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OPINION
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Motor Simulation as an Adjunct to Patient Recovery Process Following Intensive Care Unit Admission

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INTRODUCTION

Individuals commonly admitted to the intensive care unit (ICU) for acute respiratory failure, due to pulmonary or neuromuscular disease, shock and the need for airway protection or temporary respiratory support after major surgery, are generally placed on invasive mechanical ventilation support. The recovery processes of these patients is uncertain (the longer the duration of respiratory assistance, the more uncertain the vital prognosis) (1) and will take time even with the application of respiratory weaning process (i.e., spontaneous breathing periods alternated with respiratory assistance; enabling patients to gradually come back to unsupported spontaneous breathing) before leaving ICU (2). As these patients suffer from post-mechanical ventilation physical, cognitive, and mental sequelae, in addition to comorbidities (3), maximizing their recovery is therefore paramount to reduce any disabling experiences and to avoid the menace of relapse following discharge and consecutive risk of readmission (2).

It would be beneficial to adopt a multidisciplinary approach by pooling knowledge from the healthcare system—e.g., respiratory medicine and sport medicine—to advance the understanding of the (post-) ICU recovery process which will allow practitioners to set up the most beneficial rehabilitation program (4). In this view, based on neuroscience findings, we propose that Jeannerod's theory (5, 6) related motor simulation would be a useful complement to physiotherapy, motor rehabilitation and other accompanying interventions (e.g., speech therapy, nutritional, and psychological support) to optimize patients' return to autonomy.

WHAT IS MOTOR SIMULATION AND WHY INTRODUCING AFFERENT INFORMATION DURING MOTOR SIMULATION?

Ventilation support for 2–4 weeks and respiratory weaning care (i.e., alternating spontaneous breathing periods with respiratory assistance) result in significant muscle atrophy and weakness (3, 7). It imposes great challenge for optimal recovery from respiratory muscle fatigue due to patients' low breathing capacity, inability to perform basic movements and fatigability. Interestingly, motor simulation offers a motor learning/relearning alternative process without performing any movement (8). Briefly, an individual is engaged in motor simulation when he/she is able to imagine, observe or verbally describe a movement (**Figure 1**) (8). According to Jeannerod (5, 6), motor imagery or action observation (called covert stage) and action execution (called overt stage) share a common activation of cortical motor systems. Of interest, overt stages could be replayed off-line through motor simulation that enables the brain to represent the sensorial consequences and future states of simulated actions. In the field of neuroscience, systematic scientific reviews and meta-analysis have shown, first, that the imagination or the observation of a movement activates a

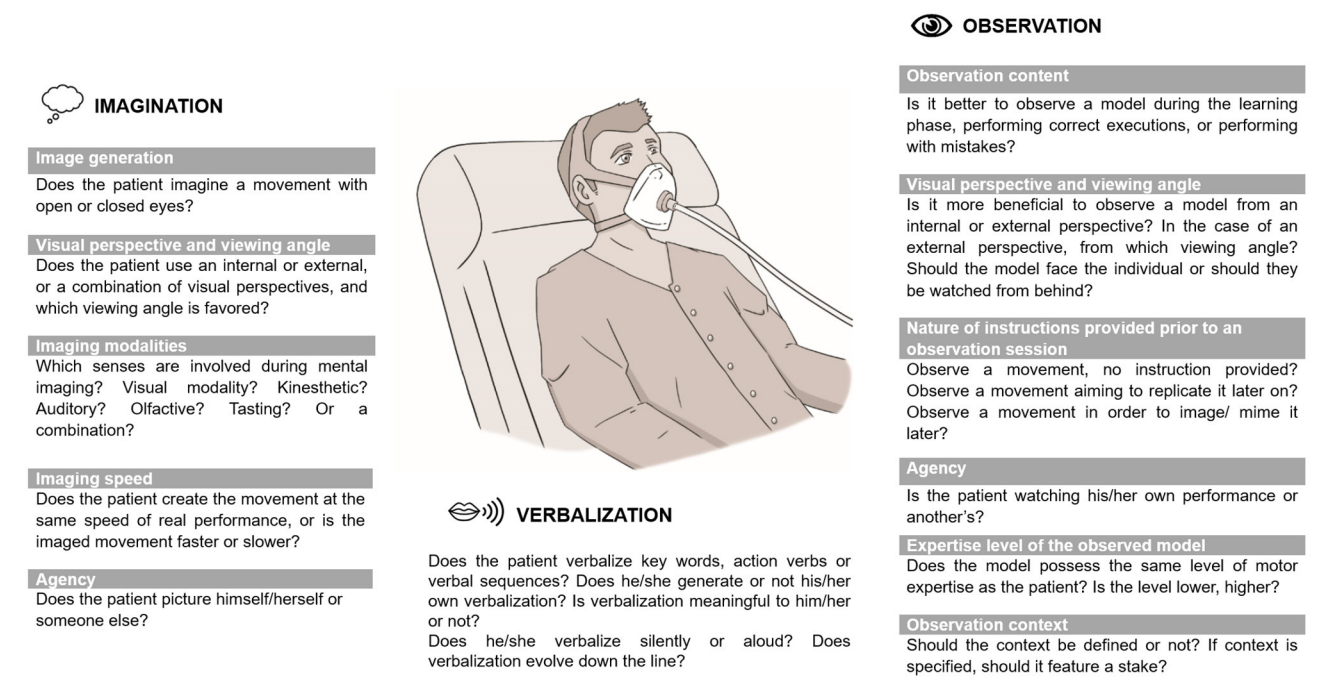

FIGURE 1 | Principles to be considered and tailored to patients' individual needs for an efficient motor simulation process.

premotor-parietal and primary somatosensory network similarly to the one involved during "real" movement execution (9); second, that premotor and primary motor areas are activated during arm or leg movement verbalization and execution (10); third and last, as suggested almost two decades ago (11), that human brain is provided by internal motor efference copies between simulated (imagined, observed, verbalized) and "real" movements (12–14). While simulating or performing movements, these internal forward models are enrolled to predict movement-induced future states and sensorial consequences. Thus, simulated movements are movements except for the fact they do not generate motor output which is blocked by a motor command inhibitory mechanism (5, 6).

However, during a motor simulation, the absence of sensorimotor feedback (i.e., sensorimotor consequences of the motor command) could inactivate the somatosensory processes underlying movement representation, thereby restricting the impact of motor simulation on motor learning/relearning process (15). In the same vein, others have argued that peripheral (proprioceptive and haptic) information is essential for accessing and maintaining motor representations stored in the brain and that, in their absence, these representations fade and even cease to be accessible (16). For instance, the effects of transient sensorimotor deprivation following orthopedic trauma in patients with no prior neurological deficits revealed motor execution impairments and maladaptive plasticity in the somatosensory and motor cortices including shrinkage of somatosensory cortical maps, decreased cortical excitability, reduced cortical thickness in the sensorimotor cortex, decreased of fractional anisotropy in the corticospinal tract and decreased interhemispheric inhibition from the impacted to the non-impacted hemisphere (8). The impaired functioning of internal forward models (referring to the interactions between motor commands and environment, useful to predict the sensory consequences of an action) accounts for these alterations. Though, these models need to be updated through experience (i.e., training that can be translated into changes in synaptic weights which will improve future forward model prediction) to operate reliably (11). Because of the lack of sensorimotor input (proprioceptive, haptic) in the case of immobilization for instance, forward models remain available but are no longer updated, generating an inaccurate prediction of sensory consequences, and thus initiating unskilled and inefficient movements (11). Consequently, integrating afferent information (i.e., proprioceptive and haptic) during motor simulation should be encouraged (i.e., mimicking a movement and handling an object related to a specific movement) (8). It has been reported that mimicking a movement concomitantly to its motor/mental simulation increases its technical quality and efficacy (17).

WHAT IS THE EVIDENCE FOR A POSITIVE IMPACT OF MOTOR SIMULATION IN REAL-WORLD CLINICAL PRACTICE?

Studies probing the effects of motor simulation interventions prescribed alongside motor rehabilitation to recover from detrimental effects of transient sensorimotor deprivation are

scarce in individuals without any neurological history (8). Notably, in patients over 60 years who underwent total hip and knee arthroplasty surgery were instructed to feel the sensations of movements they mentally simulated, results indicated some benefits through an increased motor performance following observation of locomotor tasks (18) and greater quadriceps strength subsequent to the imagination of knee flexion-extension (19). These positive outcomes are deemed to be due to equivalences between simulated and executed movements (18, 19), to the integration of proprioceptive information during motor simulation (8, 17), to the combination of motor rehabilitation and simulation sessions (18, 19), and to cortical plasticity in response to internal or external constraints such as motor learning or training interventions (8, 18, 19). The scientific community hence agrees that cortical changes in healthy individuals exposed to motor learning/training are seen in brain areas and networks related to the physical execution of movements.

WHY USING MOTOR SIMULATION FOR ICU AND POST-ICU PATIENTS?

Despite the lack of scientific evidence promoting motor simulation benefits to ICU and/or post-ICU patients so far, its integration in the rehabilitation process could appear as a very promising adjunct for the following reasons.

First, delivering early active mobilization and rehabilitation in ICU, when the cardiovascular, respiratory and neurological states of patients are stable (20), has been shown to improve the rehabilitation outcomes (improved muscle strength, functional capacity and mobility; increased number of ventilator-free day and discharged-to-home rate) (21). In this view, motor simulation can be helpful in the early rehabilitation process (i.e., when the patient is temporarily completely or partially unable to move, too weak to exercise or subject to the use of supportive devices), as it offers a motor learning/relearning alternative without requiring patient to perform any movement (8). Whenever possible, it is important to alternate motor simulation and movement execution, whether active or assisted, within the same session, as the benefit of this approach has been demonstrated (18, 19).

Second, because ICU patients suffer from sensory deprivation increased by the interference of sedative and analgesic medication, it is essential to provide visual, proprioceptive, haptic information during motor simulation (e.g., watching a video of a movement, mimicking it, handling an object related to this movement). Interestingly, as observing an object automatically potentiates actions associated to it (22), showing objects that patient used in their daily lives will activate action representations (e.g., reaching or grasping actions when a mug is shown).

Third, depending on an individual's ability to use motor simulation techniques (e.g., patients with poor imagery ability), on his/her fatigability, motivation and individual needs, a variety of different simulation packages could be offered for an optimal motor simulation process. The **Figure 1** summarizes the available motor simulation techniques that can be used alone or in combination (i.e., preferably associated with miming a movement and/or handling an object related to this movement to generate afferent information during (motor) simulation) and declined under varied modalities (8) to personalize the intervention in reference to the patient's requirements.

CONCLUDING REMARKS

The present opinion aimed to promote motor simulation as a plausible non-invasive, safe, easy to implement and low cost complementary adjunct among the healthcare delivery provided during the (post-) ICU recovery process. Hopefully, the ICU practitioners and their multidisciplinary healthcare professionals will consider motor simulation as a practical, relevant and therapeutic option to maximize patient's return to autonomy.

AUTHOR CONTRIBUTIONS

The authors listed have made substantial, direct, and intellectual contribution to the work and approved it for publication.

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