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Using Motor Imagery Therapy to Improve Movement Efficiency and Reduce Fall Injury Risk

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Abstract

Physiotherapy interventions have proven to play an important role in preventing and rehabilitating fall injury in the elderly. An important goal of such programs is to modify risk factors and thereby reduce the likelihood for future falls. Recent research observations suggest that one such factor is the ability to mentally represent and plan movements, an ability that declines with advancing age. In addition to physiotherapy exercise for balance, mobility and stabilizing strength, the use of motor imagery practice, a form of mental representation, has gained interest in the clinical community. Recent research findings highlight the merits of combining physiotherapy with motor imagery practice. Such practice has the potential to help the individual maintain motor (action) planning networks while recovering from brain and/or muscle injury. Another, more proactive approach, is to use motor imagery practice to improve action planning and subsequent movement efficiency. This brief review highlights research findings on mental representation and motor imagery, notes implications for the elderly, and provides recommendations for practice strategies to improve motor planning and potentially lower risk of movement-related injury.

Keywords: Mental representation; Aging; Motor imagery; Action representation; Action planning

Introduction

The ability to mentally represent and effectively plan motor actions underscores one's successful intentions and lowers injury risk. Recent research findings highlight the fact that as individuals enter older adulthood, the ability to mentally represent their intentions and successfully plan actions, declines. With the present article, we focus on the potential of using motor imagery practice, a form of mental representation, to improve motor planning and potentially reduce the risk of fall injury. The idea being that in addition to physiotherapy exercises, motor imagery practice can aid in reducing fall injury risk. With that understanding, we can develop strategies to improve motor representation among people, especially the elderly. The development of such strategies can lead to enhanced quality of life for this growing population in the US. With this paper, we will: (1) briefly review the idea of mental representation associated with action planning and motor imagery, (2) discuss the difficulty that has been described with older adults, (3) provide a summary of selected studies testing various practice methodologies using motor imagery, and finally, (4) provide strategies for motor imagery practice.

Mentally Representing Action and Motor Imagery

Mental representation

The ability to mentally represent one's intentions is a central issue for understanding cognitive and motor behavior across the lifespan. Mental representation has been described as an internal cognitive construct that represents external reality. One commonly associated form of mental representation is motor imagery, a key modality for the creation of representations [1]. Motor imagery, the focus of this paper, involves the creation of representations involving action in the context of movement planning and subsequent execution, that is, action representation. Most motor programming theories support the notion that action representation is a key feature in effective action planning. One prominent view contends that action representation involves an internal (forward) model, which is a neural system that mentally simulates the dynamic behavior of the body in relation to the environment [2-4]. The theory proposes that internal models make predictions (estimates) about the mapping of the self to parameters of the external world. The result is processes that enable successful planning and execution of action. Accompanying the forward model propositions, and central to the discussion here, is the widely acknowledged observation that simulation in the form of motor imagery provides a window into the process of action representation [5-8].

Motor Imagery (MI)

The ability to imagine future events and estimate consequences is an essential part of the human cognition process. MI is defined as an internal rehearsal or reenactment of movements from a first-person perspective without any overt physical movement. From another perspective, MI, also known as kinesthetic imagery, is an active cognitive process during which the representation of a specific action is internally reproduced in working memory without any overt motor output [9]. In addition to the reasonable case that MI is a reflection of action representation and motor planning; studies have found that there is a high correlation between real and simulated movements [10-13]. Furthermore, evidence has been reported showing that MI follows the basic tenets of Fitts' Law [14,15]. That is, simulated movement duration, like actual movement, increases with increasing task complexity. As opposed to visual imagery, defined as the internal enactment or reenactment of perceptual experiences [16], neuroimaging and neuropsychological studies indicate that MI is more affected by biomechanical (kinesthetic) constraints that are commonly associated with action processing [15,17].

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One of the interesting hypothesized features of motor imagery is its role in the prediction of one's actions [11,12]. Suddendorf and Moore [18] note, "The ability to imagine future events is an essential part of human cognition" (p. 295). Imagery allows us to generate specific predictions based upon past experience and allows us to answer 'what if' questions by making explicit and accessible the likely consequences of a specific action. Mental simulations generate knowledge about specific past events, and therefore make specific predictions [19]. One of the important aspects of an action plan is the ability to predict the outcome and consequences of intended actions. Imagining an action can serve several useful goals to that endeavor. According to Bourgeois and Coello [20], motor representation can be viewed as a component of a predictive system, which includes a neural process that simulates through motor imagery the dynamic behavior of the body in relation to the environment. This line of reasoning presents noteworthy developmental issues associated with a person's cognitive understanding of environmental (perceptual) information and consequences, and one's physical capabilities.

Mental representation in the elderly

Recent observations indicate that the ability to mentally represent motor actions declines with advancing age [21-29]. The following are a few brief summaries of that work in regard to the general decline with age. Mulder et al. [24] compared young and older adults on vividness of movement imagery via questionnaire. The researchers found that older adults were slightly worse than their younger counterparts, especially from a first person perspective. Although not examined with that study, a possible link between level of physical activity and imagery ability was suggested. The assertion was that physical exercise in the elderly might help preserve brain structures and mechanisms (frequently mentioned is the parietal cortex) associated with mental representation. Personnier et al. [25], used a mental chronometry paradigm to compare imagined and executed arm pointing actions between young and older adults. They reported that although it appeared that older adults displayed the ability to mentally represent action via use of motor imagery, their ability progressively deteriorated with advancing age as evidenced by the declining quality of their MI (i.e. isochrony between executed and imagined movements). The authors concluded that there was a likelihood of weakness in the formulation of internal models of action in the elderly. Testing the ability to mentally simulate/plan a complex sequential action of the whole body (i.e., rising from the floor), Saimpont et al. [26] reported that the elderly experienced significant difficulties compared to young adults' accuracy in action sequence and reaction time. In a more recent review of this body of research [27], the authors concluded that MI accuracy for simple/usual upper-limb movement's appears well preserved with aging. However, advanced aging did appear to affect the preservation and MI accuracy of upper-limb actions with unusual biomechanical constraints.

A real-world example and fall risk

To illustrate the application of research findings to possible real-world and everyday situations confronting the elderly, reports of functional reach and reach estimation via motor imagery would appear to have clinical implications. Functional reach, a frequently reported assessment with the elderly, is the maximal distance an individual is capable of reaching forward while standing, without taking a step or losing balance. It is described as a dynamic measure of postural control. The literature supports the observation that with advancing age there is a sharp decline in functional reach [30,31]. Perhaps most relevant to considerations of safety, research also indicates a significant relationship between functional reach and risk of falling [32,33]. Additionally, in a recent study of young adults (mean age 22 years) and older adults (66 years) examining the relationship between estimation of reach and functional reach, Gabbard and Cordova [34] reported that only the younger group showed a significant and positive association between the two variables. In other words, the congruence between movement planning (estimation) and execution was significantly better with the younger group, as compared to the older adults.

What is the connection between functional reach and estimation of reach? Estimation of whether an object is reachable or not from a specific body position constitutes an important aspect in efficient and effective motor planning; a situation that has both scientific and real-world implications. One of the initial steps in programming such movements is to derive a perceptual estimate of the object's distance and location relative to the body. This means that an individual must be able to perceive critical reach distances beyond which a particular reach action is no longer afforded and to which a transition to another reach mode must occur. For example, is the object close enough to reach while seated, or do I need to stand? Furthermore, with older persons, could I lose balance and fall? Such questions are not uncommon in everyday situations, for example: reaching for an object on a table or reaching and grasping a hand rail. An experimental tactic that provides insight into this phase of motor planning (estimation) is estimation of reach via use of MI. Use of that tactic has drawn the attention of researchers that wish to examine the processes involved in action representation and planning [35,36].

Over estimation (Over optimistic?)

Using the estimation of reach paradigm, Gabbard et al. [37] reported that younger adults (mean age 20 years) were significantly more accurate than older adults (mean age 77 years) when estimating reach in peripersonal and extra personal space from a seating position. Whereas, both groups made more errors in extrapersonal space, the values were significantly higher for the older group; that is, they over estimated to a greater extent. Caçola et al. [38] reported that accuracy decreased as age increased when estimating reachability in peripersonal and extrapersonal space using a 40 cm tool; the population ranged from 55 to 92 years. Lafargue et al. [39] also comparing young and older adults, reported a failure of the older group to update their internal model when asked to judge in advance whether or not they could stand on an inclined plane. As predicted, the older adults significantly overestimated their capabilities. A similar finding of overestimation with advanced aging was reported by Noël et al. [40] and Sakurai et al. [41]. Both studies examined estimation of ability to step over an obstacle. In their conclusions, Noël et al. noted that the overestimation could be a major risk of falls in the elderly.

To summarize, it would appear that older persons have difficulty estimating possible movement outcomes and updating internal models, resulting in dissociation between perception and action, a condition that may promote risky motor planning and execution.

Implications and therapeutic applications

According to the Centers for Disease Control and Prevention website, "Each year, one in every three adults age 65 and older falls." "Among older adults (those 65 or older), falls are the leading cause of injury death." These statistics display the critical need to better understand the factors that constrain the elderly in regard to mental representation and movement planning. Understanding these factors, like the connection between reaching and falling, can allow for the development of strategies to enhance movement efficiency and lower associated injury risk.

In support of the reach-fall link, four of 16 items on the Activities-Specific Balance Confidence (ABC) Scale [42] are reach-specific questions. This test is commonly cited as a self-report subjective measure of perceived balance confidence in performing various movement activities without falling. With the elderly, compared to younger adults, there is a higher risk of falling during reach actions. For example, if an older adult either significantly underestimates or overestimates a reach target (e.g., drinking glass, table, and railing), they may have more difficulty than a younger person in maintaining postural control, often resulting in a fall.

One proven effective therapy strategy for the recovery of motor planning and control is MI practice. Use of MI has been documented as an effective tool for: sport/motor performance [43-46], brain injury [47], stroke [48-51] and other neuromotor impairments, e.g., [52]. In the context of neurological impairment, the literature suggests that one of the key agents in movement recovery is use of MI to stimulate otherwise non-active or impaired neural pathways. In addition, Wohldmann et al. [53] reported evidence to support the hypothesis that mental practice strengthens abstract mental representation that does not involve specific effectors. That is, such practice strengthens 'central' features of the representation as well as representation of specific body part processes, such as the hand and fingers.

Of the training studies reviewed, unfortunately little has been reported using older adults. One particular study was conducted by Guttman et al. [48], who tested the effectiveness of MI practice with a group of older persons (mean age 69 years) with chronic hemiparesis. Practice involved performance of sit to stand and reaching to grasp movements. The researchers found that MI practice has a positive effect on actual execution.

Strategies for improving motor imagery ability

As noted earlier, information on motor imagery training with the elderly is sparse. Based in large part on the literature and our experience with such training, although individual differences and capabilities should be a significant consideration, the target age group recommendation is 65 to 85 years. In regard to training strategies for specific impairments associated with stroke for example, once again the patient should be considered in light of the individual impairment and extent of the disability in reference to mental and physical constraints.

From the information derived from the studies described here and reviews on the general topic of MI practice [54,55], the following recommendations and strategies appear worthy of consideration; that is, used in combination with physiotherapy or as a stand-alone therapy to improve motor planning.

Clear and effective script of instructions: The script of instructions should be used in early practice phases and needs to be as specific as possible. For example: "Watch and feel your hand and fingers reaching and grasping the mug. How will you grasp the mug and how fast will you move as not to spill its contents?"

Goal-setting: This is an important element of practice and a strategy that can be induced via the script, verbally, or in combination as reinforcement.

First person internalizing: That is, focus on the self as the mental image of the intended action. This state is the first component in the actor-object dyad. Part of this dyad is an understanding of one's physical capabilities and potential consequences. Ask the participant to consider the consequences if he or she were to miss-plan (over- or underestimate) the event. What will you fall into? Do you feel confident in your ability to gain stability if you have to adjust your position quickly?

Concentrate on the effectors: This is the specific part of the self that is linked with the target. For example, focus on the arm/hand when intending to reach and grasp an object.

Focus on the visual cues (target/object/goal): Concentrate on the end point of the intended action–the target. For example, where does my hand need to be to grasp the object securely? With tasks such aiming at a target, when timing is a factor, auditory cues in the form of a metronome have been effective.

Reinforcement on kinesthetically 'feeling' execution of movement: Research indicates clearly that 'feeling' rather than just seeing oneself perform the action promotes better mental representation for movement via internalization.

Combine physiotherapy with mental practice: By practicing actual movements, participants gain a better understanding of their physical capabilities and develop movement endurance, a problem that is common in the elderly. Physical practice affords the opportunity to test one's capabilities. Furthermore, research shows that mental practice combined with physical practice enhances actual performance outcome [55,56].

Progress from simple to more complex actions: Do this when practicing both imagined and actual execution movements.

Practice 15-60 minutes, 3 times/week for 4 weeks: This has been one of the most commonly reported practice durations with a variety of patient impairments. Obviously, this should be viewed as an approximate benchmark with the progression principle strictly applied.

Summary

The intent of this paper was to bring attention to the benefits of motor imagery and propose potential use of motor imagery practice (therapy) in the physiotherapy setting. Research indicates that such practice can improve motor planning, subsequently reducing the risk of fall injury, especially in the elderly. Whereas motor imagery practice can be a stand-alone program, there is good evidence that when used in combination with physical practice, results for improved overall motor performance can be significant.

References

1. Kosslyn SM, Thompson WL, Ganis G (2006) The case for mental imagery. Oxford University Press, New York.
2. Penhune VB, Steele CJ (2012) Parallel contributions of cerebellar, striatal and M1 mechanisms to motor sequence learning. Behav Brain Res 226: 579-591.
3. Schubotz R (2007) Prediction of external events with our motor system: towards a new framework. Trends Cogn Sci 11: 211-218.
4. Wolpert DM (1997) Computational approaches to motor control. Trends Cogn Sci 1: 209-216.
5. Chabeauti PY, Assaiante C, Vaugoyeau M (2012) Extreme short-term environmental constraints do not update internal models of action as assessed frommotor imagery in adults. Neuroscience 222: 69-74.
6. Jeannerod M (2001) Neural simulation of action: a unifying mechanism for motor cognition. Neuroimage 14: S103-S109.
7. Munzert J, Lorey B, Zentgraf K (2009) Cognitive motor processes: the role of motor imagery in the study of motor representations. Brain Res Rev 60: 306-326.
8. Wintermute S (2012) Imagery in cognitive architecture: representation and control at multiplelevels of abstraction. Cogn Syst Res19-20: 1-29.
9. Decety J, Grezes J (1999) Neural mechanisms subserving the perception of human actions. Trends Cogn Sci 3: 172-178.

10. Burianová H, Marstaller L, Sowman P, Tesan G, Richl AN, et al. (2013) Multimodal functional imaging of motor imagery using a novel paradigm. Neuroimage 71: 50-58.

11. Kunz BR, Creem-Regehr SH, Thompson WB (2009) Evidence for motor simulation in imagined locomotion. J Exp Psychol Hum Percept Perform 35: 1458-1471.

12. Lorey B, Bischoff M, Pilgramm S, Stark R, Munzert J, et al. (2010) The embodied nature of motor imagery: the influence of posture and perspective. Exp Brain Res 194: 233-243.

13. Lorey B, Nauman T, Pilgramm S, Peterman C, Bischoff M, et al. (2013) How equivalent are the action execution, imagery, and observation of intransitive movements? revisiting the concept of somatotopy during action simulation. Brain Cogn 81: 139-150.

14. Solodkin A, Hlustik P, Chen EE, Small SL (2004) Fine modulation in network activation during motor execution and motor imagery. Cereb Cortex 14: 1246-1255.

15. Stevens JA (2005) Interference effects demonstrate distinct roles for visual and motor imagery during the mental representation of human action. Cognition 95: 329-350.

16. Barsalou LW (2008) Grounded cognition. Annu Rev Psychol 59: 617-645.

17. Pelgrims B, Andres M, Olivier E (2005) Motor imagery while judging object-hand interactions. Neuroreport 16: 1193-1196.

18. Suddendorf T, Moore C (2011) Introduction to the special edition: the development of episodic foresight. Cogn Dev 26: 295-298.

19. Moulton ST, Kosslyn SM (2009) Imagining predictions: mental imagery as mental emulation. Philos Trans R Soc London 364: 1273-1280.

20. Bourgeois J, Coello Y (2009) Role of inertial properties of the upper limb on the perception of the boundary of personal space. Psychol Française 54: 225-239.

21. Beauchet O, Annweiler C, Assal F, Bridenbaugh S, Hermann RR, et al. (2010) Imagined timed up & go test: a new tool to assess higher-level gait and balance disorders in older adults? J Neurol Sci 294: 102-106.

22. Caçola P, Roberson J, Gabbard C (2013) Aging in movement representations for sequential finger movements: a comparison between young, middle-aged, and older adults. Brain Cogn 82: 1-5.

23. De Simone L, Tomasino B, Marusic N, Eleopra R, Rumiati RI (2013) The effects of healthy aging on mental imagery as revealed by egocentric and allocentric mental spatial transformations. Acta Psychol (Amst) 143: 146-156.

24. Mulder T, Hochstenbach JBH, Heuvelena MJG, Otter AR (2008) Motor imagery: the relation between age and imagery capacity. Hum Mov Sci 26: 203-211

25. Personnier P, Bally Y, Papaxanthis C (2010) Mentally represented motor actions in normal aging III: electromyographic features of imagined arm movements. Behav Brain Res 206: 184-190.

26. Saimpont A, Mourey F, Manckoundia P, Pfitzenmeyer P, Pozzo T (2010) Aging affects the mental simulation/planning of the ‘‘rising from the floor’’ sequence. Arch Gerontol Geriatr 51: e41-e45.

27. Saimpont A, Malouin F, Tousignant B, Jackson P (2013) Motor imagery and aging. J Mot Behav 45: 21-28.

28. Skoura X, Personnier P, Vinter A, Pozzo T, Papaxanthis C (2008) Decline in motor prediction in elderly subjects: right versus left arm differences in mentally simulated motor actions. Cortex 44: 1271-1278.

29. Zapparoli L, Invernizzi P, Gandola M, Verardi M, Berlingeri M, et al. (2013) Mental images across the adult lifespan: a behavioural and fMRI investigation of motor execution and motor imagery. Exp Brain Res.

30. Costarella M, Monteleone L, Steindler R, Zuccaro SM (2010) Decline of physical and cognitive conditions in the elderly measured through the functional reach test and the mini-mental state examination. Arch Gerontol Geriatr 50: 332-337.

31. Zuccaro SM, Steindler R, Scena S, Costarella M (2012) Changes of psychical and physical conditions in the elderly after a four-year follow-up. Arch Gerontol Geriatr 54: 72-77.

32. Duncan PW, Weiner DK, Chandler J, Studenski S (1990) Functional reach: a new clinical measure of balance. J Gerontol 45: M192-M197.

33. Huang H, Gau M, Chuan W, Kernohan G (2003) Assessing risk of falling in older adults. Public Health Nurs 20: 99-411.

34. Gabbard C, Cordova A (2013) Association between imagined and actual functional reach: a comparison of young and older adults. Arch Gerontol Geriatr 56: 487-491.

35. Coello Y, Bartolo A, Amiri B, Devanne H, Houdayer E, et al. (2008) Perceiving what is reachable depends on motor representations: evidence from transcranial magnetic stimulation study. PLoS ONE 3: e2862.

36. Lamm C, Fischer MH, Decety J (2007) Predicting the actions of others taps into one's own somatosensory representations: a functional MRI study. Neuropsychologia 45: 2480-2491.

37. Gabbard C, Cacola P, Cordova A (2011) Is there an advanced aging effect on the ability to mentally represent action? Arch Gerontol Geriatr 53: 206-209.

38. Caçola P, Martinez A, Ray C (2012) The ability to modulate peripersonal and extrapersonal reach space via tool use among the elderly. Arch Gerontol Geriatr 56: 383-388.

39. Lafargue G, Noël M, Luyat M (2013) In the elderly, failure to update internal models leads to overoptimistic predictions about upcoming actions. PLoS ONE 8: e51218.

40. Noël M, Bernard A, Luyat M (2011) The overestimation of performance: a specific bias of aging? Geriatri Psychol Neuropsychiatr Vieil 9: 287-294.

41. Sakurai R, Fujiwara Y, Ishihara M, Higuch T, Uchida H, et al. (2013) BMC Geriatr 13: 44.

42. Powell LE, Myers AM (1995) The activities-specific balance confidence (ABC) scale. J Gerontol A Biol Sci Med Sci 50A: M28-M34.

43. Gentili R, Han CE, Schweighofer N, Papaxanthis C (2010) Motor learning without doing: trial-by-trial improvement in motor performance during mental training. J Neurophysiol 104: 774-783.

44. Guillot A, Tolleron C, Collet C (2010) Does motor imagery enhance stretching and flexibility? J Sports Sci 28: 291-298.

45. Zhang H, Xu L, Wang S, Xie B, Gui J, et al. (2011) Behavioral improvements and brain functional alterations by motor imagery training. Brain.

46. Lebon F, Collet C, Guillot A (2010) Benefits of motor imagery training on muscle strength. J Strength Cond Res 24: 1680-1687.

47. Oostra KM, Vereecke A, Jones K, Vanderstraeten G, Vingerhoets G (2012) Motor imagery ability in patients with traumatic brain injury. Arch Phys Med Rehabil 93: 828-833.

48. Guttman A, Burstin A, Brown R, Bril S, Dickstein R (2012) Motor imagery practice for improving sit an stand and reaching to grasp in individuals with poststroke hemiparesis. Top Stroke Rehabil 19: 306-319.

49. Hosseini SA, Fallahpour M, Syadi M, Gharib M, Haghgoo H (2012) The impact of mental practice on stroke patient's postural balance. Journal of the Neurol Sci.

50. Malouin F, Richards CL (2010) Mental practice for relearning locomotor skills. Phys Ther 90: 240-251.

51. Sharma N, Simmons LH, Jones PS, Day DJ, Carpenter TA, et al. (2009) Motor imagery after subcortical stroke: a functional magnetic resonance imaging study. Stroke 40: 1315-1324.

52. Heremans E, Nieuwboer A, Spildooren J, De Bondt S, D'Hooge AM, et al. (2012) Cued motor imagery in patients with multiple sclerosis. Neuroscience 206: 115-121.

53. Wohldmann EL, Healy AF, Bourne LE (2008) A mental practice superiorityeffect: less retroactive interference and more transfer than physical practice. J Exp Psychol Learn Mem Cogn 34: 823-833.

54. Langhome P, Coupar F, Pollock A (2009) Motor recovery after stroke: a systematic review. Lancet Neurol 8: 741-754.

55. Schuster C, Hilfiker R, Amit O, Scheidhauer A, Andrews B, et al. (2011) Best practice for motor imagery: a systematic literature review on motor imagery training elements in five different disciplines. BMC Med 9: 75.

56. Reiser M, Busch D, Munzert J (2011) Strength gains by motor imagery with different ratios of physical to mental practice. Front Psychol 2: 194.