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Review

Effects of Movement Representation Strategies on Cardiovascular Disease: A Literature Review

Ferran Cuenca-Martínez, Elena Muñoz-Gómez, Sara Mollà-Casanova and Núria Sempere-Rubio *

Department of Physiotherapy, University of Valencia, 46010 Valencia, Spain; ferran.cuenca@uv.es (F.C.-M.); elena.munoz-gomez@uv.es (E.M.-G.); sara.molla@uv.es (S.M.-C.)

* Correspondence: nuria.sempere@uv.es

Abstract: Motor imagery (MI) and action observation (AO) techniques are two movement representation strategies that are widely used in multiple fields of study. MI is defined as the cognitive skill that involves the representation of an action, internally, without actual motor execution. AO training evokes internally, and in real time, a simulation of the actual motor gestures that the observer is visually perceiving. Both cognitive processes cause an activation of the brain areas related to the planning, adjustment, and automation of voluntary movement in a similar way as when the action is carried out in a real way. Movement representation strategies have shown that they can be a very useful complement to physical practice to improve some particularly relevant aspects in neurological and musculoskeletal patients. In this narrative review, we discuss the effect that the implementation of these motion representation strategies might have on patients with cardiovascular disease. At the cardiovascular level, MI and AO training should be considered as interventional tools for the management of these patients. With these clinical tools, we could try to improve the generation of cardiopulmonary adaptations, improve exercise tolerability, and also increase functionality. However, more research is needed in this field where these clinical tools are combined with cardiac rehabilitation programs to see if the clinical effect is greater than cardiac rehabilitation programs in isolation.

Keywords: cardiovascular disease; heart failure; motor imagery; action observation

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1. Introduction

Movement representation strategies are a set of cognitive and dynamic processes widely studied in sport psychology, clinical physical therapy, and also in the field of cognitive neurosciences. It is practically impossible to analyze movement representation strategies without first considering two key brain processes that occur during these strategies: representation and brain processing [1]. A representation is a physical state that provides information symbolizing an entity (an object, an action, an event, etc.), a category, or a characteristic. The representation process has, in the first place, a format or codification, as it could be a real image, a drawing, or an action. Secondly, the representation always has an argument, referred to in terms of the meaning that a given representation communicates [1,2]. The same argument or content is capable of being conveyed in different formats (e.g., by verbal description, metaphorically, or also by images or codes, etc.). On the other hand, processing is the transformation of incoming information to produce a given response. It is, therefore, that the representations of movement require an information-processing system to be carried out. This process is complex and requires multiple interactions in order to be carried out [1].

There are two movement representation strategies that are widely used in multiple fields of study, such as the clinical-health-care field [3–5] or the sports field, on performance [6,7], among others. The first of these strategies is called motor imagery (MI) and the second corresponds to action observation (AO) training. MI is defined as the cognitive skill that involves the representation of an action, internally, without actual motor execution [8].

On the other hand, AO training evokes internally, and in real time, a simulation of the actual motor gestures that the observer is visually perceiving [9]. Both cognitive processes cause an activation of the brain areas related to the planning, adjustment, and automation of voluntary movement in a similar way as when the action is carried out in a real way [10,11]. Movement representation strategies have shown that they can be a very useful complement to physical practice to improve some particularly relevant aspects, such as the learning of specific motor skills, sports performance, or even to improve key psychosocial aspects inherent to those occurring during any competitive event [12,13].

Every time an individual prepares to perform a real movement voluntarily, it is previously subjected to a precise planning system through the action of the premotor and supplementary motor brain areas. These provide information to the motor cortex, which, based on this information, triggers information through the corticospinal pathways to the spinal cord, which, in turn, manages to reach the muscle effectors in order to perform the desired action, previously planned in the cerebral cortex [14]. Through neuroimaging, it has been found that when training is carried out using movement representation strategies, this brain activity, which occurs neurophysiologically before the generation of real voluntary movement, also occurs, although at a lower intensity [15,16]. Lebon et al. [17] even argued that the coincidence between the cortical activation of the areas related to the planning and execution of voluntary movement given during actual motor execution and that which occurs during brain training could provide, through neuroimaging, a reliable means of assessing the quality of movement representation.

The set of motor schemes and programs stored in the procedural memory systems allows for the generation of motor images without the need for an external stimulus, although it has been shown that providing visual information prior to an imagination task facilitates it and provokes greater neurophysiological activity than if it is performed in isolation [18]. Finally, both observation and imagination allow for the practice of voluntary and eligible movements without the need to perform them, which is why it has been widely used in the training of skills in different environments.

2. Movement Representation Strategies and Autonomic System

Both AO training and the MI process are capable of provoking an activation of the autonomic nervous system [19]. Recent studies, such as the one conducted by Cuenca-Martinez et al. [20], have found that training using movement representation strategies causes an increase in heart rate, respiratory rate, and skin electrodermal activity, even in brain training on simple, functional, low-complexity movements. This information supports, in a robust way, the findings previously found through the studies of very relevant authors in the field of cognitive neurosciences, authors such as Jeannerod, Decety, or Guillot, and their collaborative groups where they found similar results [19,21].

At the neurophysiological level, motor responses dependent on autonomic function are mediated, to a large extent, by the central nervous system, as shown by Vissing et al. [22] in the 1990s. Sympathetic pathways are modulated by the activity of the anterior cingulate cortex, and cardiovagal activity is under the control of the ventral medial prefrontal cortex [22]. The electrodermal activity of the skin is exclusively innervated by the sympathetic nervous system, thus missing the established precept of dual autonomic innervation (sympathetic/parasympathetic) that follows heart rate or respiratory rate parameters, and its neural networks involve the parietal cortex, insular cortex, and limbic system structures, including the medial temporal lobe, amygdala, and hippocampus [23]. Thus, when the sympathetic–excitatory nervous system is activated, there is a response in skin sweating, and when this sympathetic activation ceases, the physiological response stops. It is, therefore, that electrodermal activity is a good indicator that the sympathetic system is activated or, on the contrary, not. At the functional level, Collet et al. [19] conducted a thorough review of the state of the art in order to offer solutions regarding the functional relationships between movement representation strategies and the autonomic nervous system. The functional relationships between both neurocognitive processes and the autonomic nervous system could be based on a preparation phase, where the activation of the autonomic nervous system occurs at a forthcoming effort and, therefore, at a forthcoming energy expenditure where physiological processes, such as cardio-respiratory, temperature, and sweating adaptations, will take place in anticipation of the metabolic change produced by the voluntary movement itself. But, in addition, hypotheses have been described in relation to the fact that not only the autonomic nervous system has the qualitative aim of providing energy to the muscular effectors, but also, quantitatively, it designs and adapts the parameters on demand, in a specific way, in an attempt to economize the energy provided for each precise motor execution. However, the neurophysiological basis is for the moment based on hypotheses and requires further research to provide more solid and reliable data [19].

3. Movement Representation Strategies on Cardiovascular Disease

Both MI and AO training have been extensively studied at the clinical level in different populations of interest. For example, in patients with chronic musculoskeletal pain, Cuenca-Martínez et al. [24] found that adding movement representation strategies to usual physical therapy treatment showed beneficial effects in the management of chronic musculoskeletal pain. Similar results were found by Ferrer-Peña et al. [25]. Regarding functional and motor variables, such as gait, upper limb function, range of motion, activities of daily living, etc., movement representation strategies in combination with usual treatment have shown a positive effect on improving function, with a very low to moderate quality of evidence in neurological patients [26] and also in patients with musculoskeletal disorders due to immobilization or after surgery [27]. Table 1 shows a summary of some relevant papers where the effect of MI and AO has been tested in different clinical populations of interest.

Table 1. Summary of some previous research in the field of motor imagery and action observation training.

Authors	Population (Condition)	Interventions	Study Design	Results
Suso-Martí et al. [28]	Patients with musculoskeletal pain (musculoskeletal)	AO or MI + UC vs. UC	Systematic review and Meta-analysis	AO or MI + UC are capable of producing a decrease in pain intensity compared with UC, in both post-surgical and chronic pain.
Cuenca-Martínez et al. [24]	Patients with musculoskeletal pain (musculoskeletal) and patients with phantom limb pain and poststroke pain (neurological)	AO, MI, or MT + UC vs. UC	Umbrella review with Meta-meta-analysis	Results show that mental practice could be effective for chronic musculoskeletal pain. However, the results did not show a reduction in pain intensity in patients with phantom limb pain or poststroke pain.
Ferrer-Peña et al. [25]	Patients with total knee arthroplasty (musculoskeletal)	MI + UC vs. UC	Systematic review and Meta-analysis	Adding an MI to UC improved quadriceps strength and pain intensity, but the effects on range of motion and physical function was unclear.
Li et al. [29]	Patients with total knee arthroplasty (musculoskeletal)	MI + UC vs. UC	Systematic review and Meta-analysis	MI + UC achieved an effective treatment for strength enhancement, pain reduction and physical activities improvement.
Herranz-Gómez et al. [26]	Stroke patients (neurological)	AO or MI + UC vs. UC	Umbrella review with Meta-meta-analysis	MI and AO showed positive results for improving functional variables.
Benito-Villalvilla et al. [30]	Patients with multiple sclerosis (neurological)	AO, MI, or MT + UC vs. UC or no intervention	Systematic review	MI + exercises showed to be effective in the treatment of fatigue, gait, balance, depression, and quality of life. AO was useful in upper limb rehabilitation and improvement in attention, executive control, and activation of sensorimotor networks.
Gil-Bermejo-Bernardez-Zerpa et al. [31]	Patients with multiple sclerosis (neurological)	MI + UC vs. UC or no intervention	Systematic review	MI showed improvements in walking speed and distance, fatigue, and quality of life. In addition, several benefits were also found in dynamic balance and perceived walking ability.
Díaz-López et al. [32]	Stroke patients (neurological)	MI + UC vs. UC or no intervention	Systematic review	MI + UC was an effective method for the recovery of functionality after stroke.

Table 1. *Cont.*

Authors	Population (Condition)	Interventions	Study Design	Results
Fernández-Gómez and Sánchez-Cabeza [33]	Stroke patients (neurological)	MI + UC vs. UC or no intervention	Systematic review	MI, combined with conventional therapy, showed positive effects on the motor rehabilitation of the upper limb following a stroke.
Barreto-Monteiro et al. [34]	Stroke patients (neurological)	MI + UC vs. UC	Systematic review and Meta-analysis	MI has been shown to be an efficacious technique in the treatment of post-stroke patients when used as a complement to UC.
Kho et al. [35]	Stroke patients (neurological)	MI + UC vs. UC	Systematic review and Meta-analysis	Review of the literature revealed a trend in support of the use of MI for upper extremity motor rehabilitation after stroke.
Opsommer et al. [36]	Patients with spinal cord injury (neurological)	MI + other interventions vs. control	Systematic review	In most, results were an improvement in motor function and decreased pain.
Behrendt et al. [37]	Children and adolescents (healthy and neurological)	MI + physical practice vs. physical practice	Systematic review and Meta-analysis	MI combined with physical practice might have a high potential for healthy and impaired children and adolescents.
Paravlic et al. [38]	Adults (healthy)	MI alone; MI alone vs. physical practice and MI + physical practice vs. physical practice	Systematic review and Meta-analysis	Results showed that compared to a no-exercise control group of healthy adults, MI practice increases maximal voluntary strength, but less than physical practice.
Liu et al. [38]	Young and old adults (healthy)	MI alone; MI alone vs. physical practice and MI + physical practice vs. physical practice	Systematic review and Meta-analysis	Results showed that MI has better estimated effects on enhancing maximum voluntary muscle contraction force compared to no exercise but is inferior to physical practice. The combination of MI + physical practice is equivalent to physical practice in isolation in enhancing muscle strength.

Notes: AO: Action Observation; MI: Motor Imagery; vs.: versus; UC: Usual Care; MT: Mirror Therapy.

However, there is limited scientific literature regarding the impact of movement representation strategies on patients with cardiovascular disease. The research group led by de Souza et al. [39] published an Editorial in 2019 regarding this topic with the aim of asking what implication the MI could have regarding the modulation of cardiovascular variables and whether it could be implemented in patients with cardiorespiratory alterations in addition to physical exercise, with the aim of increasing effectiveness, as well as facilitating the performance of physical practice or even carried out in isolation.

The article by de Souza et al. [39] comments, firstly, that MI is capable of promoting a chronotropic effect, an inotropic effect, as well as an increase in arterial pressure (baroreflex modulation) [39]. These variations are probably caused by the similarities in the cortical areas responsible for the preparation and scheduling of the same motor task, which control cardiopulmonary feedforward responses during the performance and imagination of an activity [39]. Finally, De Souza et al. [39] commented on something very interesting, which is that, to date, the impact of movement representation strategies on the neurovegetative system has been studied mainly in healthy subjects or athletes but not in patients with cardiovascular disease. MI and AO training could probably be applied to cardiac rehabilitation, alongside the standardized cardiovascular rehabilitation program. For example, De Souza et al. [39] commented that patients with heart failure in the most severe functional classes (III and IV) according to the New York Heart Association (NYHA) usually have a very low tolerance to therapeutic physical exercise. These patients could benefit from the use of MI and AO as clinical intervention strategies, both in isolation and in combination with physical exercise to improve exercise tolerability, elicit greater cardiopulmonary and metabolic adaptations, and also improve functional variables.

In fact, recently, de Souza et al. [40] worked on their hypothesis and transferred their ideas to research by conducting a study with the aim to assess the clinical effects of MI on cardiopulmonary variables in patients with heart failure. De Souza et al. selected twenty patients with type II heart failure according to the NYHA, and after performing a real and imagined exercise of the two-minute walk test, they found that MI elicited an increase in heart rate and respiratory frequency similar to that occurring in healthy subjects. De Souza et al. [40] concluded that the anticipatory cardiopulmonary response of patients with heart failure was immediately modulated by MI activity in a safe manner, but further studies are needed to investigate the effects of MI associated with cardiovascular physical therapy.

Within cardiovascular diseases, there is one disease in particular that we believe patients suffering with could benefit greatly from the application of movement representation strategies. We are referring to patients undergoing open valve surgery or coronary artery bypass surgery. People undergoing this type of surgery seem to have a loss of motor function for days or even weeks, depending on the type of intervention. In addition, these patients seem to present alterations in autonomic regulation, and we believe that they could benefit from performing MI and AO during these early phases of rehabilitation, in isolation, with the aim of minimizing the impact of inactivity and, in addition, later, it could be complemented with the usual treatments (involving pharmacology, physical therapy, and other types of intervention) with the aim of improving parameters related to strength, gait, and cardiorespiratory fitness. In reality, this could be applicable to any intervention process that results in physical downtime. This could be considered a priority in mental practice research in this field of study.

Finally, with regard to research priorities in the field of mental practice and cardiovascular disease, we believe that research in this field should begin in depth. Patients with cardiovascular diseases, and also with cardiorespiratory pathology, could benefit if we add to the usual rehabilitation programs of movement representation techniques, as it could have an impact on different clinical variables of interest, such as improvements in strength, physical fitness, motor control, gait related variables, etc. Future studies should be conducted to test this and see the potential of these sensorimotor training tools in these clinical populations before transferring to clinical practice, as has happened in different neurological as well as musculoskeletal populations.

4. Conclusions

Both MI and AO training are clinical tools of great potential that have been shown to be effective in combination with physical practice on different variables of interest, as well as in different clinical populations, such as neurological or musculoskeletal patients. At the cardiovascular level, MI and AO training should also be considered as interventional tools for the management of these patients. With these clinical tools, we could try to improve the generation of cardiopulmonary adaptations, improve exercise tolerability, and also increase functionality. However, more research is needed in this field where these clinical tools are combined with cardiac rehabilitation programs to see if the clinical effect is greater than cardiac rehabilitation programs in isolation. Finally, consideration could also be given to implementing these techniques in isolation at times when physical practice is not possible.

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