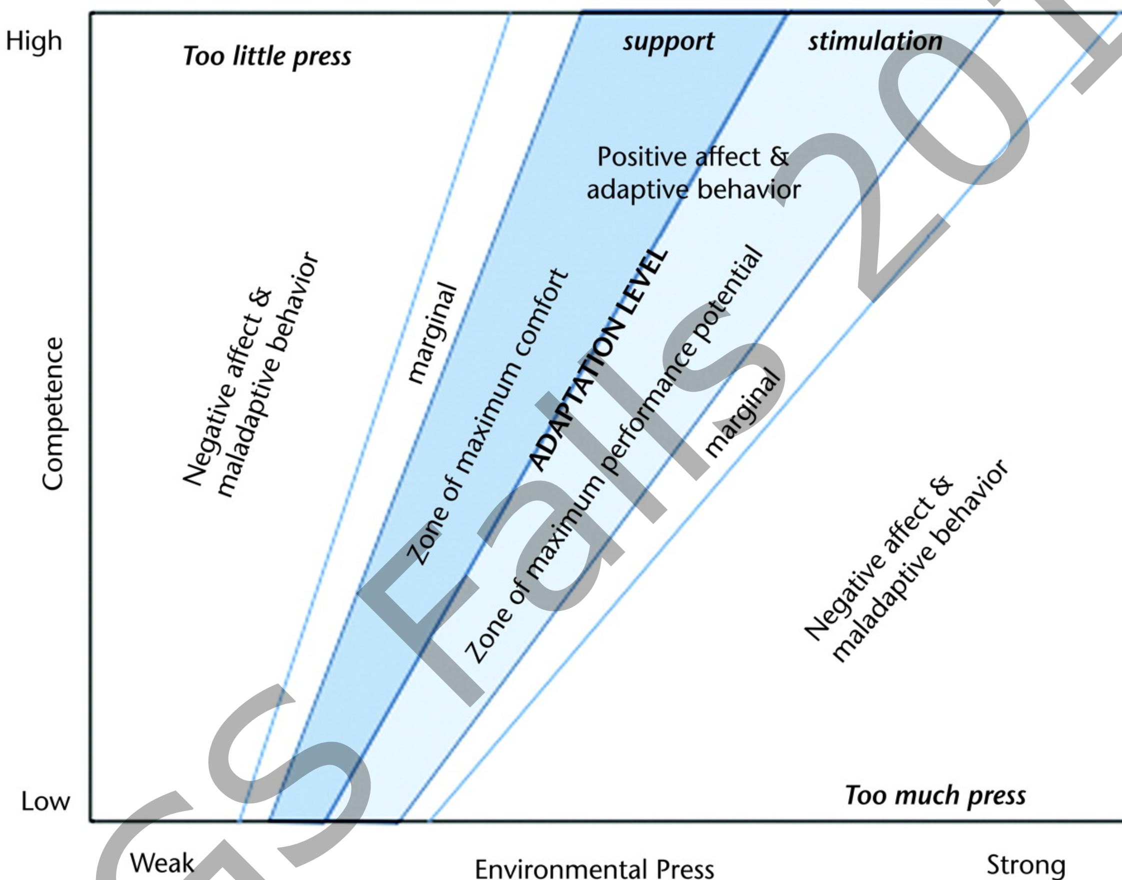
Intrinsic Capacity: "*the combination of the individual's physical and mental – including psychosocial – capacities*"

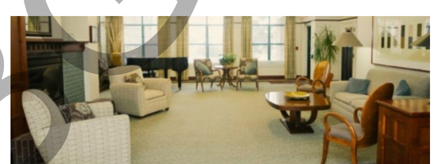
- *Mobility*, *Cognition*, *Vitality* (*Psycho-social*, neuro-sensorial), V*ision, Hearing*

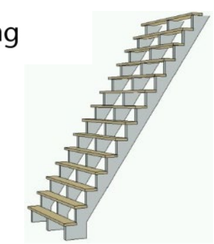
Functional Ability: "*having the capabilities that enable all people to be and do what they have reason to value.*"

[1] WHO Clinical Consortium on *Healthy Ageing* 2017 – report of consortium meeting 21 and 22 November 2017 in Geneva, Switzerland. Geneva: World Health Organization; 2018. Licence: CC BY-NC-SA 3.0 IGO. [2] http://www.aging-news.net/w-h-o-world-health-organization-program-on-maintaining-intrinsic-capacities-with-aging/

Environmental gerontology: Lawton's press-competence model.

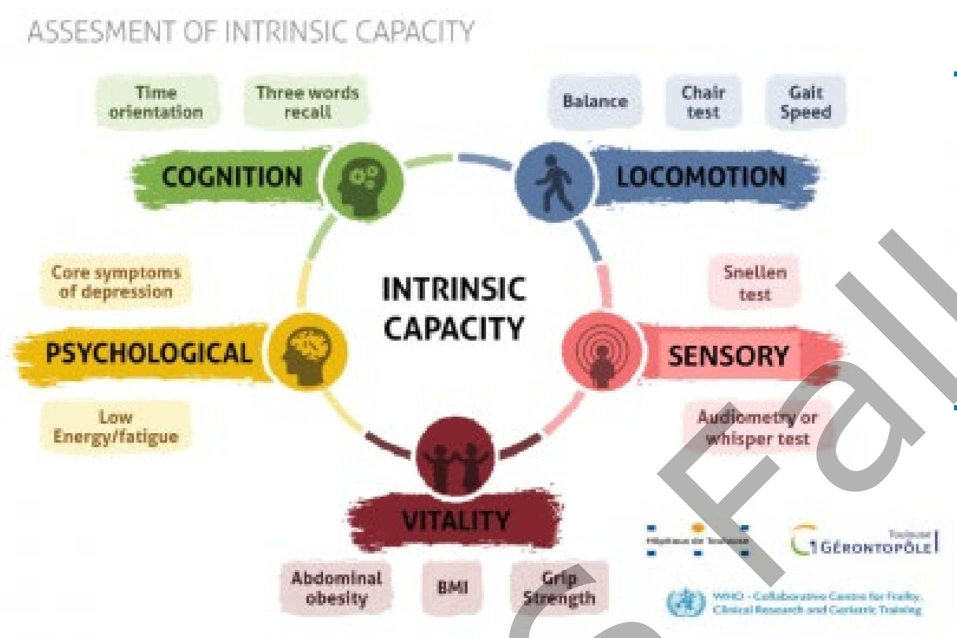






Lawton MP, Nahemow L. Ecology and the aging process. In: Eisdorfer C, Lawton MP, eds. *The Psychology of Adult Development and Aging*. Washington, DC: American Psychological Association; 1973.

INTRINSIC CAPACITY VS. (PHYSICAL) FITNESS



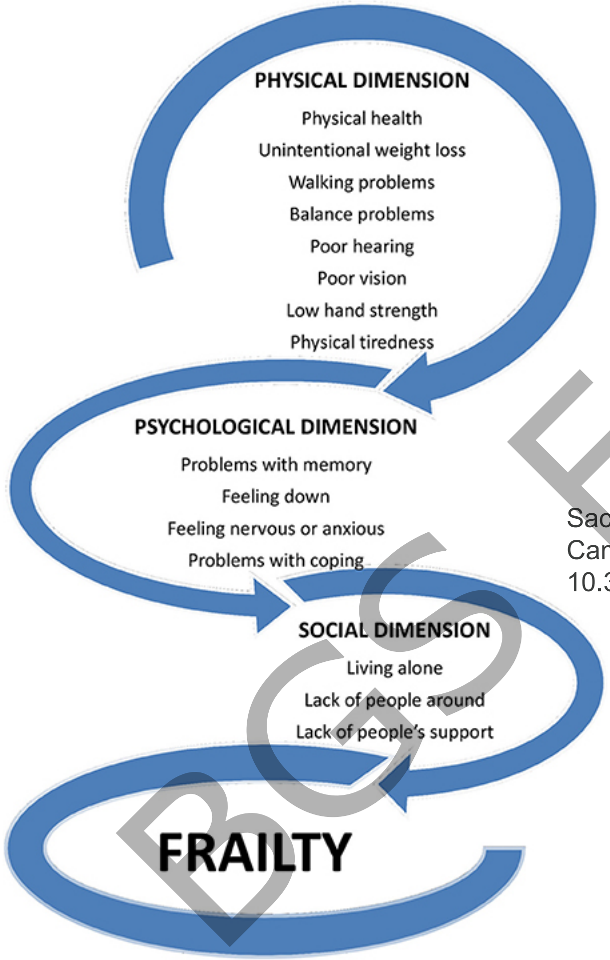
- Health related
  - Cardio-respiratory & muscle endurance, muscle strength, body composiotion, flexibility
- Skill related
  - Agility, balance, coordination, speed, power, reaction time

http://www.aging-news.net/w-h-o-world-health-organization-program-on-maintaining-intrinsic-capacities-with-aging/

Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public Health Rep. **1985**;100(2):126-31.

NEUROMUSCULAR CONTROL

– "involves the detection, perception, and utilization of relevant sensory information in order to perform specific tasks"



Multidimensional concept of frailty integrating various domains of human functioning that, by interaction, may accelerate frailty development

Sacha J, Sacha M, Soboń J, Borysiuk Z and Feusette P (2017) Is It Time to Begin a Public Campaign Concerning Frailty and Pre-frailty? A Review Article. *Front. Physiol*. 8:484. doi: 10.3389/fphys.2017.00484

Video capture of the circumstances of falls in elderly people residing in long-term care: an observational study

Stephen N Robinovitch*, Fabio Feldman*, Yijian Yang, Rebecca Schonnop, Pet Ming Lueng, Thiago Sarraf, Joanie Sims-Gould, Marie Loughin

www.thelancet.com Published online October 17, 2012 http://dx.doi.org/10.1016/S0140-6736(12)61263-X

Impairment in sensory filtering (e.g., longer time to characterize stimuli in working memory), presumed to explain the deficits in motor processes (i.e., selection of motor responses). Cognitive working memory changes in aging lead to slowing down of motor response selection.

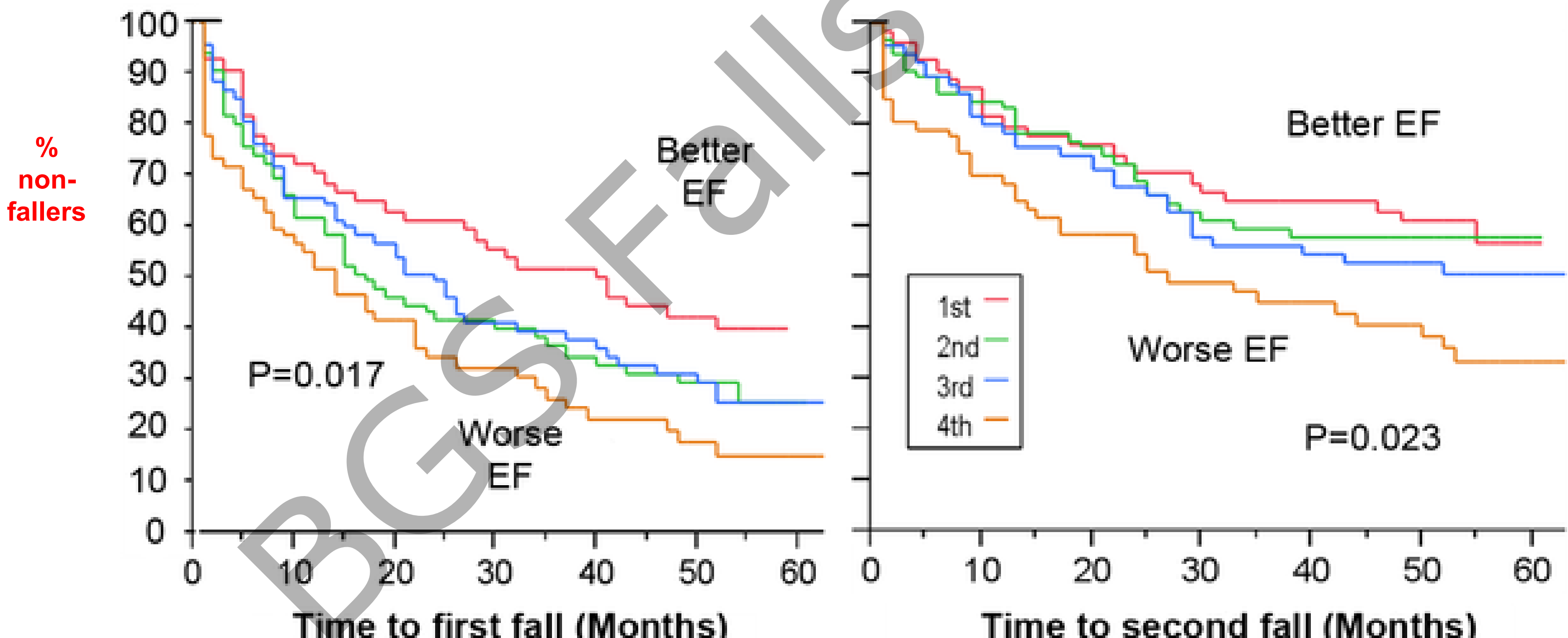
Cid-Fernandez et al. (2014). Front. Hum. Neurosci. 8:745. doi: 10.3389/fnhum.2014.00745

Journal of Gerontology: MEDICAL SCIENCES

Executive Control Deficits as a Prodrome to Falls in Healthy Older Adults: A Prospective Study Linking Thinking, Walking, and Falling

Talia Herman,[1] Anat Mirelman,[1,2] Nir Giladi,[1,3] Avraham Schweiger,[4,5] and Jeffrey M. Hausdorff[1,2,6]

Conclusions. Among healthy older adults, individuals with poorer EF are more prone to falls. Higher-level cognitive functions such as those regulated by the frontal lobes are apparently needed for safe everyday navigation that demands multi-tasking. Optimal screening, early detection, and treatment of falls should, apparently, also target this cognitive domain.



Mirelman et al. 2012, PLoS ONE 7(6): e40297

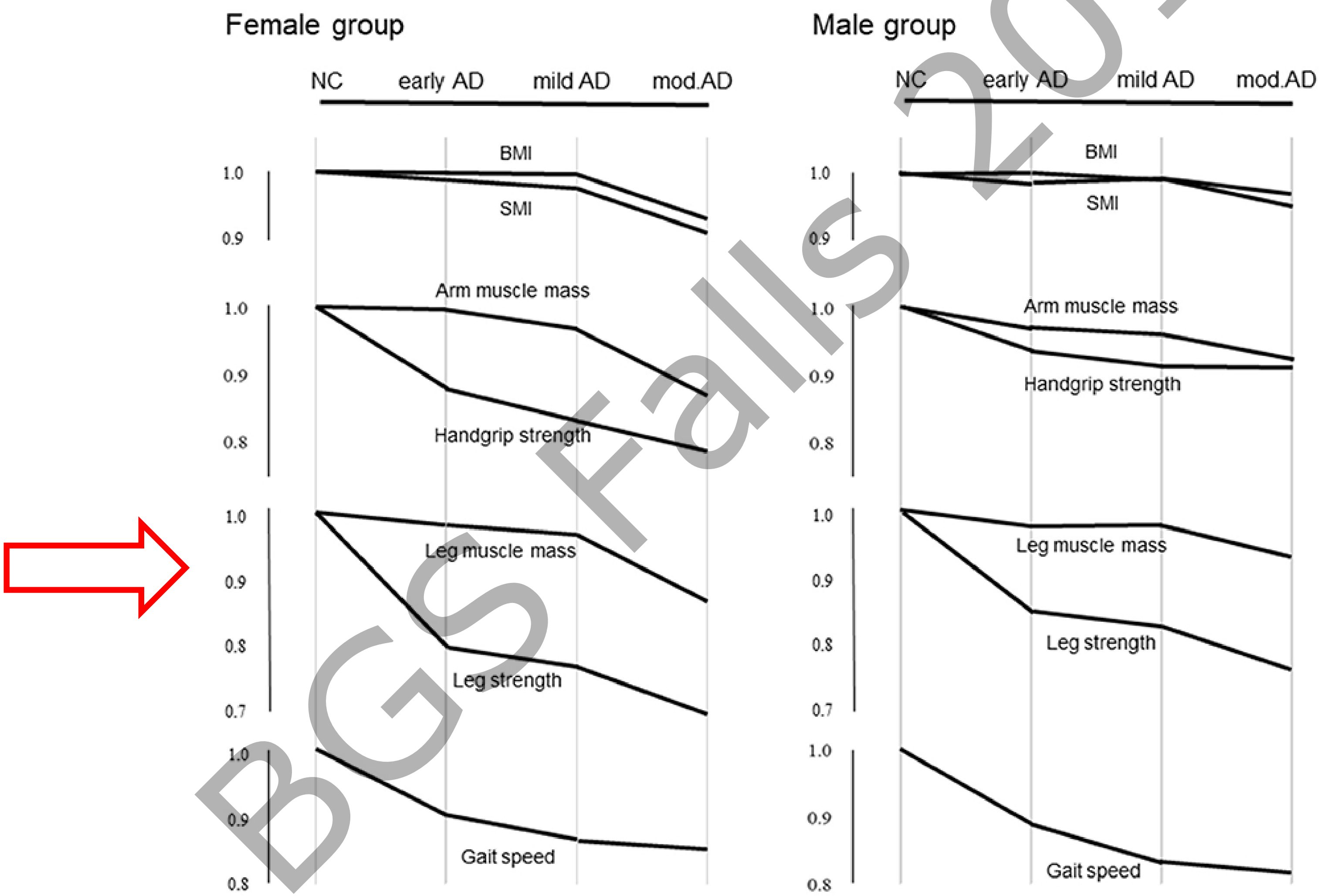
Brian C. Clark, Todd M. Manini, Sarcopenia ≠ Dynapenia, *The Journals of Gerontology: Series A*, Volume 63, Issue 8, August 2008, Pages 829–834

- **There is no equivalence between muscle mass and strength**
  - *longitudinal aging studies indicate a disassociation between the loss of muscle mass and strength*
  - *the changes in muscle mass and in strength resulting from altered physical activity levels (i.e., exercise training or disuse) do not follow the same time course*
- Thus, **adaptations in other properties in the human neuromuscular system must be involved in the regulation of strength**
- mechanisms accounting for ▲ or ▼ in strength can arise from neurological and skeletal muscle factors
- potential sites that can affect maximal voluntary force output:
  - *excitatory drive from supraspinal centers, α-motoneuron excitability, antagonistic muscle activity, motor unit recruitment and rate coding, neuromuscular transmission, muscle mass, E-C coupling processes, and muscle morphology and architecture*

ORIGINAL RESEARCH ARTICLE
Front. Neurol., 28 August 2018 | https://doi.org/10.3389/fneur.2018.00710

Sarcopenia and Muscle Functions at Various Stages of Alzheimer Disease

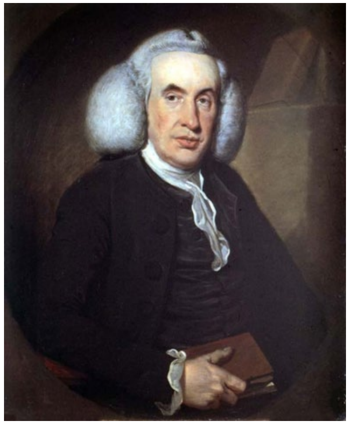
Yusuke Ogawa, Yoshitsugu Kaneko, Tomohiko Sato, Soichiro Shimizu, Hidekazu Kanetaka and Haruo Hanyu*



William Cullen (1710-1790; from *Institutions of Medicine, Pt.*)

Sensation and volition, so far as they are connected with corporeal motions, are functions of the brain alone...the will operating in the brain only, by a motion begun there, and propagated along the nerves, produces the contraction of the muscles.

https://en.wikipedia.org/wiki/William_Cullen



IS MUSCLE STRENGTH LOSS CAUSED BY FAILING EFFICIENCY OF BRAIN-MUSCLES COMMUNICATION (E.G. A NEUROGENIC DRIVEN SYNDROME)?

Brain (Transmitter

Structural Δs:
Cortex Atrophy, Degen. / Slowed Regeneration of Pyramidal Neurons, Loss of Dopamine Neurons

Functional Δs:
▲ variability motor performance, reduced neuroplasticity, impaired sensorimotor integration, ▼ cortico-cortico connectivity, ▼ descending command, ▲ neural noise, etc.

Peripheral nervous system

Degeneration of Motoneurons, Slowed Axonal Regeneration, Neuromuscular Junction Remodeling

Slowed Nerve Conduction, Neuromusc. Junction Transmission Failure, ▼ Myelin Expression, Chronic Inflammation & Oxidative Stress, etc.

Skeletal muscle (receiver)

Manini, T. M., Hong, S. L., & Clark, B. C. (2013). Aging and muscle: a neuron's perspective. *Current opinion in clinical nutrition and metabolic care*, *16*(1), 21–26.

Clark, B. C., & Taylor, J. L. (2011). Age-related changes in motor cortical properties and voluntary activation of skeletal muscle. *Current aging science*, *4*(3), 192–199.

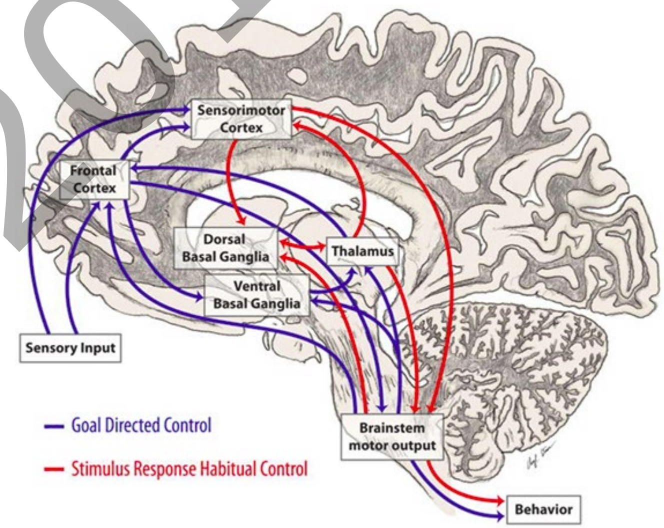
- *«Deficits in the neural drive can contribute to much of the muscle weakness observed in the very elderly – at least in the knee extensor muscles»*
- *«Clinically meaningful deficits in voluntary activation do exist in the knee extensors when a population of older adults is considered»*
- *«There is also evidence for a deficit in activation of the knee extensors, which are clinically important as the level of muscle strength has been linked to disability development and functional capacity»*

frontiers in Public Health
REVIEW
published: 25 May 2016
doi: 10.3389/fpubh.2016.00094

Thinking, Walking, Talking: Integratory Motor and Cognitive Brain Function

Gerry Leisman[1,2]*, Ahmed A. Moustafa[3] and Tal Shafir[4]

Motor control integrates both cortical and subcortical structures principally involving those connections between the basal ganglia and frontal lobes involved in automaticity of motor function and its cognitive mediation.



Front. Public Health
https://doi.org/10.3389/fpubh.2016.00094

Gait in the elderly is a **complex motor-cognitive task**

Attention, *executive functions* and *memory* are needed

de Bruin, E. D., & Schmidt, A. (2010). Walking behaviour of healthy elderly: attention should be paid. *Behavioral and Brain Functions, 6*. doi: 10.1186/1744-9081-6-59
Pichierri, G., Wolf, P., Murer, K., & de Bruin, E. D. (2011). Cognitive and cognitive-motor interventions affecting physical functioning: A systematic review. *Bmc Geriatrics, 11*. doi: 10.1186/1471-2318-11-29

Loss of white matter integrity is associated with gait disorders in cerebral small vessel disease

Karlijn F. de Laat,[1,*] Anil M. Tuladhar,[1,*] Anouk G. W. van Norden,[1] David G. Norris,[2] Marcel P. Zwiers[2,3] and Frank-Erik de Leeuw[1]

Brain 2011: 134; 73–83

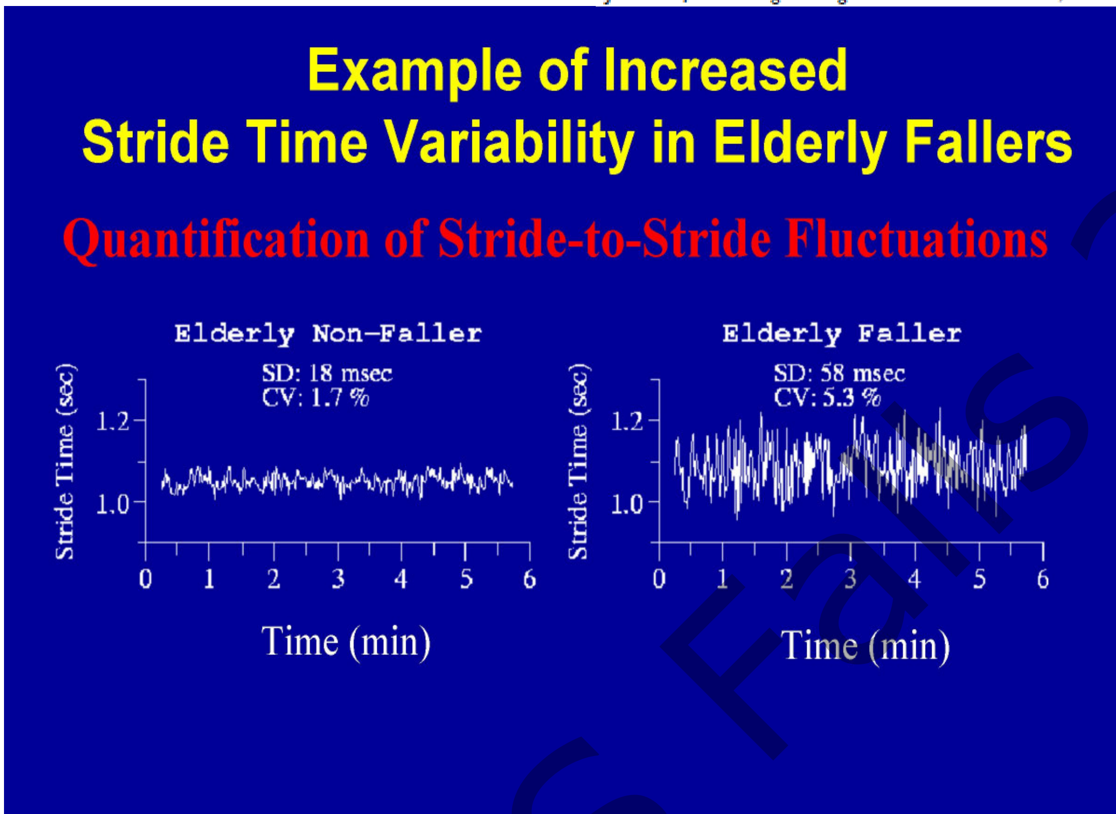
- *«.. in elderly subjects with small vessel disease, widespread disruption of white matter integrity, predominantly in the normal-appearing white matter, is involved in gait disturbances.*
- *In particular, loss of fibres interconnecting bilateral cortical regions, especially the prefrontal cortex that is involved in cognitive control on motor performance, may be important ..»*

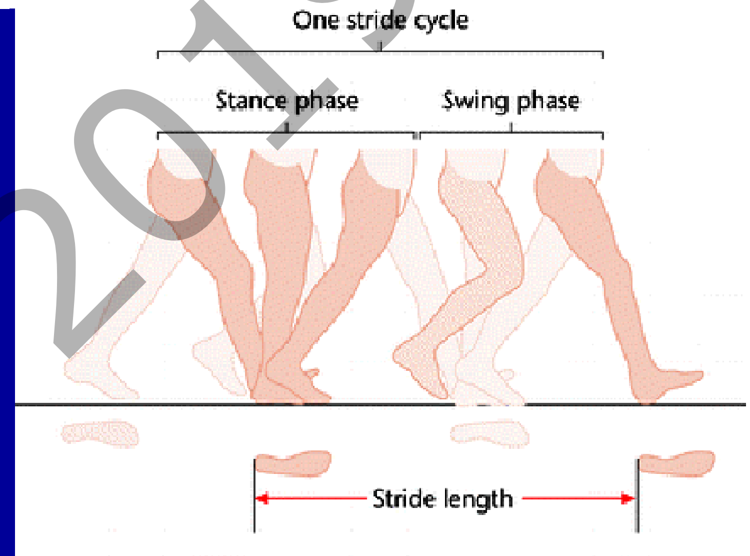
J Am Geriatr Soc. 2010 February ; 58(2): 275–281. doi:10.1111/j.1532-5415.2009.02699.x.

White Matter Hyperintensities Predict Functional Decline in Voiding, Mobility and Cognition in Older Persons

Dorothy B. Wakefield, MS[1], **Nicola Moscufo, PhD**[3], **Charles R. Guttmann, MD**[3], **George A. Kuchel, MD**[4], **Richard F. Kaplan, PhD**[2], **Godfrey Pearlson, MD**[5], and **Leslie Wolfson, MD**[1]

Journal of NeuroEngineering and Rehabilitation 2005, 2:19

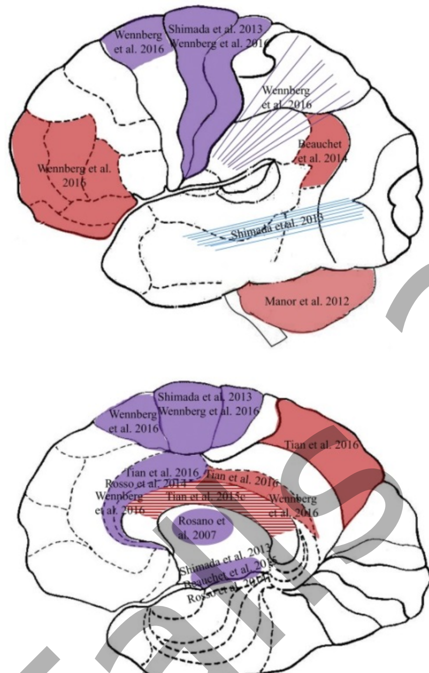




Upper threshold 2.6% - Lower threshold 1.1% for ***pathologic variability***

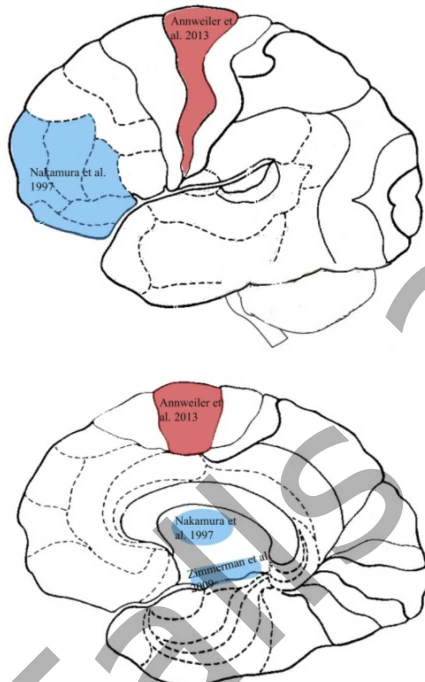
N. König et al. / Neuroscience and Biobehavioral Reviews 68 (2016) 111–119

The mean values of the stride time are essentially identical in both subjects, the magnitude of the stride-to-stride fluctuations is much larger in the faller.
SD: standard deviation; CV: coefficient of variation



The brain map of gait variabiliy in aging. Caption: Brain gray matter (solid fill) and white matter (line fill) on sagittal view of the lateral cortex (top) and the medial cortex (bottom), that are associated with temporal gait variability (red), spatial gait variability (purple)

Qu Tian, Nathalie Chastan, Woei-Nan Bair, Susan M. Resnick, Luigi Ferrucci, Stephanie A. Studenski. **The brain map of gait variability in aging, cognitive impairment and dementia—A systematic review.** Neuroscience & Biobehavioral Reviews, Volume 74, Part A, 2017, 149–162; http://dx.doi.org/10.1016/j.neubiorev.2017.01.020



The brain map of gait variability in cognitive impairment or dementia. Caption: Brain gray matter areas on sagittal view of the lateral cortex (top) and the medial cortex (bottom), that are associated with temporal gait variability (red) and spatial gait variability (blue)

Qu Tian, Nathalie Chastan, Woei-Nan Bair, Susan M. Resnick, Luigi Ferrucci, Stephanie A. Studenski. **The brain map of gait variability in aging, cognitive impairment and dementia—A systematic review.** Neuroscience & Biobehavioral Reviews, Volume 74, Part A, 2017, 149–162; http://dx.doi.org/10.1016/j.neubiorev.2017.01.020

New Technologies & Neuroplasticity: VR / Exergames

NZZ, 9.5.2016

«*Use dependent plasticity*»: Practicing movements results in improvement in performance and in plasticity of the motor cortex. Non-practicing gives the opposite effect!

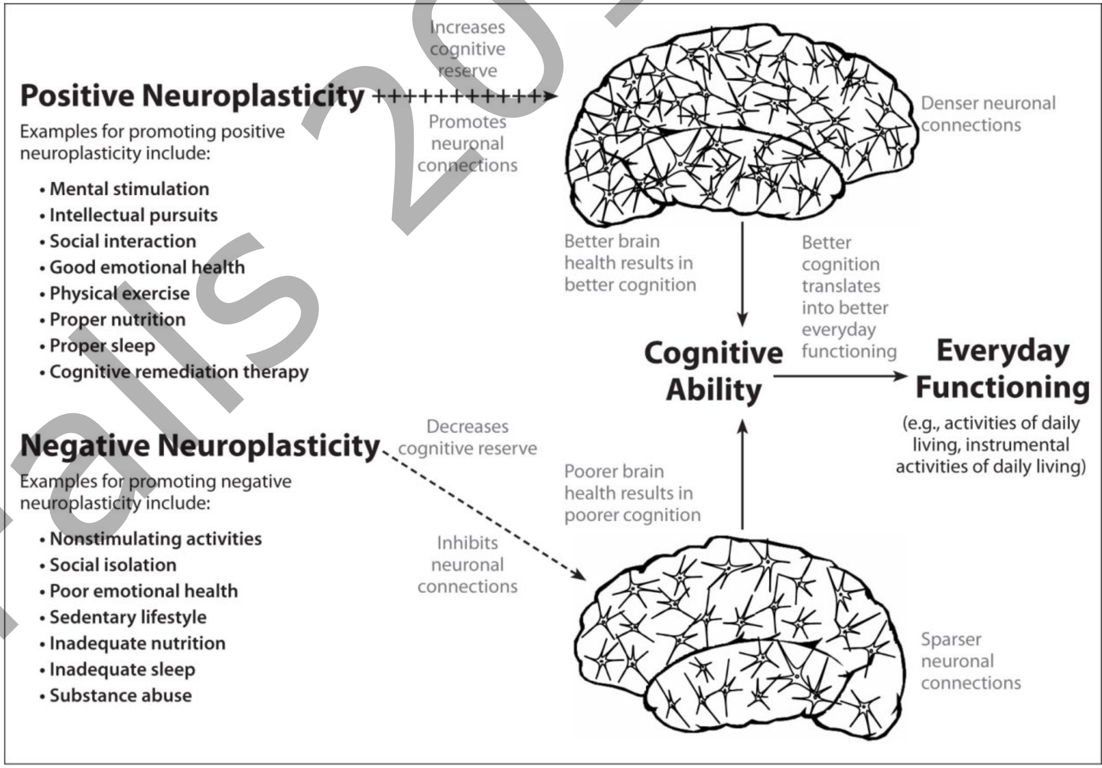
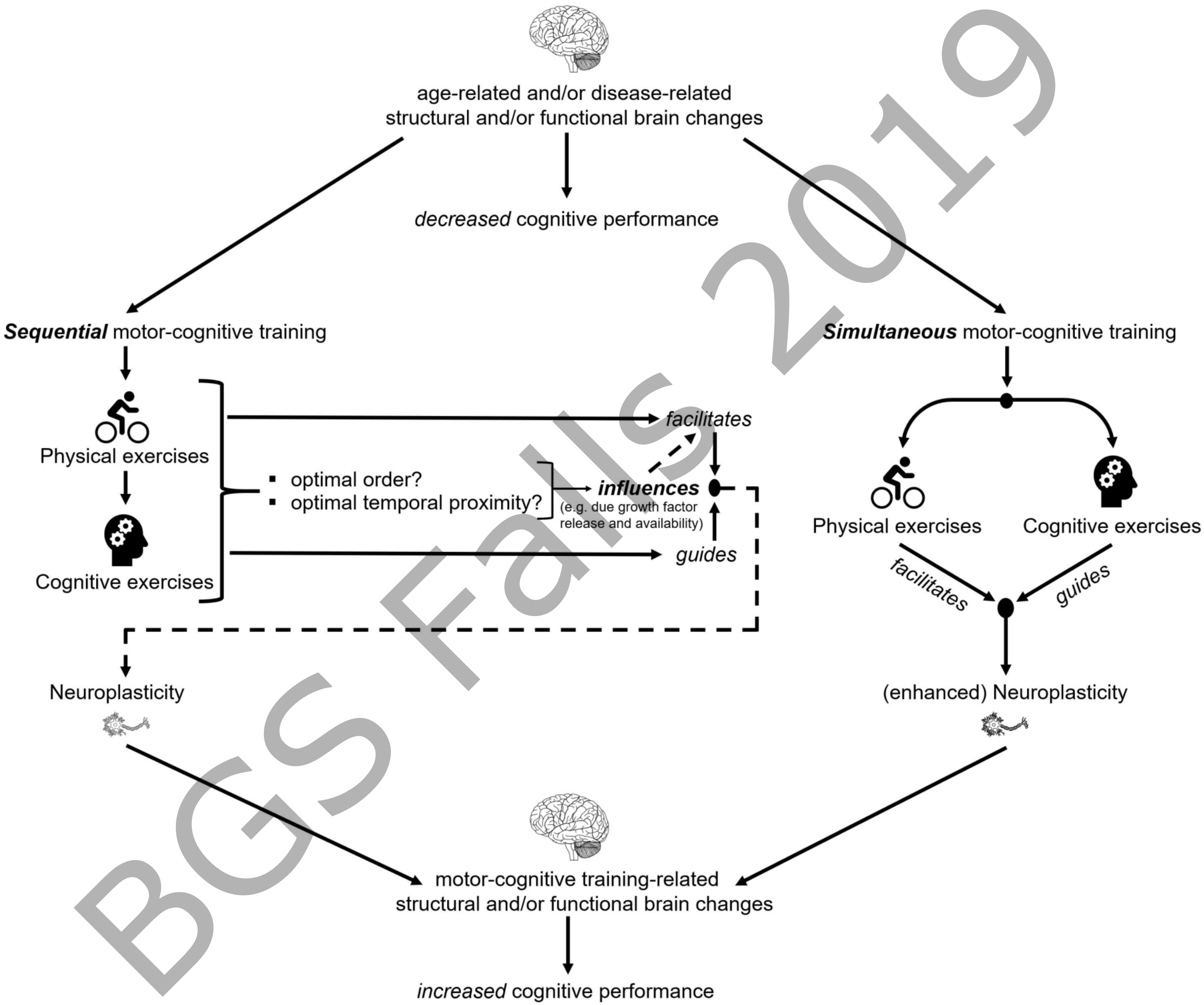
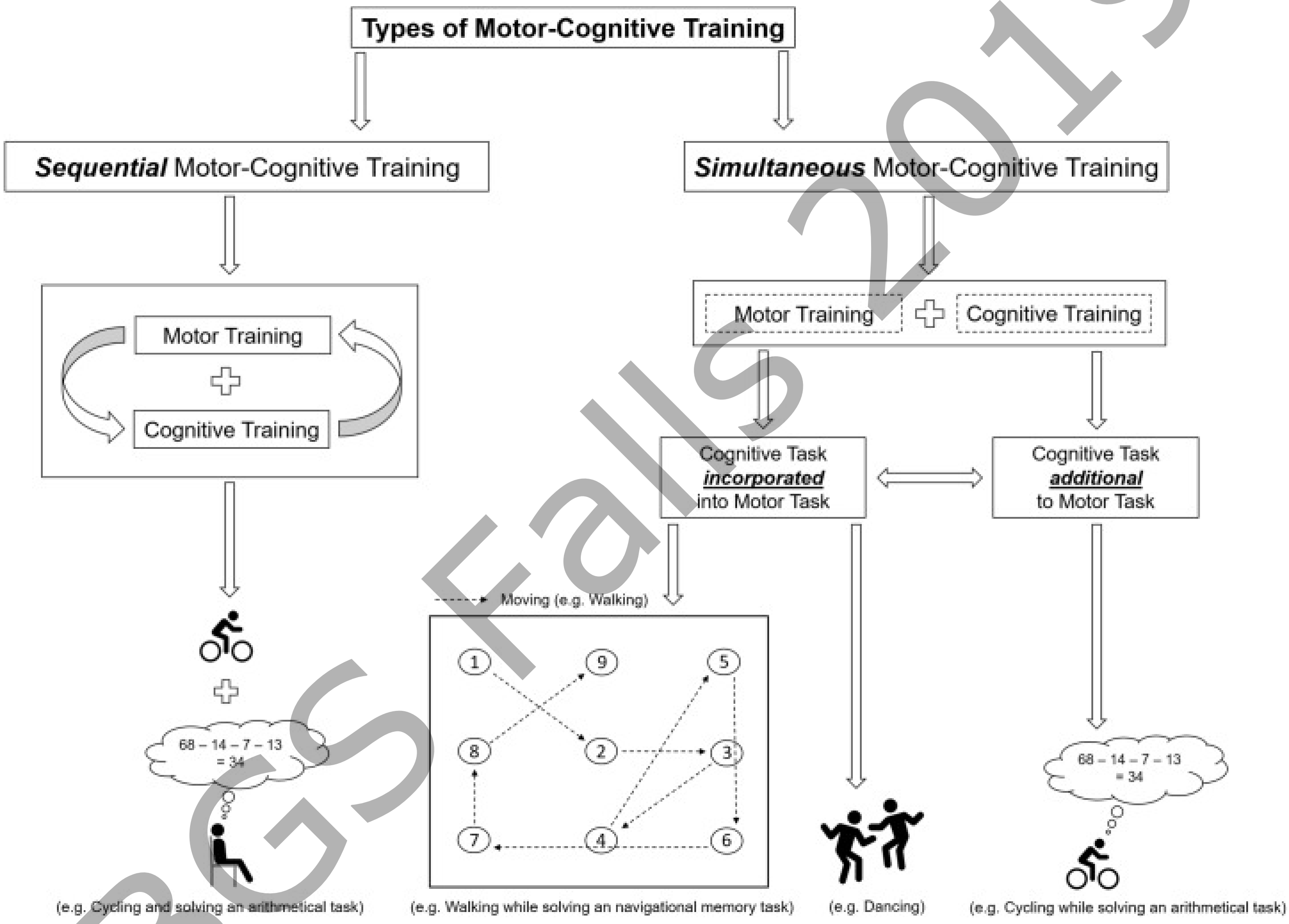


Figure. Methods of promoting positive and negative neuroplasticity.

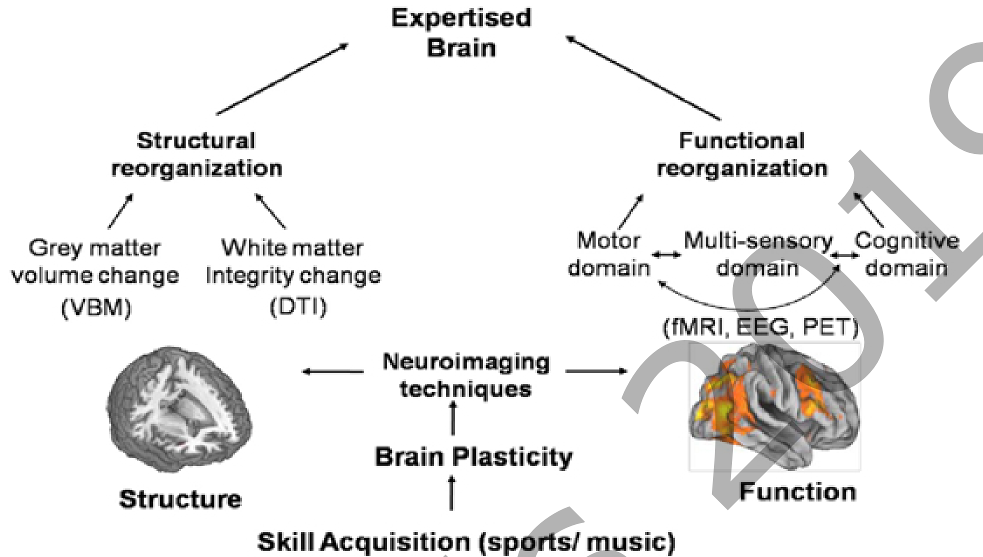
“Guided plasticity facilitation” framework



Herold, F., Hamacher, D., Schega, L., & Müller, N. G. (2018). Thinking While Moving or Moving While Thinking - Concepts of Motor-Cognitive Training for Cognitive Performance Enhancement. *Frontiers in aging neuroscience*, *10*, 228. doi:10.3389/fnagi.2018.00228



Herold, F., Hamacher, D., Schega, L., & Müller, N. G. (2018). Thinking While Moving or Moving While Thinking - Concepts of Motor-Cognitive Training for Cognitive Performance Enhancement. *Frontiers in aging neuroscience*, *10*, 228. doi:10.3389/fnagi.2018.00228



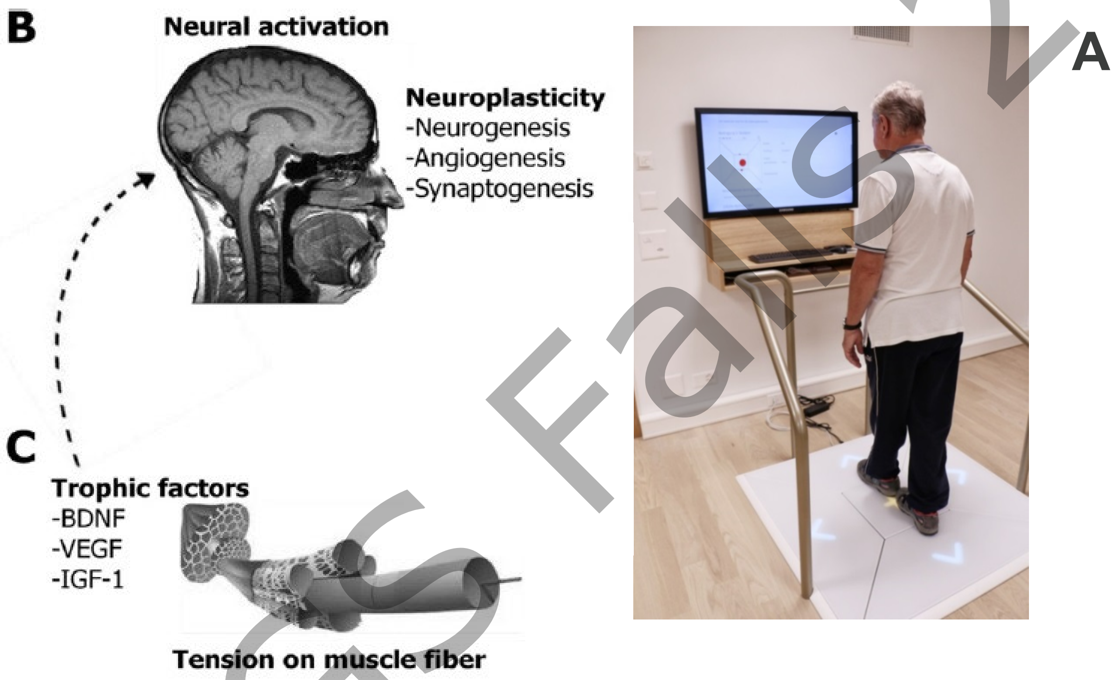
Front. Hum. Neurosci. 2014 | https://doi.org/10.3389/fnhum.2014.00035

VR = the use of computer technology to create a simulated environment

- *Your brain treats VR like a real life experience*
- *Real life experiences are the best way to learn and remember*
- *Experiences in VR help you learn better, remember more and improve*

(American College of Sports Medicine. “Exergaming.” ACSM.org . http://www.acsm.org/docs/brochures/exergaming.pdf (accessed February 24, 2017).)

«…technology-driven physical activities, such as video game play, that requires participants to be physically active or exercise in order to play the game»



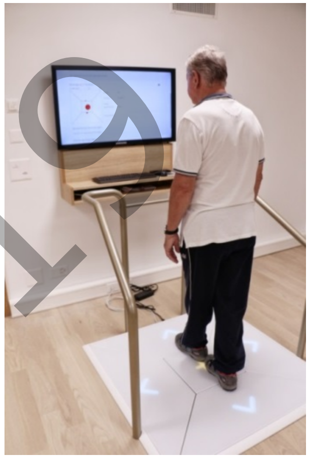
*(**A**) An individual playing exergame; (**B**) increases neural activation; (**C**) promotes a muscle fiber tension.*

Monteiro-Junior, R. S., Vaghetti, C. A., Nascimento, O. J., Laks, J., & Deslandes, A. C. (2016). Exergames: neuroplastic hypothesis about cognitive improvement and biological effects on physical function of institutionalized older persons. *Neural regeneration research*, *11*(2), 201–204.

Review article

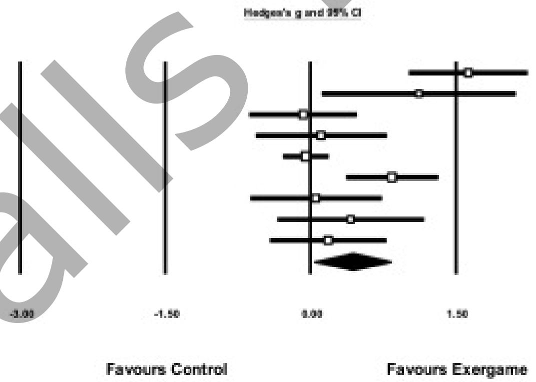
The effect of active video games on cognitive functioning in clinical and non-clinical populations: a meta-analysis of randomized controlled trials

Emma Stanmore[a], Brendon Stubbs[b, c], Davy Vancampfort[d, e], Eling D. de Bruin[f], Joseph Firth[g]



www.dividat.ch

Study name	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value	Exergame	Control
	Statistics for each study							Sample size	
Anderson-Hanley 2012	1.628	0.312	0.098	1.016	2.240	5.214	0.000	38	41
Barcelos 2015	1.118	0.509	0.259	0.119	2.116	2.194	0.028	8	9
Eggenberger 2015	-0.078	0.283	0.080	-0.632	0.476	-0.277	0.781	24	25
Eggenberger 2016	0.109	0.344	0.118	-0.565	0.783	0.316	0.752	19	14
Mitelman 2016	-0.051	0.119	0.014	-0.284	0.182	-0.425	0.671	146	136
Park 2015	0.841	0.243	0.059	0.364	1.318	3.454	0.001	36	36
Pompeu 2012	0.055	0.345	0.119	-0.620	0.731	0.160	0.873	16	16
Schattin 2016	0.413	0.384	0.148	-0.340	1.166	1.076	0.282	13	14
Simsek 2015	0.181	0.304	0.092	-0.414	0.777	0.597	0.550	20	22
	0.435	0.201	0.040	0.042	0.829	2.169	0.030	320	312



Meta-analysis showing effects of exergame interventions on global cognition in comparison to physically-active control conditions. Box size represents study weighting. Diamond represents overall effect size and 95% confidence intervals.

Domain-specific analyses found exergames improved executive functions, attentional processing and visuospatial skills.

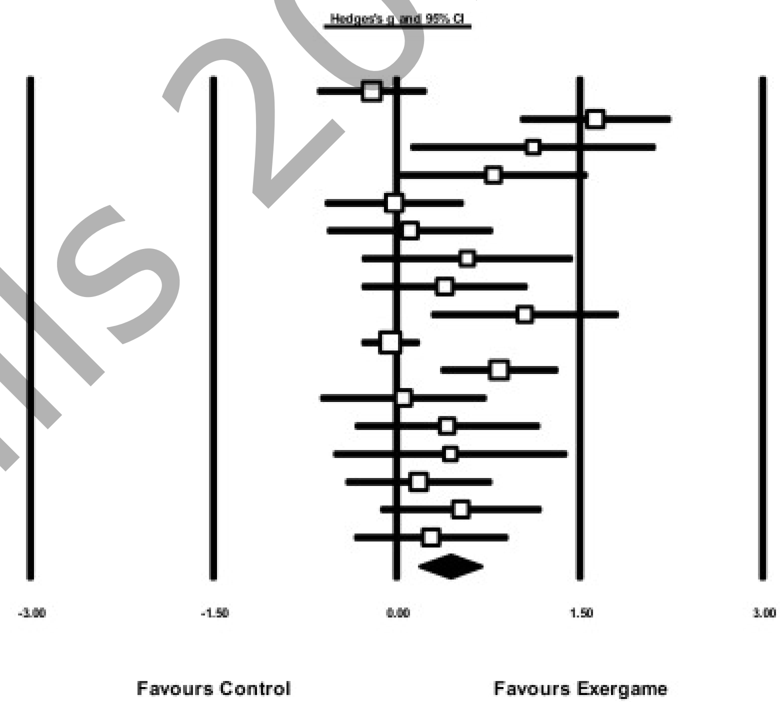
Neuroscience & Biobehavioral Reviews, 2017, Available online 23 April 2017; http://dx.doi.org/10.1016/j.neubiorev.2017.04.011

Review article

The effect of active video games on cognitive functioning in clinical and non-clinical populations: a meta-analysis of randomized controlled trials

Emma Stanmore[a], Brendon Stubbs[b, c], Davy Vancampfort[d, e], Eling D. de Bruin[f], Joseph Firth[g]

Study name	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value	Exergame	Control
	Statistics for each study							Sample size	
Ackerman 2010	-0.202	0.226	0.051	-0.645	0.240	-0.896	0.370	39	39
Anderson-Hanley 2012	1.628	0.312	0.098	1.016	2.240	5.214	0.000	38	41
Barcelos 2015	1.118	0.509	0.259	0.119	2.116	2.194	0.028	8	9
Chan 2010	0.794	0.391	0.153	0.028	1.560	2.033	0.042	12	15
Eggenberger 2015	-0.019	0.288	0.083	-0.583	0.545	-0.065	0.948	24	24
Eggenberger 2016	0.109	0.344	0.118	-0.565	0.783	0.316	0.752	19	14
Hughes 2014	0.580	0.438	0.192	-0.278	1.439	1.324	0.185	10	10
Kimhy 2015	0.393	0.343	0.118	-0.279	1.066	1.146	0.252	16	17
Maillot 2012	1.050	0.389	0.151	0.288	1.812	2.700	0.007	15	15
Mirelman 2016	-0.051	0.119	0.014	-0.284	0.182	-0.425	0.671	146	138
Park 2015	0.841	0.243	0.059	0.364	1.318	3.454	0.001	36	36
Pompeu 2012	0.055	0.345	0.119	-0.620	0.731	0.160	0.873	16	16
Schattin 2016	0.413	0.384	0.148	-0.340	1.166	1.076	0.282	13	14
Schoene 2013	0.439	0.486	0.236	-0.514	1.392	0.904	0.366	15	17
Simsek 2015	0.181	0.304	0.092	-0.414	0.777	0.597	0.550	20	22
Staniano 2012	0.526	0.333	0.111	-0.127	1.179	1.579	0.114	18	18
Zimmermann 2014	0.281	0.320	0.103	-0.346	0.909	0.879	0.379	19	20
	0.436	0.129	0.017	0.184	0.688	3.391	0.001	464	462



Meta-analysis of exergames effects on global cognition in comparison to control conditions. Box size represents study weighting. Diamond represents overall effect size and 95% confidence intervals.

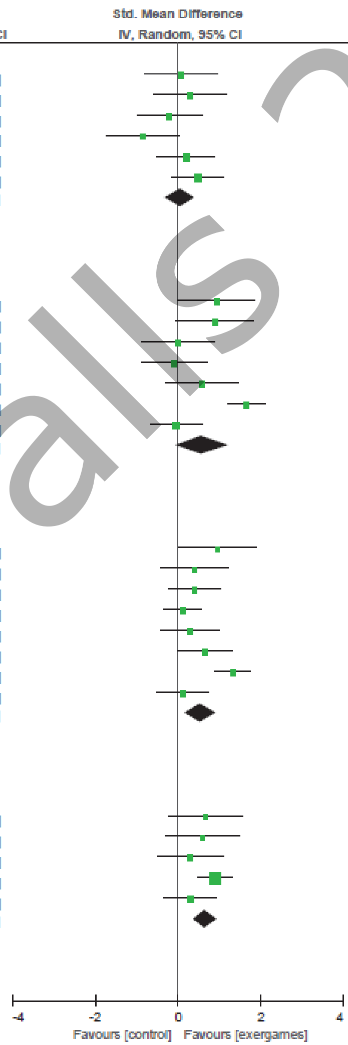
Neuroscience & Biobehavioral Reviews, 2017, Available online 23 April 2017; http://dx.doi.org/10.1016/j.neubiorev.2017.04.011

Active exergames to improve cognitive functioning in neurological disabilities: a systematic review and meta-analysis

Gioia MURA [1] *, Mauro G. CARTA [1], Federica SANCASSIANI [1], Sergio MACHADO [2, 3, 4], Luca PROSPERINI

European Journal of Physical and Rehabilitation Medicine 2018 June;54(3):450-62

Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
1.1.1 Global cognition								
Choi et al. 2014	25.8	3.5	10	25.5	3.3	10	13.8%	0.08 [-0.79, 0.96]
Hughes et al. 2014	27.4	5.1	10	25.4	7.6	10	13.6%	0.30 [-0.59, 1.18]
Hung et al. 2017	89	11.5	12	90.9	5	13	16.3%	-0.21 [-1.00, 0.58]
Padala et al. 2012	22.4	2.8	11	25.5	4.1	11	13.7%	-0.85 [-1.73, 0.03]
Pompeu et al. 2012	23.1	4.6	16	22.2	4.5	16	19.5%	0.19 [-0.50, 0.89]
Simsek et al. 2015	33.3	2.79	20	31.59	4.14	22	23.1%	0.47 [-0.14, 1.09]
Subtotal (95% CI)			79			82	100.0%	0.05 [-0.32, 0.41]
Heterogeneity: Tau² = 0.05; Chi² = 6.68, df = 5 (P = 0.25); I² = 25%								
Test for overall effect: Z = 0.26 (P = 0.80)								
1.1.2 Attention								
Choi et al. 2014	122.6	10.2	10	104.4	24.9	10	13.1%	0.92 [-0.02, 1.85]
Franceschini et al. 2013	-320	74	10	-402	100	10	13.1%	0.89 [-0.04, 1.82]
Hughes et al. 2014	0.04	0.02	10	0.04	0.02	10	13.5%	0.00 [-0.88, 0.88]
Hung et al. 2017	7.33	0.98	12	7.42	0.79	13	14.3%	-0.10 [-0.88, 0.69]
Prosperini et al. 2015	46.2	7.6	10	39.9	12.3	11	13.5%	0.58 [-0.29, 1.46]
Wuang et al. 2015	-50.4	3.2	52	-54.7	1.8	53	16.9%	1.65 [1.20, 2.09]
Zimmermann et al. 2014	-275	75.8	20	-272	41.7	19	15.6%	-0.05 [-0.68, 0.58]
Subtotal (95% CI)			124			126	100.0%	0.57 [-0.05, 1.19]
Heterogeneity: Tau² = 0.54; Chi² = 29.48, df = 6 (P < 0.0001); I² = 80%								
Test for overall effect: Z = 1.81 (P = 0.07)								
1.1.3 Executive functions (dual-task performance)								
Hughes et al. 2014	0.02	0.01	10	0.01	0.01	10	8.7%	0.96 [0.02, 1.89]
Hung et al. 2017	10.3	1.8	12	9.7	1.1	13	10.4%	0.39 [-0.40, 1.19]
Kramer et al. 2014	-59	38	21	-75	40	20	12.8%	0.40 [-0.22, 1.02]
Nilsagard et al. 2012	13.3	6.2	41	12.6	6.8	38	15.6%	0.11 [-0.33, 0.55]
Pompeu et al. 2012	26	20.3	16	20.3	19.8	16	11.7%	0.28 [-0.42, 0.97]
Rozental-Iluz et al. 2016	-130.8	67.3	20	-187.5	101.5	19	12.4%	0.65 [0.00, 1.29]
Wuang et al. 2015	-48.3	2.23	52	-51.8	2.98	53	15.8%	1.32 [0.89, 1.74]
Zimmermann et al. 2014	2.42	0.63	20	2.35	0.53	19	12.7%	0.12 [-0.51, 0.75]
Subtotal (95% CI)			192			188	100.0%	0.53 [0.16, 0.90]
Heterogeneity: Tau² = 0.18; Chi² = 20.08, df = 7 (P = 0.005); I² = 65%								
Test for overall effect: Z = 2.82 (P = 0.005)								
1.1.4 Perception (visuo-spatial abilities)								
Choi et al. 2014	128.5	11	10	121.3	9.7	10	9.6%	0.66 [-0.24, 1.57]
Franceschini et al. 2013	0.38	0.14	10	0.28	0.18	10	9.7%	0.59 [-0.31, 1.49]
Hung et al. 2017	17.5	0.8	12	17.2	1.1	13	12.6%	0.30 [-0.49, 1.09]
Wuang et al. 2015	71.38	6.65	52	66.2	4.6	53	48.5%	0.90 [0.50, 1.30]
Zimmermann et al. 2014	26.8	11.2	20	23.5	10.8	19	19.7%	0.29 [-0.34, 0.93]
Subtotal (95% CI)			104			105	100.0%	0.65 [0.37, 0.93]
Heterogeneity: Tau² = 0.00; Chi² = 3.49, df = 4 (P = 0.48); I² = 0%								
Test for overall effect: Z = 4.57 (P < 0.00001)								



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Review

Step training improves reaction time, gait and balance and reduces falls in older people: a systematic review and meta-analysis

Yoshiro Okubo[1,2], Daniel Schoene[3], Stephen R Lord[1,4]

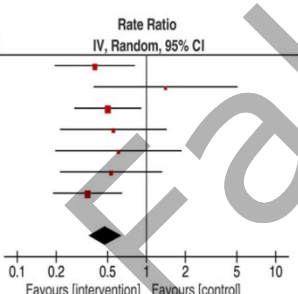
- This training could be either volitional or reactive but should be performed in an upright position and undertaken in response to environmental challenges which mimic common fall situations such as stepping onto a target, avoiding an obstacle or responding to a perturbation.

FALLS 50% ↓

A

Study or Subgroup	log[Rate Ratio]	SE	Intervention Total	Control Total	Weight	Rate Ratio IV, Random, 95% CI
Lurie, 2013	-0.92	0.36	26	33	17.6%	0.40 [0.20, 0.81]
Mansfield, 2010	0.34	0.65	16	15	5.4%	1.40 [0.39, 5.02]
Pai, 2014	-0.69	0.3	109	103	25.4%	0.50 [0.28, 0.90]
Shigematsu, 2008a	-0.59	0.48	20	19	9.9%	0.55 [0.22, 1.42]
Shigematsu, 2008b	-0.5	0.57	32	31	7.0%	0.61 [0.20, 1.85]
Shimada, 2004	-0.63	0.46	15	11	10.8%	0.53 [0.22, 1.31]
Yamada, 2013	-1.05	0.31	112	118	23.8%	0.35 [0.19, 0.64]
Total (95% CI)			330	330	100.0%	0.48 [0.36, 0.65]

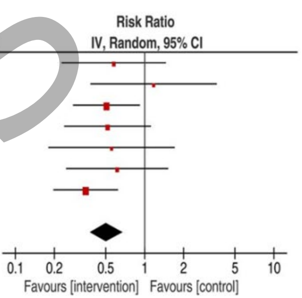
Heterogeneity: Tau² = 0.00; Chi² = 4.37, df = 6 (P = 0.63); I² = 0%
Test for overall effect: Z = 4.83 (P < 0.00001)



B

Study or Subgroup	log[Risk Ratio]	SE	Intervention Total	Control Total	Weight	Risk Ratio IV, Random, 95% CI
Lurie, 2013	-0.55	0.47	26	33	10.1%	0.58 [0.23, 1.45]
Mansfield, 2010	0.16	0.57	16	15	6.8%	1.17 [0.38, 3.59]
Pai, 2014	-0.68	0.3	109	103	24.7%	0.51 [0.28, 0.91]
Shigematsu, 2008a	-0.66	0.39	20	19	14.6%	0.52 [0.24, 1.11]
Shigematsu, 2008b	-0.59	0.57	32	31	6.8%	0.55 [0.18, 1.69]
Shimada, 2004	-0.49	0.46	15	11	10.5%	0.61 [0.25, 1.51]
Yamada, 2013	-1.05	0.29	112	118	26.4%	0.35 [0.20, 0.62]
Total (95% CI)			330	330	100.0%	0.51 [0.38, 0.68]

Heterogeneity: Tau² = 0.00; Chi² = 4.07, df = 6 (P = 0.67); I² = 0%
Test for overall effect: Z = 4.55 (P < 0.00001)

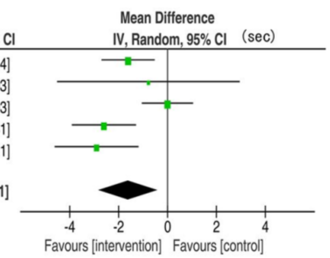


WALKING

A

Study or Subgroup	Intervention Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Fung, 2012	-1.37	1.41	16	0.24	1.61	15	24.9%	-1.61 [-2.68, -0.54]
Lurie, 2013	-3.38	7.73	20	-2.6	3.71	23	7.8%	-0.78 [-4.49, 2.93]
Schoene, 2013	-0.5	1.35	15	-0.5	1.61	17	25.3%	0.00 [-1.03, 1.03]
Teixeira, 2013b	-1.2	1.88	21	1.4	2.31	20	22.8%	-2.60 [-3.89, -1.31]
Yamada, 2013	-1.8	6.55	112	1.1	6.55	118	19.2%	-2.90 [-4.59, -1.21]
Total (95% CI)			184			193	100.0%	-1.61 [-2.81, -0.41]

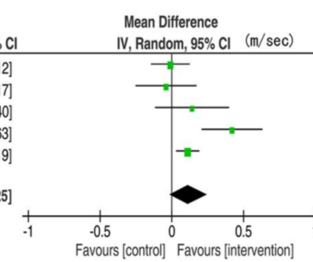
Heterogeneity: Tau² = 1.21; Chi² = 13.73, df = 4 (P = 0.008); I² = 71%
Test for overall effect: Z = 2.63 (P = 0.009)



B

Study or Subgroup	Intervention Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Bhatt, 2012	-0.05	0.24	25	-0.04	0.17	13	23.5%	-0.01 [-0.14, 0.12]
Bieryla, 2007	0.02	0.14	6	0.06	0.22	6	17.3%	-0.04 [-0.25, 0.17]
Shigematsu, 2008a	0.4017	0.39	20	0.2606	0.42	19	14.2%	0.14 [-0.11, 0.40]
Shimada, 2004	0.4197	0.34	15	0	0.2	11	17.3%	0.42 [0.21, 0.63]
Yamada, 2013	0.1045	0.32	112	-0.006	0.28	118	27.8%	0.11 [0.03, 0.19]
Total (95% CI)			178			167	100.0%	0.11 [-0.02, 0.25]

Heterogeneity: Tau² = 0.01; Chi² = 13.58, df = 4 (P = 0.009); I² = 71%
Test for overall effect: Z = 1.71 (P = 0.09)



Efficacy of video game-based interventions for active aging. A systematic literature review and meta-analysis

Fernando L. Vázquez[1]*, Patricia Otero[2], J. Antonio García-Casal[1], Vanessa Blanco[3], Ángela J. Torres[4], Manuel Arrojo[5]

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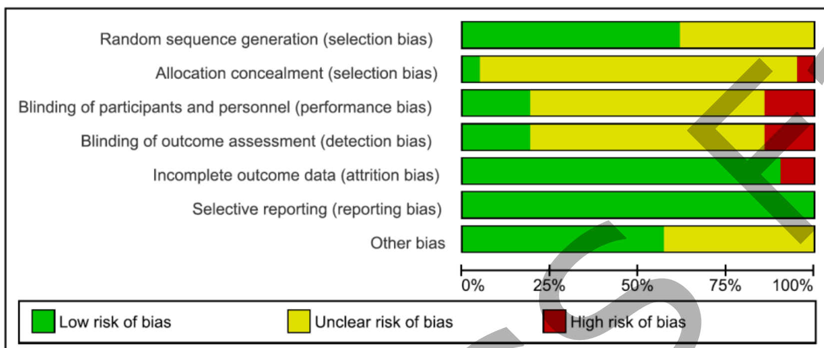

Author (year)	Risk of Bias	Downs & Black's criteria					Total	%
		Reporting (11)	External Validity (3)	Internal Validity-Bias (7)	Confounding (6)	Power (5)		
Ballesteros et al., 2014	1-2-2-2-3-1-1	10	0	5	5	1	21	66
Buitenweg et al., 2017	1-1-1-1-1-1-1	11	1	7	6	2	27	84
Dustman et al., 1992	4-4-4-4-1-1-1	9	0	5	5	1	20	63
Eggenberger et al., 2016	1-2-2-3-1-1-1	9	0	6	4	1	20	63
Fu et al., 2015	1-2-3-1-1-1-2	9	1	6	5	2	23	72
Goldstein et al., 1997	2-2-3-3-1-1-2	8	1	5	5	0	19	59
Gronhölm et al., 2017	4-3-2-3-1-1-2	9	0	5	5	1	20	63
Kahlbaugh et al., 2011	2-2-2-2-1-1-2	6	1	4	4	1	16	50
Karahan et al., 2015	1-2-2-2-1-1-2	8	0	5	5	2	20	63
Kim et al., 2015	2-2-2-2-1-1-2	5	0	4	3	1	13	41
Li et al., 2016	1-2-2-2-1-1-1	11	0	4	4	1	20	63
Maillot et al., 2012	2-2-2-2-1-1-2	10	0	5	4	1	20	63
Nouchi et al., 2012	1-2-1-2-3-1-1	10	2	6	6	1	25	78
Nouchi et al., 2016	1-2-1-2-1-1-1	10	1	6	5	2	24	75
Ribeiro et al., 2018	1-2-1-1-1-1-1	10	0	7	6	1	24	75
Sato et al., 2015	1-2-2-2-1-1-1	8	0	4	6	2	20	63
Schattin et al., 2016	1-2-4-4-1-1-1	8	0	6	5	1	20	63
Schoene et al., 2015	1-2-3-1-1-1-1	10	1	6	6	2	25	78
Souders et al., 2017	2-2-2-2-1-1-1	8	1	5	4	2	20	63
Toulotte et al., 2012	2-2-2-2-1-1-2	8	0	5	4	0	17	53
Whyatt et al., 2015	2-2-2-2-1-1-2	7	0	5	4	2	18	56
	Max score	231	63	147	126	105	672	
	Total score	184	9	111	101	27	432	
	%	80	14	76	80	26	64	

Note: Risk of bias values reflect categories proposed by Cochrane, in order: random sequence generation; allocation concealment; blinding of participants and personnel; blinding of outcome assessment; incomplete outcome data; selective reporting; and other sources of bias.1 = low; 2 = Unclear; 3 = high, 4 = Not Reported. Max. Score: maximum possible score all the studies together.

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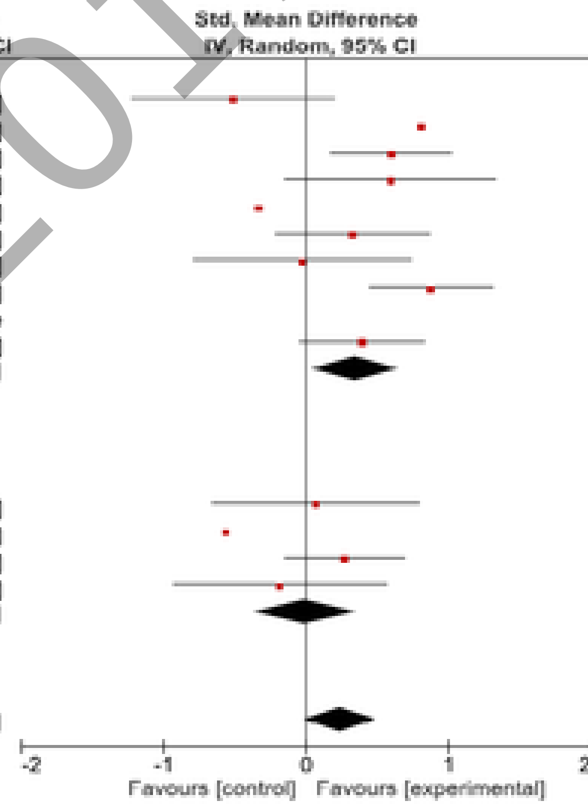
Fig 3. Forest plot of comparisons: Experimental vs. control group change in physical health.

Study or Subgroup	Std. Mean Difference	SE	Experimental Total	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
1.3.1 Objective						
Eggenberger et al., 2016	-0.516	0.362	19	14	6.5%	-0.52 [-1.23, 0.19]
Fu et al., 2015	0.804	0.27	30	30	8.4%	0.80 [0.27, 1.33]
Karahan et al., 2015	0.594	0.217	48	42	9.7%	0.59 [0.17, 1.02]
Maillot et al., 2012	0.589	0.378	15	15	6.2%	0.59 [-0.15, 1.33]
Ribeiro et al., 2018	-0.336	0.299	23	23	7.8%	-0.34 [-0.92, 0.25]
Sato et al., 2015	0.324	0.276	28	26	8.3%	0.32 [-0.22, 0.86]
Schattin et al., 2016	-0.032	0.389	13	14	6.0%	-0.03 [-0.79, 0.73]
Schoene et al., 2015	0.873	0.222	47	43	9.6%	0.87 [0.44, 1.31]
Toulotte et al., 2012	3.356	0.801	9	9		Not estimable
Whyatt et al., 2015	0.386	0.224	40	42	9.5%	0.39 [-0.05, 0.83]
Subtotal (95% CI)			**263**	**249**	**71.9%**	**0.34 [0.04, 0.64]**
Heterogeneity: Tau² = 0.13; Chi² = 21.59, df = 8 (P = 0.006); I² = 63%						
Test for overall effect: Z = 2.23 (P = 0.03)						
1.3.2 Self-Reported						
Ballesteros et al., 2014	0.065	0.372	17	13	6.3%	0.07 [-0.66, 0.79]
Kahlbaug et al., 2011	-0.57	0.395	16	12	5.9%	-0.57 [-1.34, 0.20]
Karahan et al., 2015	0.267	0.213	48	42	9.8%	0.27 [-0.15, 0.68]
Kim et al., 2015	-0.187	0.383	14	14	6.1%	-0.19 [-0.94, 0.56]
Subtotal (95% CI)			**95**	**81**	**28.1%**	**-0.01 [-0.37, 0.35]**
Heterogeneity: Tau² = 0.03; Chi² = 3.87, df = 3 (P = 0.28); I² = 23%						
Test for overall effect: Z = 0.04 (P = 0.97)						
Total (95% CI)			**358**	**330**	**100.0%**	**0.23 [-0.02, 0.48]**
Heterogeneity: Tau² = 0.12; Chi² = 29.92, df = 12 (P = 0.003); I² = 60%						
Test for overall effect: Z = 1.82 (P = 0.07)						
Test for subgroup differences: Chi² = 2.15, df = 1 (P = 0.14), I² = 53.4%						



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https://doi.org/10.1371/journal.pone.0208192
https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0208192

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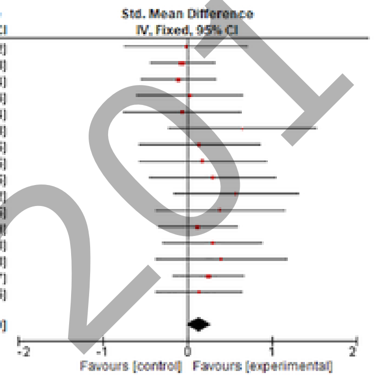
Fig 4. Forest plot of comparisons: Experimental vs. control group change in cognitive and emotional mental health.

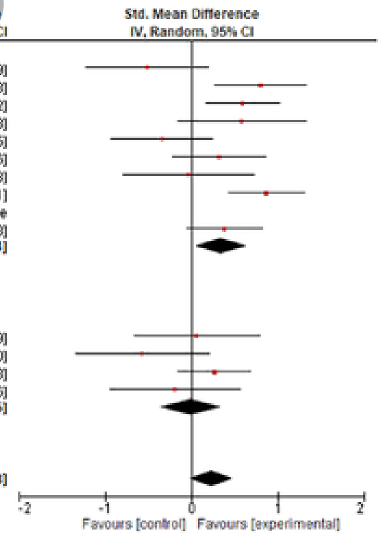
Cognitive Mental Health

Study or Subgroup	Std. Mean Difference	SE	Favours [control] Total	Control Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
Ballesteros et al., 2014	-0.01	0.37	17	13	4.0%	-0.01 [-0.74, 0.72]
Buitenweg et al., 2017	-0.055	0.195	33	50	14.3%	-0.06 [-0.44, 0.33]
Buitenweg et al., 2017	-0.103	0.225	56	50	10.8%	-0.10 [-0.54, 0.34]
Dustman et al., 1992	0.032	0.318	20	20	5.4%	0.03 [-0.59, 0.66]
Eggenberger et al., 2016	-0.059	0.355	19	14	4.3%	-0.06 [-0.75, 0.64]
Goldstein et al. 1997	0.653	0.448	10	12	2.7%	0.65 [-0.23, 1.53]
Gronhölm et al. 2017	0.143	0.363	16	15	4.1%	0.14 [-0.57, 0.85]
Kahlbaug et al., 2011	0.187	0.387	16	12	3.6%	0.19 [-0.57, 0.95]
Kim et al., 2015	0.3	0.384	14	14	3.7%	0.30 [-0.45, 1.05]
Maillot et al., 2012	0.579	0.377	15	15	3.8%	0.58 [-0.16, 1.32]
Nouchi et al., 2012	0.391	0.388	14	14	3.7%	0.39 [-0.37, 1.15]
Nouchi et al., 2016	0.125	0.237	36	36	9.7%	0.13 [-0.34, 0.59]
Ribeiro et al., 2018	0.299	0.298	23	23	6.1%	0.30 [-0.29, 0.88]
Schattin et al., 2016	0.405	0.394	28	26	3.5%	0.41 [-0.37, 1.18]
Schoene et al., 2015	0.252	0.212	47	43	12.1%	0.25 [-0.16, 0.67]
Souders et al., 2017	0.141	0.26	30	30	8.1%	0.14 [-0.37, 0.65]
Total (95% CI)			394	387	100.0%	0.14 [-0.00, 0.29]
Heterogeneity: Chi² = 7.06, df = 15 (P = 0.96); I² = 0%						
Test for overall effect: Z = 1.96 (P = 0.05)						



Emotional Mental Health

Study or Subgroup	Std. Mean Difference	SE	Experimental Total	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
1.3.1 Objective						
Eggenberger et al., 2016	-0.516	0.362	19	14	6.5%	-0.52 [-1.23, 0.19]
Fu et al., 2015	0.804	0.27	30	30	8.4%	0.80 [0.27, 1.33]
Karahan et al., 2015	0.594	0.217	48	42	9.7%	0.59 [0.17, 1.02]
Maillot et al., 2012	0.589	0.378	15	15	6.2%	0.59 [-0.15, 1.33]
Ribeiro et al., 2018	-0.336	0.299	23	23	7.8%	-0.34 [-0.92, 0.25]
Sato et al., 2015	0.324	0.276	28	26	8.3%	0.32 [-0.22, 0.86]
Schattin et al., 2016	-0.032	0.389	13	14	6.0%	-0.03 [-0.79, 0.73]
Schoene et al., 2015	0.873	0.222	47	43	9.6%	0.87 [0.44, 1.31]
Toulotte et al., 2012	3.356	0.801	9	9		Not estimable
Whyatt et al., 2015	0.386	0.224	40	42	9.5%	0.39 [-0.05, 0.83]
Subtotal (95% CI)			263	249	71.9%	0.34 [0.04, 0.64]
Heterogeneity: Tau² = 0.13; Chi² = 21.59, df = 8 (P = 0.006); I² = 63%						
Test for overall effect: Z = 2.23 (P = 0.03)						
1.3.2 Self-Reported						
Ballesteros et al., 2014	0.065	0.372	17	13	6.3%	0.07 [-0.66, 0.79]
Kahlbaug et al., 2011	-0.57	0.395	16	12	5.9%	-0.57 [-1.34, 0.20]
Karahan et al., 2015	0.267	0.213	48	42	9.8%	0.27 [-0.15, 0.68]
Kim et al., 2015	-0.187	0.383	14	14	6.1%	-0.19 [-0.94, 0.56]
Subtotal (95% CI)			95	81	28.1%	-0.01 [-0.37, 0.35]
Heterogeneity: Tau² = 0.03; Chi² = 3.87, df = 3 (P = 0.28); I² = 23%						
Test for overall effect: Z = 0.04 (P = 0.97)						
Total (95% CI)			358	330	100.0%	0.23 [-0.02, 0.48]
Heterogeneity: Tau² = 0.12; Chi² = 29.92, df = 12 (P = 0.003); I² = 60%						
Test for overall effect: Z = 1.82 (P = 0.07)						
Test for subgroup differences: Chi² = 2.15, df = 1 (P = 0.14), I² = 53.4%						



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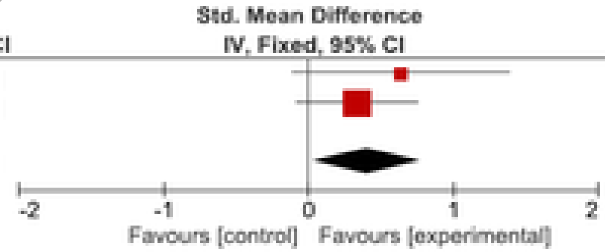
https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0208192

Fig 5. Forest plot of comparisons: Experimental vs. control group change in social health.

Study or Subgroup	Std. Mean Difference	SE	Experimental Total	Control Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
Ballesteros et al., 2014	0.634	0.382	17	13	23.7%	0.63 [-0.11, 1.38]
Karahan et al., 2015	0.329	0.213	48	42	76.3%	0.33 [-0.09, 0.75]
Total (95% CI)			65	55	100.0%	0.40 [0.04, 0.77]

Heterogeneity: Chi² = 0.49, df = 1 (P = 0.49); I² = 0%

Test for overall effect: Z = 2.16 (P = 0.03)



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Special Article

Recommendations on Physical Activity and Exercise for Older Adults Living in Long-Term Care Facilities: A Taskforce Report

Current Physical Activity Guidelines for Older Adults[12,13]

Minimum Recommendations of Physical Activity for Adults 65 Years and Older	
Recommendation from the American College of Sports Medicine and the American Heart Association (2007)[*]	*Recommendation from the World Health Organization (2010)*[†]
Aerobic/endurance (bouts of >10 min). Moderate-intensity aerobic PA, 30 minutes, 5 d/wk or vigorous-intensity aerobic PA, 20 min, 3 d/wk. These moderate or vigorous PAs are in addition to the light-intensity activities performed in daily life (eg, self-care) or moderate-intensity PAs lasting 10 min or less + **Strength**. 8–10 exercises, 10–15 repetitions, for strengthening the major muscles of the body, ≥ twice/wk, moderate to high intensity + **Flexibility**. ≥ twice/wk, 10 min + **Balance/coordination**. "To reduce risk of injury from falls, *community-dwelling older adults* with substantial risk of falls should perform exercises that maintain or improve balance."[12]	**Aerobic/endurance** (bouts of ≥10 min). Moderate-intensity aerobic PA, ≥ 150 min/wk or vigorous-intensity aerobic PA, ≥ 75 min/wk + **Strength**. ≥ twice/wk, muscle-strengthening involving major muscle groups + **Balance/coordination**. ≥ 3 d/wk, for older adults with poor mobility in order to enhance balance and prevent falls.

PA, physical activity.

*Adapted from: Nelson ME, Rejeski WJ, Blair SN, et al. Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. Med Sci Sports Exerc 2007;39:1435–1445.

†Adapted from: World Health Organization. Global Recommendations on Physical Activity for Health. Geneva: WHO Press, 2010.

Summary of key recommendations of physical activity and exercise for older adults in long-term care facilities

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Journal of the American Medical Directors Association

Volume 17, Issue 5, 1 May 2016, Pages 381–392

JAMDA

Special Article

Recommendations on Physical Activity and Exercise for Older Adults Living in Long-Term Care Facilities: A Taskforce Report

Increasing Overall Physical Activity Levels in Daily Life	Exercise Training for Residents Dependent in Basic Activities of Daily Living, but Capable of Ambulating/Rising From a Chair*
1. Motivation and pleasure are the key aspects to take into account so as to increase overall activity levels among older adults living in long-term care facilities (LTCFs).	1. Every resident who has no contraindications must have a personalized exercise program as part of his or her health care plan.
2. LTCF staff should adopt strategies for breaking (short breaks of 2–5 minutes) the sedentary time of LTCF residents, twice or 3 times a day.	2. Exercise type. The best exercise type is a multicomponent training composed of muscle strength and cardiorespiratory endurance exercises as the core components. Other exercise types, particularly flexibility and balance, should be added to the exercise program whenever possible.
3. LTCF staff should systematically use simple strategies to stimulate residents to move, such as walking to the lunch/dining hall rather than using wheelchairs for people who are able to ambulate. The risk/benefit of using drugs that reduce patients' activity levels, especially psychotropic drugs, must be systematically evaluated. Physical restraints should be avoided. The use of medical equipment and LTCF architecture should be oriented to optimize residents' mobility.	3. Exercise intensity. Moderate-intensity exercises are feasible, effective, and safe. Moderate exercises can be achieved by performing the following: (1) Strength, 1 or 2 sets of exercises, performed at 13–15 repetitions maximum; (2) Aerobic, exercises that noticeably increase heart and respiratory frequency, without generating breathlessness or undue fatigue (scoring 5 or 6 in a 10-point scale of perceived effort). High-intensity exercises can be executed, but may require closer monitoring.
4. LTCF staff should organize group activities that are motivating and pleasant, such as groups to look after the garden, dance, or walk in green spaces.	4. Frequency. Twice a week, with an interval of at least 48 hours between sessions. Higher weekly frequency is safe and may be feasible for fitter residents.
5. The use of innovative solutions, such as using animal interventions and new technologies (eg, robots), should be encouraged to increase residents' motivation and pleasure and, then, overall activity levels.	5. Duration: 35–45 minutes per session. Lesser durations may be needed during the first weeks of exercise. Longer sessions are feasible for most people.

*Capable of ambulating/rising from a chair with or without human assistance.

Innovations in technology and IT solutions for cognition in relation to falls

"Thank you for your attention"

„We don't stop playing because we grow old; we grow old because we stop playing."

George Bernard Shaw

European Journal of Physical and Rehabilitation Medicine 2018 June;54(3):450-62
DOI: 10.23736/S1973-9087.17.04680-9

SYSTEMATIC REVIEW

Active exergames to improve cognitive functioning in neurological disabilities: a systematic review and meta-analysis

Gioia MURA [1] *, Mauro G. CARTA [1], Federica SANCASSIANI [1], Sergio MACHADO [2, 3, 4], Luca PROSPERINI [5, 6]

The effect of active video games on cognitive functioning in clinical and non-clinical populations: A meta-analysis of randomized controlled trials

Emma Stanmore[a,*], Brendon Stubbs[b,c], Davy Vancampfort[d,e], Eling D. de Bruin[f], Joseph Firth[g]

Review

A Systematic Review on the Cognitive Benefits and Neurophysiological Correlates of Exergaming in Healthy Older Adults

Robert Stojan and Claudia Voelcker-Rehage *

Movements of older adults during exergaming interventions that are associated with the Systems Framework for Postural Control: A systematic review

Robin Tahmosybayat[a], Katherine Baker[a], Alan Godfrey[b], Nick Caplan[a], Gill Barry[a,*]

Maturitas 111 (2018) 90–99

Highlights

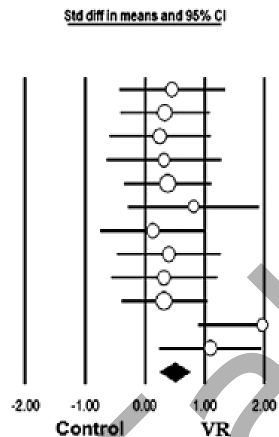
- The totality of **postural control** is not currently trained in exergaming interventions.
- The choice of exergame console and game influence the areas of postural control trained.
- Sensory integration and reactive postural control is not currently trained using exergames.
- *Exergames that utilise a changing base of support* better meet the requirements for training postural control.

Jerome Iruthayarajah, Amanda McIntyre, Andreea Cotoi, Steven Macaluso & Robert Teasell (2017) The use of virtual reality for balance among individuals with chronic stroke: a systematic review and meta-analysis, Topics in Stroke Rehabilitation, 24:1, 68-79, DOI: 10.1080/10749357.2016.1192361

BBS

Total BBS

Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Barcala et al. 2013	0.457	0.453	0.205	-0.431	1.345	1.008	0.313
Fritz et al. 2013	0.335	0.382	0.146	-0.413	1.083	0.878	0.380
Cho et al. 2012	0.253	0.428	0.183	-0.586	1.092	0.591	0.554
Gil-Gomez et al. 2011	0.320	0.489	0.239	-0.639	1.278	0.654	0.513
Cho & Lee 2014	0.386	0.369	0.136	-0.337	1.108	1.047	0.295
Cho et al. 2013	0.816	0.556	0.309	-0.274	1.906	1.467	0.142
In-chul et al. 2012	0.138	0.448	0.200	-0.739	1.016	0.309	0.757
Lee et al. 2014	0.405	0.441	0.195	-0.460	1.270	0.918	0.359
Llorens et al. 2014	0.323	0.450	0.203	-0.560	1.205	0.717	0.473
Llorens et al. 2015	0.327	0.368	0.135	-0.393	1.047	0.890	0.374
Lee 2015b	1.967	0.545	0.297	0.899	3.034	3.611	0.000
Kim et al. 2009	1.102	0.438	0.192	0.243	1.961	2.516	0.012
	0.506	0.126	0.016	0.259	0.753	4.015	0.000



Nintendo® Wii Fit balance board

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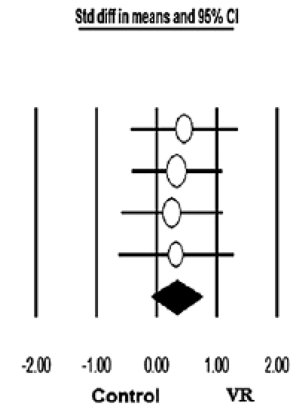
	0.339	0.216	0.047	-0.085	0.763	1.567	0.117



VR + treadmill training

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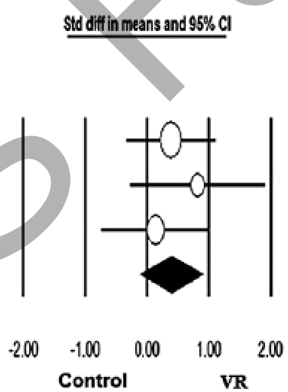
In-chul et al. 2012	0.138	0.448	0.200	-0.739	1.016	0.309	0.757
	0.396	0.253	0.064	-0.101	0.892	1.562	0.118



Postural VR training

Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
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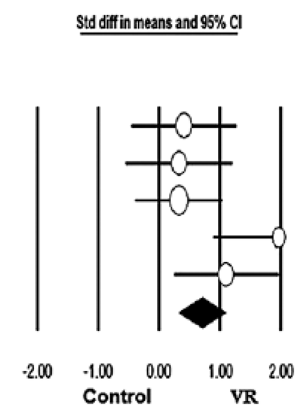
Kim 2009	1.102	0.438	0.192	0.243	1.961	2.516	0.012
	0.709	0.196	0.038	0.325	1.093	3.617	0.000



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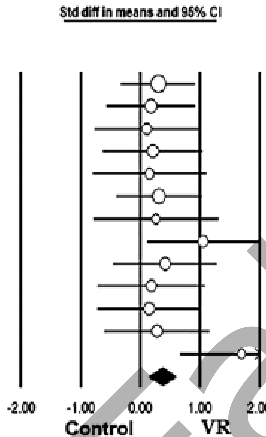
TUG

Total TUG

Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Song et al. 2015	0.301	0.318	0.101	-0.322	0.924	0.946	0.344
Hung et al. 2014	0.179	0.380	0.144	-0.565	0.923	0.472	0.637
Barcala et al. 2013	0.111	0.448	0.200	-0.766	0.988	0.247	0.805
Cho et al. 2012	0.209	0.428	0.183	-0.629	1.047	0.488	0.626
Gil-Gomez et al. 2011	0.157	0.487	0.237	-0.797	1.111	0.323	0.747
Cho & Lee 2014	0.314	0.367	0.135	-0.407	1.034	0.853	0.393
Cho & lee 2013	0.261	0.537	0.288	-0.791	1.313	0.486	0.627
Kang et al. 2012	1.059	0.478	0.228	0.123	1.995	2.218	0.027
Jung 2012	0.415	0.442	0.195	-0.450	1.281	0.940	0.347
In-Chul et al. 2012	0.187	0.460	0.212	-0.715	1.090	0.406	0.685
Lee et al. 2014	0.147	0.438	0.191	-0.710	1.005	0.337	0.736
Yom et al. 2015	0.284	0.449	0.202	-0.597	1.165	0.632	0.527
Lee et al. 2015b	1.696	0.521	0.272	0.674	2.718	3.252	0.001
	0.367	0.119	0.014	0.134	0.601	3.082	0.002



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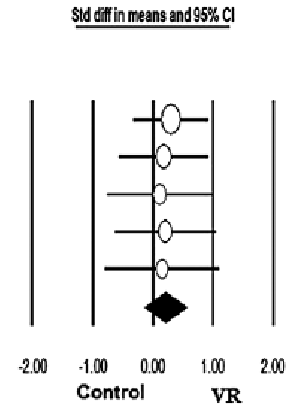
	0.209	0.178	0.032	-0.140	0.558	1.172	0.241



VR + treadmill training

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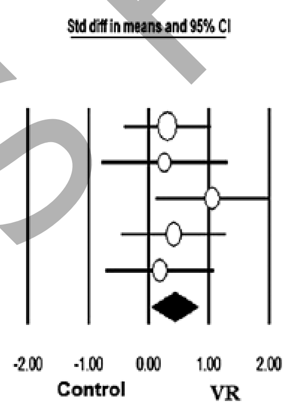
In-Chul et al. 2012	0.187	0.460	0.212	-0.715	1.090	0.406	0.685
	0.434	0.200	0.040	0.042	0.825	2.172	0.030



Postural VR training

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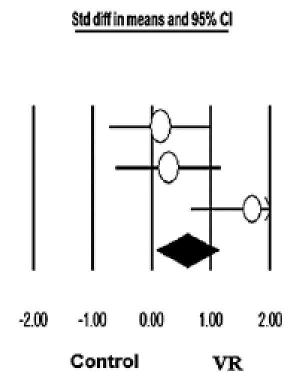
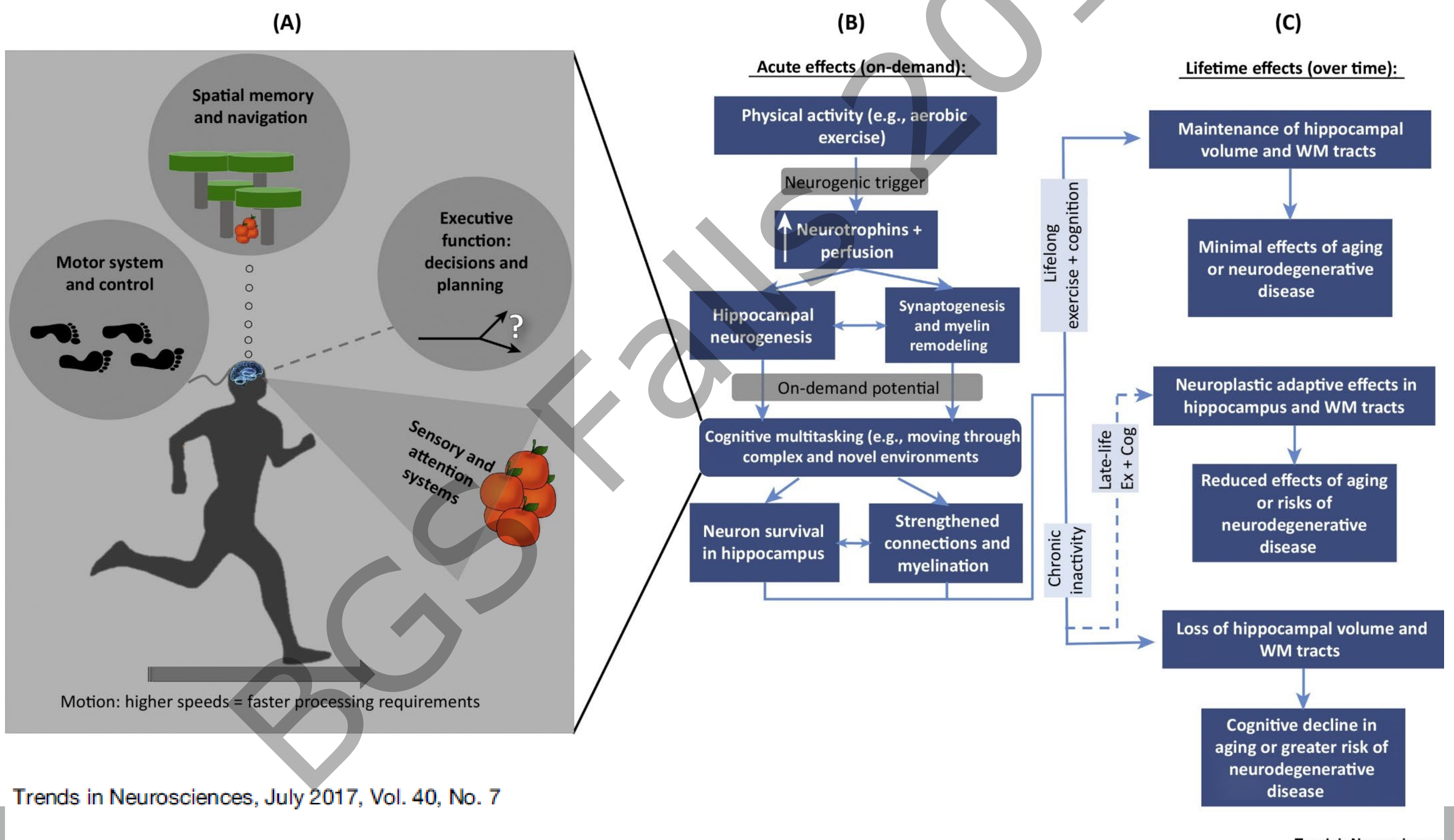
	0.607	0.269	0.072	0.081	1.134	2.261	0.024

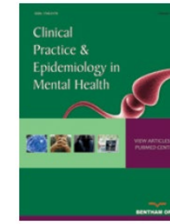


95% of human biology believed to have been naturally selected in the time when our ancestors were hunters and gatherers (Trevathen et al., 1999). The lifestyles we live today are ones that may be maladaptive to those directed by our evolutionary makeup. Particularly, a sedentary lifestyle and a change in dietary habits seem to be prominent contributing factors to many diseases of the body and mind.

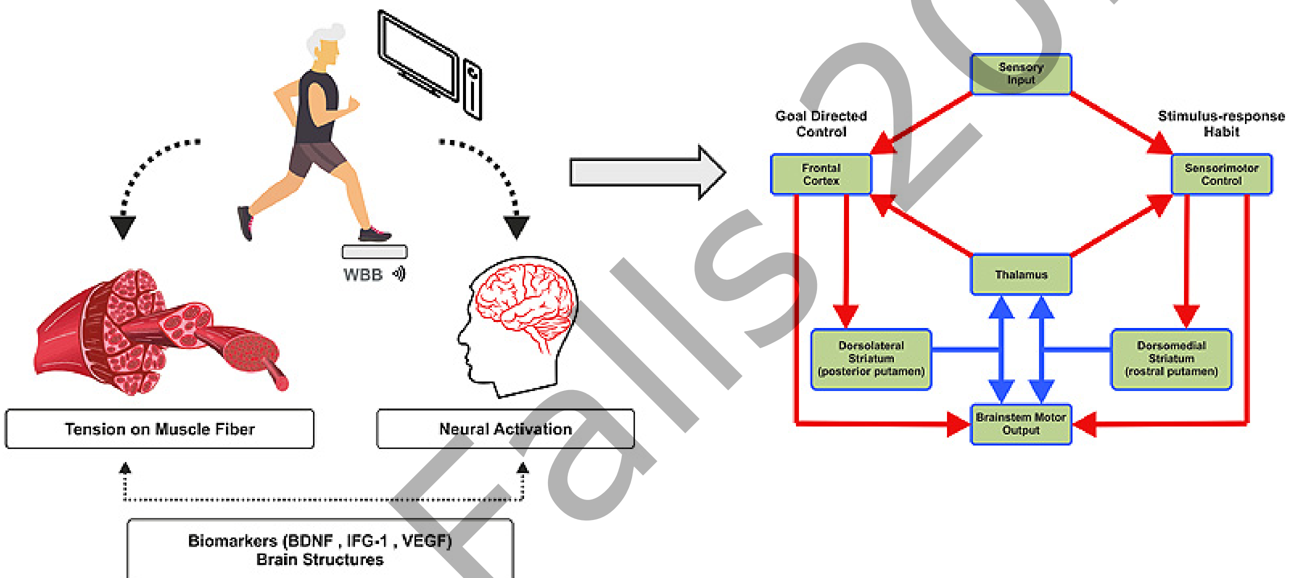


Trends in Neurosciences, July 2017, Vol. 40, No. 7

Virtual Reality-Based Exercise with Exergames as Medicine in Different Contexts: A Short Review



Marcos Túlio Silva Costa[1], Lanna Pinheiro Vieira[1], Elizabete de Oliveira Barbosa[2], Luciana Mendes Oliveira[2,3], Pauline Maillot[4], César Augusto Ottero Vaghetti[5], Mauro Giovani Carta[6], Sérgio Machado[7], Valeska Gatica-Rojas[8] and Renato Sobral Monteiro-Junior[2,*]



If exercise is considered as "remedy" for its preventive potential and for the treatment of chronic diseases, it is possible to infer that an association with virtual reality could potentiate its therapeutic effects, especially in certain cases, for example, in the improvement of the cognitive functions of older adults, in augmenting balance and motor function of PD and stroke patients, as well as reducing spasticity in children with cerebral palsy.

Costa, M., Vieira, L. P., Barbosa, E. O., Mendes Oliveira, L., Maillot, P., Ottero Vaghetti, C. A., … Monteiro-Junior, R. S. (2019). Virtual Reality-Based Exercise with Exergames as Medicine in Different Contexts: A Short Review. *Clinical practice and epidemiology in mental health : CP & EMH*, *15*, 15–20.

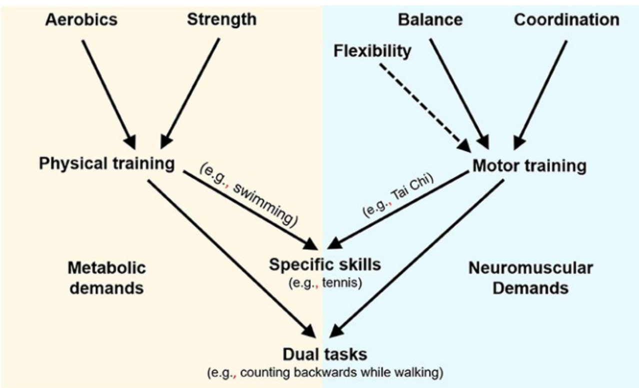
frontiers in Medicine

REVIEW
published: 29 March 2019
doi: 10.3389/fmed.2019.00057

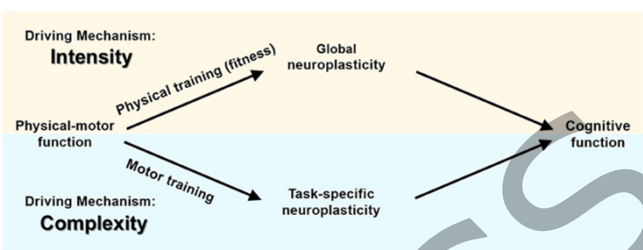
Check for updates

Is There a Preferred Mode of Exercise for Cognition Enhancement in Older Age?—A Narrative Review

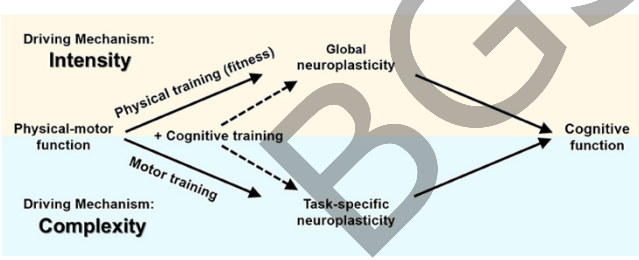
*Yael Netz**



Basic modes of exercise—neuromuscular vs. metabolic demands.



Physical-motor training and cognition—different pathways and driving mechanisms.



Physical-motor training and cognition—dual tasks.

Netz Y. (2019). Is There a Preferred Mode of Exercise for Cognition Enhancement in Older Age?-A Narrative Review. *Frontiers in medicine*, *6*, 57.