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Can Whole-Body Electromyostimulation Replicate the Cognitive-Motor Demands of Coordinative Sports? A Rationale for Reactive Light-Based Dual-Task Protocols

Luca Peroncini[1*]

[1] Independent Researcher, Italy. lucaperoncini1732@gmail.com

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ABSTRACT

Sports that pair motor execution with real-time decision-making — racquet sports, martial arts, exergaming — appear to yield stronger cognitive benefits than purely repetitive exercise, plausibly through neuroplasticity, BDNF release, and myokine signaling. Whole-body electromyostimulation (WB-EMS), now widespread in fitness and rehabilitation practice, has been studied almost exclusively for motor and body-composition outcomes: to date, only one randomized controlled trial has directly assessed its cognitive effects, alongside a handful of studies linking WB-EMS to neurotrophic biomarkers in Parkinson's disease. This conceptual paper proposes a training model integrating reactive light systems (e.g., FITLIGHT, BlazePod) into the pause phase of WB-EMS protocols, hypothesizing that unpredictable visual-decisional cues could reproduce the cognitive-motor demands typical of coordinative sports. Unlike prior WB-EMS research, largely confined to older or clinical samples, this rationale is framed as potentially lifespan-wide — relevant both to frail older adults who cannot access coordinative sports and to active adults seeking added cognitive stimulus within strength training. We discuss the model's theoretical basis, practical implementation, and current limitations, chief among them the absence of direct trials on this specific combination, and outline directions for applied validation.

Keywords: whole-body electromyostimulation, cognitive-motor training, dual-task, reactive agility, executive function, lifespan training

Corresponding Author:

Luca Peroncini

- Independent Researcher, Italy.
- Email: lucaperoncini1732@gmail.com | ORCID: 0009-0009-3976-3180

Highlights

• Coordinative/racquet sports boost cognition more than pure motor exercise

• WB-EMS literature remains almost exclusively focused on motor outcomes

• Reactive light cues during WB-EMS pauses may add real-time decisional load

• Proposed rationale extends potentially lifespan-wide, beyond prior elderly-focused work

• Direct trials on WB-EMS combined with cognitive dual-tasking are still lacking

1. Introduction

1.1 Physical Activity and Cognition: Not All Sports Are Equal

Regular physical activity is associated with reduced risk of cognitive decline and improved executive function across the lifespan, with a well-documented dose-response relationship (Gallardo-Gómez et al., 2022). However, evidence suggests that the type of activity matters as much as its volume or intensity. Diamond and Ling (2016), in a widely cited review, concluded that pure aerobic and resistance exercise are among the least effective methods tested so far for improving executive functions — whereas activities that integrate an explicit cognitive load (martial arts, yoga, mindfulness) show superior results. This suggests that it is not movement per se that produces cognitive benefits, but the perceptual-decisional processing that accompanies it — a principle developed by Pesce (2012) in the concept of "gross-motor cognitive training," i.e., motor training enriched by cognitive and coordinative demands.

A consistent epidemiological signal comes from the Copenhagen City Heart Study (Schnohr et al., 2018), which followed 8,577 subjects for 25 years: tennis was associated with the largest life-expectancy gain among the sports analyzed (+9.7 years versus sedentary individuals), ahead of badminton, soccer, cycling, and running. It should be noted that the authors attribute this advantage primarily to the social interaction inherent to paired/team sports rather than to an explicit cognitive-decisional mechanism — an interpretation that nonetheless leaves

room for complementary hypotheses, given that racquet sports also rank among the highest in real-time perceptual-motor demand.

1.2 The Gap in WB-EMS Research

Whole-body electromyostimulation (WB-EMS) is a training modality that superimposes electrical impulses on voluntary muscle contraction across multiple muscle groups simultaneously, widespread in commercial fitness, rehabilitation, and geriatric exercise settings for its time efficiency and joint-friendly profile (Kemmler et al., 2018, 2021). The majority of WB-EMS research to date has addressed motor and morphological outcomes — strength, body composition, bone density, sprint and jump performance — with comparatively little attention to cognitive outcomes. To our knowledge, only one randomized controlled trial has directly assessed the impact of WB-EMS on cognitive performance, reporting improvements in memory and selective attention in older adults at risk of dementia after a 12-week combined aerobic/WB-EMS intervention delivered with continuous stimulation (35 Hz), not an intermittent duty cycle (Centorbi et al., 2024). A small number of additional studies, conducted by the same Italian research group, have examined WB-EMS in Parkinson's disease, reporting changes in neurotrophic biomarkers such as BDNF and α-synuclein following WB-EMS-supplemented exercise (di Cagno et al., 2023; Fiorilli et al., 2021) — discussed in detail in Section 2.2. These studies, while not designed to test dual-task or decision-based cognitive engagement, indicate biological plausibility for a neurotrophic effect of WB- EMS.

1.3 Aim of This Paper

Existing WB-EMS protocols, whether static or dynamic, remain almost entirely motor in nature: the participant's cognitive engagement is minimal and predictable. This contrasts with the unpredictable, decision-driven engagement associated with the sports shown to confer the strongest cognitive benefits. We propose that this gap can be addressed by embedding a reactive, decision-based cognitive task — delivered through commercially available light-based training systems such as FITLIGHT or BlazePod, already validated in sport settings (Hassan et al., 2022) — within the pause phase of the WB-EMS duty cycle. Unlike prior WB-EMS-cognition research, confined to older or clinical populations, we hypothesize that the proposed mechanism could extend beyond these groups, with potential relevance across the lifespan — from frail older

adults who cannot access coordinative sports, to active adults seeking an additional cognitive stimulus alongside strength-oriented training. This extension remains, at this stage, a theoretical inference to be tested empirically (see Section 5).

2. Theoretical Background

2.1 Shared Mechanisms Between Cognitive-Motor Sport and Neuroplasticity

The cognitive benefits associated with dual motor-decisional activities are explained in the literature through several convergent mechanisms, distinct from those activated by simple repetitive exercise. The first concerns brain-derived neurotrophic factor (BDNF), a neurotrophin supporting neuronal survival, synaptic plasticity, and hippocampal neurogenesis, whose expression is modulated by physical exercise through the release of myokines from contracting skeletal muscle (Rai & Demontis, 2022). The second mechanism involves the broader muscle-brain axis: myokines and exerkines released during muscle contraction cross the blood-brain barrier and influence neurogenesis and long-term synaptic potentiation, acting as biological mediators even independently of the aerobic component of exercise (Rai & Demontis, 2022; Vints et al., 2022).

The third mechanism, most directly relevant to the present proposal, is dual-task-induced neuroplasticity: when a motor action is coupled with real-time perceptual-decisional processing (perceiving an unpredictable stimulus, selecting a response, executing it under time constraint), motor and prefrontal/attentional neural networks are simultaneously activated, with a potential transfer to executive functions greater than that of isolated motor or cognitive tasks alone (Diamond & Ling, 2016; Pesce, 2012). This is the rationale underlying "cognitively engaging physical activity" protocols, and the reason why sports such as tennis, badminton, or martial arts are associated with superior cognitive effects compared with running or lap swimming — predictable, low decisional-load activities.

2.2 What WB-EMS Adds to This Picture

WB-EMS introduces an additional variable relative to pure voluntary exercise: electrically induced muscle contraction recruits a greater number of motor units and muscle groups than typically achievable through voluntary contraction alone, within a reduced session time. Three studies from the same Italian

research group help delineate what is currently known about the biological plausibility of a cognitive effect. The first (Fiorilli et al., 2021) tested the acute effect of a single WB-EMS session in 10 early-stage Parkinson's patients, finding increased serum proNGF alongside immediate improvements in strength, endurance, and eye-hand coordination — a signal that even a single exposure produces a measurable neurotrophic response. The second (di Cagno et al., 2023), in 24 patients randomized into three arms (high-frequency WB-EMS for strength, low-frequency WB-EMS for aerobic training, inactive control), extended the observation to 12 weeks, finding that the low-frequency protocol increased serum BDNF and decreased α-synuclein — the latter of particular interest given its role in the pathological aggregation characteristic of Parkinson's neurodegeneration. The third study, in an older population at risk of dementia (Centorbi et al., 2024), was the first to demonstrate a behavioral cognitive benefit measured with standardized neuropsychological batteries (not only biomarkers), in a larger sample (61 subjects) over a comparable timeframe (12 weeks).

Taken together, these three studies trace a path from biological plausibility (neurotrophic biomarkers) to behavioral evidence (measured cognitive performance), but none introduced an explicit decisional component into the motor task: the exercise, whether aerobic or resistance-based, remains devoid of choice, discrimination, or reaction to unpredictable stimuli. This is precisely the element that the sport-cognition literature (Section 2.1) identifies as determinant for executive benefit, and which the present model proposes to introduce.

3. Conceptual Model and Proposed Protocol

3.1 Basic Structure: Where the Cognitive Task Fits

A standard WB-EMS protocol is organized around an impulse-pause duty cycle (typically 4-6 second impulses alternated with 4-6 second pauses, with variations depending on whether the protocol targets strength or aerobic goals). In current protocols, the pause phase is generally used for passive recovery or repositioning between exercises — cognitively "free" time. We propose using this window for the cognitive-decisional stimulus, so that neuromuscular load (impulse phase) and cognitive load (pause phase) alternate within the same training cycle, rather than being superimposed — a cautious choice that avoids interfering with force production during electrically induced contraction and is straightforward to implement with existing instrumentation.

3.2 Duty Cycle Time Budget: A Cognitively Oriented Protocol

If the primary goal of the protocol is cognitive stimulation — rather than maximal strength — it is reasonable to invert the impulse/pause ratio typically used in hypertrophy-oriented WB-EMS protocols, allocating more time to the neuro-cognitive window (see Figure 1). Over a 20-minute session of active stimulation (1200 seconds) with a 4-second impulse / 6-second pause duty cycle:

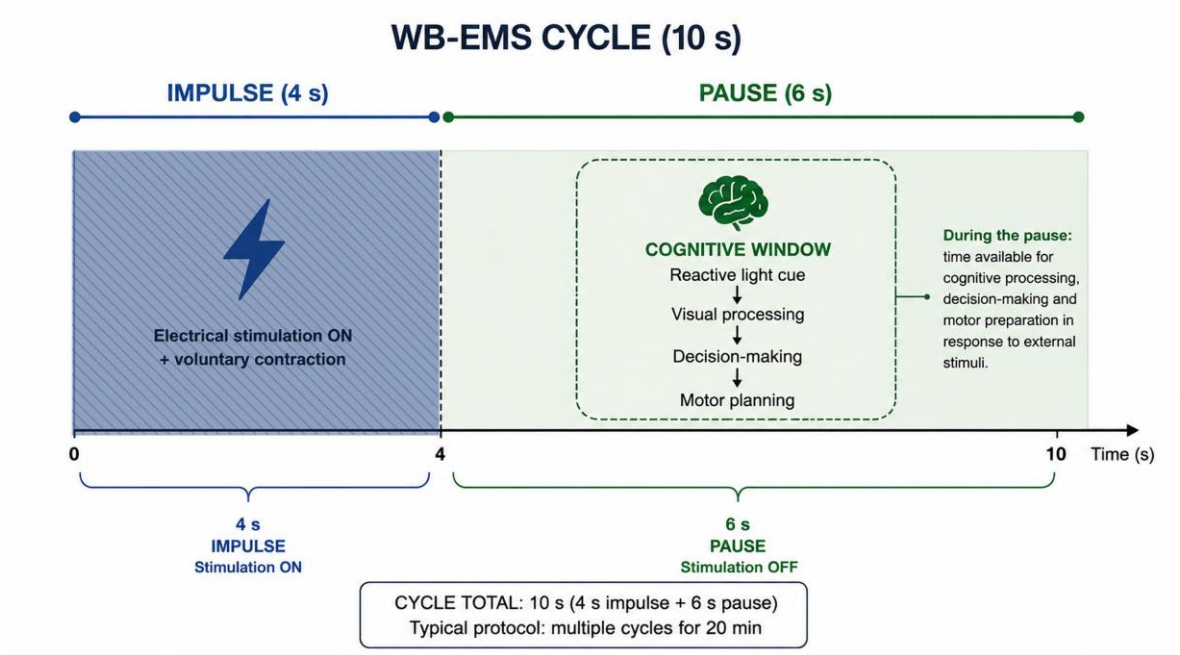


Figure 1. Proposed WB-EMS Duty Cycle Integrating a Cognitive Window

Note. A 10-s cycle consists of a 4-s stimulation phase, during which electrical stimulation is combined with voluntary muscle contraction, followed by a 6-s pause. The pause phase represents the proposed cognitive window, during which reactive visual cues can be processed and transformed into decision-making and motor responses.

Cycle duration: 4 + 6 = 10 seconds → 120 cycles per session. Total contraction time: 120 × 4 s = 8 minutes. Total cognitive-window time: 120 × 6 s = 12 minutes.

Within the 6-second pause there is room for 3-4 simple reactive trials (reaction time 200-300 ms per trial) or 2-3 discriminative/conditional-choice trials (350-500 ms, corresponding roughly to the P300 component window in EEG recordings). Across 120 cycles, the cumulative exposure volume per session reaches approximately 240-360 trials. This is a purely arithmetic estimate based on minimum trial durations, to be verified under real conditions: setup time and individual variability in response speed will likely reduce this theoretical volume. Even accounting for this, the estimated volume is comparable to, or

exceeds, that of a dedicated standalone cognitive-motor training session (e.g., FITLIGHT protocols in basketball or judo athletes, typically delivered over 15-20 minute sessions with similar trial volumes).

It is important to note that this administration scheme differs structurally from the only direct WB-EMS-cognition RCT available in the literature (Centorbi et al., 2024), which used continuous stimulation superimposed on aerobic exercise. The present model therefore introduces a double novelty relative to that precedent: not only the addition of an explicit cognitive-decisional task, but also an intermittent, inverted-ratio duty cycle logic never previously tested in this context.

A related implication should be made explicit: at this ratio, the contraction (4 s, presumably submaximal) assumes a different role than in a pure strength protocol — it functions as a background neuromuscular load, consistent with the mechanisms already described (Section 2.1: muscle-brain axis, BDNF, myokines), while the actual driver of adaptation is the high-frequency repetition of the perception-decision-action cycle within the pause window. This is consistent with Diamond and Ling's (2016, Section 2.1) observation: contraction alone, however submaximal and distributed, is not sufficient to justify an executive benefit — it is the superimposed cognitive window that supplies the missing element.

3.3 Components of the Cognitive-Decisional Task

The task, delivered via reactive light systems (FITLIGHT, BlazePod, or equivalent), can be scaled along three independent axes: (1) Stimulus density — number of simultaneously active light units and activation frequency, determining attentional load. (2) Response rule — from purely reactive (touch the light that activates) to discriminative (touch only lights of a specific color, ignore others) to conditional choice (red light → one motor pattern, green light → another), introducing inhibition and cognitive flexibility beyond simple reaction speed. (3) Motor component of the response — from a simple hand touch to a lateral step to a weight shift, allowing calibration of balance/coordination demand alongside cognitive demand.

3.4 Target-Specific Applications

Frail older adults / population at risk of cognitive decline: simple reactive task (1-2 lights, dominant-hand touch), low-intensity EMS stimulation volume, primary goal of safety and functional recovery. This is the target for which direct WB-EMS-cognition evidence already exists (Centorbi et al., 2024), representing the most immediate and lowest-risk extension of the protocol.

Active adults in strength training: discriminative or conditional-choice task (3-4 lights, color rule, weight-shift response), standard EMS volume for strength/hypertrophy goals, aim of adding cognitive stimulus within an already performance-oriented session.

Post-injury / rehabilitation population: task calibrated to residual motor capacity, emphasizing the proprioceptive/balance component paired with the visual stimulus, in line with the already established use of BlazePod in rehabilitation settings.

Populations with neurodegenerative disease: for the reasons discussed in Section 2.2, the Parkinson's population merits specific mention as a priority target for initial validation of the proposed model. Parkinson's disease is characterized not only by motor impairment but also by decline in executive function and slowed reaction time, often preceding overt motor symptoms. A low-density reactive task could serve simultaneously as a cognitive stimulus and, in a purely speculative and untested sense, as a longitudinal functional monitoring tool — an idea that falls outside the scope of this paper but could motivate dedicated future research. In this population specifically, the task should emphasize the discriminative/decisional component over pure motor response speed, calibrated to the patient's residual motor capacity.

3.5 Parameters Requiring Future Validation

The model, as proposed, leaves several operational choices open that would require instrumented validation before large-scale application: the optimal duration of the cognitive window within the pause (the entire pause or only a portion of it), the progression of cognitive load over time (fixed vs. adaptive based on performance), and the choice of the most sensitive outcome measures (reaction time, accuracy, standardized neuropsychological batteries, or biological markers as in the previous Parkinson's studies).

4. Hypothesis on Mental Fatigue in a Combined Protocol

A critical point, often overlooked in proposals of this kind, concerns what happens when a session combines a near-maximal muscular effort component with a high-attentional-density cognitive task. The Brain Endurance Training (BET) literature — protocols that deliberately combine physical effort and simultaneous cognitive tasks — offers mixed but informative indications.

On one hand, a line of research shows that prior mental fatigue (induced by a cognitive task before exercise) reduces subsequent strength and muscular endurance performance, an effect documented in both resistance training and bodyweight tasks (Brown et al., 2020). On the other hand, chronic combined-training protocols (weeks of training alternating physical effort and cognitive tasks) show adaptation over time: a 4-week pilot study in trained individuals found that systematically adding a cognitive task after each strength set not only did not impair performance but increased 1RM and muscular endurance, with a reduction in perceived mental fatigue over time — suggesting a central adaptation/habituation effect, not only a peripheral one (Rautu et al., 2025). A third line of research, on genuinely simultaneous (not sequential) high-physical-intensity dual tasks, shows an inverted-U pattern: cognitive performance tends to worsen only when physical intensity approaches very high thresholds (near-maximal, with prefrontal oxygen desaturation measured via NIRS), while at submaximal intensities the dual task is manageable without significant interference (Goepp et al., 2025).

Working hypothesis for the present model: the choice not to superimpose the two components (submaximal contraction in the impulse phase, cognitive task in the pause phase, never simultaneous) is consistent with the BET literature and reduces the risk of acute attentional-motor interference observed in near-maximal intensity protocols. However, this remains a hypothesis to be empirically validated regarding whether: (a) residual fatigue from one EMS contraction cycle affects the quality of the cognitive response in the immediately following cycle (a cascading interference effect between closely spaced cycles), and (b) as in chronic BET protocols, repeated exposure over time leads to an adaptation that reduces perceived cognitive cost, potentially allowing progression to higher EMS intensities without loss of cognitive task quality.

5. Limitations and Practical Implications

This work presents important limitations that must be explicitly stated. First, it is a conceptual proposal, not an empirical study: no primary data were collected to test the central hypothesis, and the specific combination of WB-EMS with reactive light systems has never been validated in the literature. Second, the model rests on a mechanistic analogy between two independently developed research strands — cognitive-motor sport and electromyostimulation — whose biological compatibility is plausible but unproven: it is unknown whether electrically induced muscle recruitment produces the same myokine and BDNF release profile observed during voluntary contraction in real sporting activity. Third, the proposed operational parameters (impulse/pause ratio, density and type of cognitive trials, load progression) are extrapolated from different contexts (sport, rehabilitation, BET) and require direct validation within the specific WB-EMS context.

From an applied standpoint, the model nonetheless has immediate operational value for practitioners: the cognitively oriented duty cycle structure (4-second submaximal impulse, 6-second cognitive window) is implementable immediately with already available commercial instrumentation (commercial WB-EMS devices, reactive light systems such as FITLIGHT or BlazePod), without requiring dedicated technological development. This makes the protocol a realistic candidate for initial pilot validation in applied settings, ahead of a large-scale randomized controlled trial.

Future Research Directions

A natural validation pathway involves three progressive phases: (1) a single-session pilot study comparing reaction time and accuracy of the cognitive task with and without superimposed WB-EMS, to verify the absence of acute interference; (2) a several-week study replicating the logic of chronic combined training (following the model of Rautu et al., 2025), measuring both motor outcomes (strength, endurance) and cognitive outcomes (reaction time, executive function) before and after the intervention; (3) a randomized controlled trial in populations differentiated by age and functional status, with both behavioral and biological outcome measures (neurotrophic markers, following the model of the existing Parkinson's studies).

6. Conclusions

Sports that integrate a motor component with real-time decisional load show superior cognitive benefits compared with purely repetitive exercise, plausibly through neuroplasticity mechanisms mediated by the muscle-brain axis. WB-EMS, though established as a total-body training technology, remains anchored to an almost exclusively motor paradigm, with direct evidence on cognitive outcomes still limited to a single randomized controlled trial in an older population. This work proposes a conceptual model to bridge this gap, integrating a reactive visuo-decisional task into the pause phase of the WB-EMS duty cycle, with a rationale explicitly framed as potentially lifespan-wide rather than confined to the older or clinical populations studied so far. If empirically validated, this approach could represent an accessible tool for delivering a combined cognitive-motor stimulus even to those unable to access coordinative sports, extending the field of application of WB-EMS beyond the purely muscular and metabolic outcomes for which it is currently known.

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Declaration of Generative AI Use

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Conflict of Interest Statement

The author declares that there is no conflict of interest. No commercial relationship exists with any WB-EMS device or reactive light system manufacturer mentioned in this paper.

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