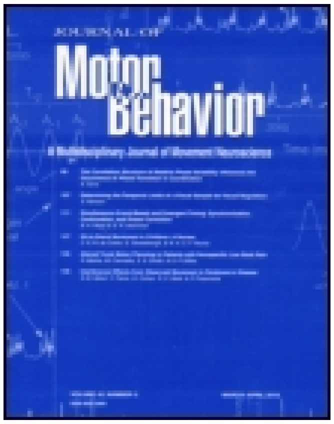

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REVIEW ARTICLE

Motor Imagery and Aging

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ABSTRACT. Motor imagery (MI) is the mental simulation of an action without its actual execution. It has been successfully used through mental practice—the repetition of imagined movements—to optimize motor function either in sport or rehabilitation settings. Healthy elderly individuals facing age-related impairments in motor function could also benefit from this method of training–retraining. The authors review studies that have investigated MI in physically and mentally healthy adults aged 55 years and older. First, they provide an overview of the psychophysical data on MI in the elderly, which show no changes with aging in the ability to imagine simple–usual movements but reveal some age-related alterations in the mental simulation of difficult–unusual movements. Second, they present emerging neuroimaging and neurostimulation data revealing that the sensorimotor system is engaged during MI in older adults. Finally, the authors emphasize the potential of using mental practice as a safe and easy way to help preserving/improving motor function in the elderly and provide some recommendations for future research in this direction.

Keywords: aging, mental practice, motor imagery

One exciting property of the human brain is its capacity to simulate the external world as well as behaviors, even in the absence of external stimulation. For motor acts, the ability to imagine or mentally simulate an action without any overt output is often referred as motor imagery (MI) ability. In young adults, there is accumulating evidence of functional similarities between imagined and executed actions, notably regarding the temporal characteristics, neural correlates and autonomic responses associated with both states (see Decety, 1996; Jeannerod, 1995; Munzert & Zentgraf, 2009). The demonstration of these similarities has refueled the interest for mental practice (or MI training; i.e., the repetition of imagined movements with the intention of improving motor function). Mental practice has been widely used by athletes to enhance their performance (see Feltz & Landers, 1983; Murphy, 1994) and its efficiency to help retrain motor function in people with physical disabilities has received increasing attention since the 2000s (see Dijkerman, Ietswaart, & Johnston, 2010; Jackson, Lafleur, Malouin, Richards, & Doyon, 2001; Malouin & Richards, 2010).

Curiously, there are very few reports on the use of MI training specifically with healthy older adults. Yet, even normal aging is associated with motor impairments affecting gait, balance and coordination (see Seidler et al., 2010). Hence, mental practice could be used to help reducing the impact of age-related decline in motor function (and thus eventually help preserving functional autonomy in the elderly). As the ability to form mental representations of movements is a prerequisite to engage in mental practice (Malouin, Richards, Jackson, & Doyon, 2010), there is a need to explore whether and how MI ability evolves with aging to potentially adapt mental practice accordingly. In this perspective, in the present article we review studies that have investigated MI in physically and mentally healthy adults aged 55 years and older. First, we discuss the psychophysical data indicating that MI ability for simple and unconstrained movements is well preserved with aging whereas it may be altered for constrained movements. Second, we present the results on the neural basis of MI in the elderly, which show that the core regions underpinning MI in younger adults are also engaged in older adults. Finally we report the scarce literature on MI training with older adults and touch on future research directions to promote the use of mental practice to help preserving/improving motor function in the elderly.

Is MI Ability Preserved With Aging?

Due to its mental and covert nature, MI cannot be directly observed and must be accessed by self-reports or via its behavioral or neurophysiological correlates. Three dimensions of MI are classically studied: the vividness of the motor representations, the temporal characteristics of the simulated movements, and the accuracy of MI (see McAvinue & Robertson, 2008). All three dimensions have been explored to varying degrees in the elderly.

MI Vividness and Aging

Movements can be mentally simulated from a first-person perspective (i.e., as if one is the actor of the action) or from a third-person perspective (i.e., as if one is a spectator of the action). During first-person MI, an individual elicits kinesthetic sensations or visual representations of the action as if he or she were actually performing it; during third-person MI, visual representations are primarily involved, as if an individual were observing him- or herself or someone else executing the action. The vividness of MI refers to the content of MI (i.e., the clarity of the images or the intensity of the sensations perceived during the mental simulation of the movement). This property is generally assessed via self-report questionnaires, which contain explicit instructions to imagine movements and where subjects typically rate the vividness by means of Likert-type scales. To date, two studies have specifically documented the effects of aging on MI

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vividness, by comparing vividness scores in three different age groups. Each study, however, has used a different MI questionnaire, one that assesses visual MI from both perspectives, and one that assesses visual and kinesthetic MI from the first-person perspective.

Hence, Mulder, Hochstenbach, van Heuvelen, and den Otter (2007) used the Vividness of Movement Imagery Questionnaire (VMIQ; Isaac, Marks, & Russel, 1986) with young (*M* age = 24.8 ± 3.0 years), intermediately aged (*M* age = 44.1 ± 10.0 years), and older (*M* age = 74.2 ± 5.4 years) adults to assess the clarity of images formed during either first- or third-person MI of 24 more or less complex movements of the limb and the body. In this questionnaire, for each movement and perspective, subjects are asked to report the level of clarity of their mental images by means of a 5-point Likert-type ordinal scale ranging from 1 (*perfectly clear and as vivid as normal vision*) to 5 (*no image at all*). Whatever the perspective taken, subjects of the three age groups reported having formed moderately clear images of movements (mean vividness scores superior to 2). Interestingly however, whereas no differences were found between groups in their vividness scores for the third-person perspective, the vividness scores for the first-person perspective were significantly less good in the older adults than in the middle-aged and younger adults. This latter result indicates that the elderly could be better at forming visual motor images in the third-person compared with the first-person perspective. The authors suggested that this difference could result from the age-related decline in physical activity that leads older adults to spend more time watching others moving that actually moving.

By means of the Kinesthetic and Visual Imagery Questionnaire (KVIQ; Malouin et al., 2007), which includes 10 simple movements involving either the upper-limb, the lower-limb or the trunk, Malouin, Richards, and Durand (2010) explored the vividness of kinesthetic and visual first-person MI in young (*M* age = 26.0 ± 5.0 years) intermediate (*M* age = 53.6 ± 5.4 years) and elderly (*M* age = 67.6 ± 4.6 years) subjects. For each movement, the clarity of images and the intensity of sensations perceived are rated on a 5-point Likert-type scale from 1 (*no image/no sensation*) to 5 (*image as clear as when seeing the movement/sensation as intense as when executing the movement*). Younger, middle-aged, and older adults were able to create moderately clear images and intense sensations of movements since their vividness scores were, in average, superior to 3. Also, whereas the young and intermediate subjects had significantly higher visual than kinesthetic scores—as classically reported in the literature (see Malouin, Richards, & Durand, 2010)—this visual dominance was no longer observed in the elderly. Considering the links between MI and working memory (Decety, 1996; Malouin, Belleville, Richards, Desrosiers, & Doyon, 2004), the authors suggested that this loss of visual dominance could be associated with the greater decline in visuospatial working memory compared with kinesthetic working memory found in the elderly subjects of their study. Of note is the fact that although Mulder et al. (2007) and Malouin, Richards, and Durand used a different questionnaire, their findings argue for an age-related decrease of vividness during first-person visual MI. Likewise, in a recent study from our group (Saimpont, Malouin, Tousignant, & Jackson, 2012), a lack of visual dominance during first-person MI has also been documented with the short version of the KVIQ in elderly subjects (*M* age = 72.7 ± 5.5 years). However, Heremans et al. (2011) did not find such a loss of visual dominance in healthy older adults (*M* age = 61.1 ± 6.6 years) whose KVIQ scores were significantly higher for visual MI compared with kinesthetic MI. A possible explanation for these findings that seem contradictory is that the older group in the study of Heremans et al. was younger compared with the older groups in the previous studies. Another potential explanation could be that visuospatial working memory was preserved in the subjects of the Heremans et al. study, but this was not tested.

To sum up, the main finding from the studies reported in this section is that, based on MI scores, older adults appear able to form mental representations of movements as vividly as younger adults. However, an age-related alteration in MI vividness for first-person visual MI would also take place—possibly after 65 years—but this qualitative change in MI remains to be further documented.

Temporal Characteristics of MI and Aging

If movement execution and MI—at least first-person MI—involve similar central processes, their duration should be close. Furthermore, the movement rules and constraints (spatiotemporal, biomechanical) that apply during actual execution should also be taken into account during MI and consequently affect its duration (see Jeannerod, 2006). Indeed, results from chronometric studies in young adults indicate that the durations of mentally simulated and physically executed movements are similar for a large variety of tasks (Decety, Jeannerod, & Prablanc, 1989; Landauer, 1962; Sirigu et al., 1996; see Guillot & Collet, 2005). This phenomenon may be referred as the temporal congruence between MI and movement execution. While in young adults the temporal congruence is not affected by movements' constraints, recent findings indicate that in older adults it is not always maintained when they imagine constrained movements.

Hence, for unconstrained upper-limb movements such as pointing visual targets at natural speed (Personnier, Paizis, Ballay, & Papaxanthis, 2008; Skoura, Papaxanthis, Vinter, & Pozzo, 2005; Skoura, Personnier, Vinter, Pozzo, & Papaxanthis, 2008) as well as for usual whole-body movements such as walking on short distances (Schott & Munzert, 2007; Skoura et al., 2005) or sit-to-stand/stand-to-sit movements (Skoura et al., 2005), the temporal congruence between MI and movement execution has been shown equivalent in younger and older adults. However, for constrained movements such as fast and accurate arm movements between targets of decreasing sizes, the temporal congruence appears altered with aging (Personnier, Ballay, &

Papaxanthis, 2010; Skoura et al., 2005; Skoura et al., 2008). Indeed, in these studies, while both young and elderly subjects progressively slowed down as the size of the targets decreased during movement execution—thus following Fitts's law (Fitts, 1954)—only the younger adults displayed the same speed–accuracy trade-off during MI (in older adults, the duration of MI tended to stay constant whatever the size of the targets). This lack of time modulation during MI with increasing spatiotemporal constraints has also been reported for whole-body movements such as walking on narrow (Personnier, Kubicki, Laroche, & Papaxanthis, 2010) and long (Schott & Munzert, 2007) paths. Also, Personnier et al. (2008) showed a lack of temporal congruence in older adults (*M* age = 70.1 ± 4.5 years) for arm movements performed with a load in the hand (thus presenting unusual dynamical constraints). This age-related dissociation between the correct integration of the movement constraints during their actual execution but not during their mental simulation suggests that motor control in older adults could rely more on online feedback mechanisms—absent during MI—than in their younger counterparts (Poston, Van Gemmert, Barduson, & Stelmach, 2009).

On the other hand, when asked to execute and imagine the timed up and go test that includes five subtasks—rising from a chair, walking 3 m forward, turning around, walking back to the chair, and sitting down—older adults (*M* age = 65.3 ± 7.3 years) demonstrated a good temporal congruence between the imagination and execution conditions for each subtask as well as for the whole sequence (Malouin, Richards, Jackson et al., 2010). The latter results indicate that the temporal congruence can be maintained with aging for a relatively complex task involving sequential constraints. Also, in a recent study conducted by Heremans, Nieuwboer, Feys et al. (2012), older adults (*M* age = 61.1 ± 6.6 years) had to physically and mentally transport 20 blocks with the hand, as fast as possible, from one side of a box to the other. This task thus presented spatiotemporal constraints. MI was performed under three conditions: (a) with visual cues (i.e., subjects were allowed to see the box and the blocks during MI), (b) with auditory cues (no vision of the box and blocks was provided but a metronome paced the movements of the subjects during MI), and (c) without visual or auditory cues. Results showed that MI was performed significantly more slowly than actual execution in the conditions without cues or with auditory cues. However, there were no differences between imagined and executed times in the condition where visual information was provided. This finding indicates that the addition of visual cues may help elderly subjects to reproduce the temporal characteristics of constrained movements during MI (note that Heremans et al. [2009] had already reported that young subjects could benefit from visual cueing). Interestingly, in the same spirit, Saimpont et al. (2012) showed that when required to actually walk and imagine walking (by simultaneously forming kinesthetic and visual representations of walking movements, which was a demanding task), both young (*M* age = 23.2 ± 2.4 years) and elderly (*M* age = 72.7 ± 5.5 years) subjects presented a better temporal congruence when they imagined walking while being in a standing position (congruent with walking) compared with a sitting position (incongruent with walking).

It is worth noting that, in the study by Skoura et al. (2005), two groups of elderly subjects were in fact included, one aged 62–67 years and the other one aged 71–75 years, and only the performance of the oldest subjects significantly differed from that of young controls. Also, Schott and Munzert (2007) showed that the temporal congruence between overt and covert walking was more or less important depending on the distance to cover and whether the participants were in their sixties, seventies, or eighties. Precisely, whereas similar actual and imagined durations were found for walking distances from 7 to 25 m in older subjects aged 57–69 years and in younger controls, this temporal congruence was found only from 7 to 22 m in subjects aged 70–79 years and from 7 to 13 m in subjects aged over 80 years. In these two latter groups, covert walking times did not increase after 22 and 13 m, respectively. Although these latter results should be taken with some caution because of the restricted samples (female participants only) and the small number of trials performed by the subjects (one by condition), together with the results of Skoura et al. (2005), they suggest that the age-related alterations in the integration of the movement constraints during MI could begin around the seventh decade of life. Note, however, that, beyond age, other factors not assessed in these studies such as working memory and the level of the subjects' physical activity could also have accounted for the differences in MI ability between the older groups.

In sum, the ability of the older adults to reproduce the temporal characteristics of movements during MI seems preserved for simple and usual movements but may be altered for unusual and constrained movements, a least in the oldest subjects. External (visual) and internal (postural) cues may help the elderly increase the temporal congruence between simulated and executed movements.

Accuracy of MI and Aging

Another interesting dimension to take into account when exploring MI is the accuracy of motor representations (Heremans et al., 2011; Malouin & Richards, 2010). This dimension may be explored by means of tasks where subjects imagine—most of the time implicitly—a movement in order to make a decision about some visual stimuli (see McAvinue & Robertson, 2008). A typical example of such tasks is the hand-laterality task in which an individual has to judge the laterality of rotated pictures of hands (Parsons, 1987). Here the motor nature of the mental process involved in solving the task may be inferred from the response times' profiles (see Jeannerod & Frak, 1999) and MI accuracy from the correctness of the responses (Heremans et al., 2011; Sharma, Jones, Carpenter, & Baron, 2008).

Saimpont, Pozzo, and Papaxanthis (2009) asked young (*M* age = 23.9 ± 2.8 years) and elderly (*M* age = 78.3 ±

4.5 years) subjects to determine the laterality of images of hands presented in two different views (back and palm) and four different orientations (0°, 90° with fingers facing away from the body, 90° with fingers facing toward the body, 180°). Response times' results indicated that both age groups solved the task by mentally rotating their own hands from their current position to the orientation of the stimuli for comparison. Indeed, in the two groups, response times increased with the length of the hand trajectories as well as with the biomechanical constraints on the arm movements that would be performed to actually match the subjects' hands with the hand stimuli. The older adults performed the task with high accuracy overall (*M* accuracy = 90%), albeit they were less accurate than their younger counterparts (*M* accuracy = 98%). More precisely, whereas the percentage of correct responses was similar for all stimuli in the younger group, they were significantly lower for the hand stimuli presented in palm view at 90° with fingers facing away from the body (*M* accuracy = 83%) and for the hands shown in back view at 180° (*M* accuracy = 70%) compared with the other stimuli (*M* accuracy = 94%) in the older group. Interestingly, these two stimuli elicit the simulation of movements that mobilize the arm joints to their limits, whereas the other stimuli involve the simulation of movements relatively free of biomechanical constraints. In a subsequent study, Devlin and Wilson (2010) required young (*M* age = 23.6 years) and elderly (*M* age = 74.5 years) subjects to solve a hand-laterality task in which pictures of hands were presented in a back view and in six different orientations (between 0° and 180° in 30° increments in either a clockwise or an anticlockwise direction). Response times' results indicated that both age groups performed the task by mentally moving their upper limbs. Concerning the percent of correct responses, the elderly subjects were overall very accurate (*M* accuracy = 91%) and their performance was not statistically different from that of the younger subjects (*M* accuracy = 94%). Also, here, no particular drop in performance was found for the hands shown at 180° in the older group. This is possibly due to the fact that the task used by Saimpont et al. (2009) was more difficult than that used by Devlin and Watson (2010) because the hand stimuli could be seen in two different views in the former, whereas they were shown only in a single view in the latter (palm down). Finally, a mean accuracy of 85% was found in elderly subjects (*M* age = 61.1 ± 6.6 years) required to discriminate between left and right hands presented in four different views (back, palm, ulnar, radial) and twelve different orientations (30° steps; Heremans et al., 2011). This score is again rather good if we consider the number of different postures (48) in which the hand stimuli could be seen. Note that the separate results for the different views and orientations are not reported in this study.

To our knowledge, only two other studies have used different approaches to assess MI accuracy in the elderly. First, by means of a reachability judgment task, Gabbard, Cacola, and Cordova (2011) have shown that older adults (*M* age = 77.1 ± 8.6 years) were less accurate than younger ones (*M* age = 20.1 ± 1.5 years) at estimating—through the simulation of movements of their arm—the reachability of an object placed at different spatial locations in front of them. However, some caution should be exercised in interpreting these results because other factors not controlled for in this experiment such as potential age-related changes in depth perception could have accounted for these findings. For their part, Saimpont, Mourey, Manckoundia, Pfitzenmeyer, and Pozzo (2010) used a puzzle task in which young (*M* age = 26.6 ± 4.9 years) and elderly (*M* age = 85.2 ± 5.5 years) subjects were required to put in order six images depicting the main movements necessary to get up from the floor. Here, the ability of the subjects to retrieve the correct sequence of images served as an indicator of MI accuracy. It was shown that whereas 100% of the younger subjects were able to complete the task correctly, only 68% of the older subjects succeeded. However these results should also be interpreted with some caution because the task also involved planning skills. Furthermore, the fact that the elderly subjects were very old could explain the great difference in performance found between age groups.

Hence, MI accuracy for usual upper-limb movements appears well preserved with aging whereas it may be affected for upper-limb movements with strong biomechanical constraints or requiring the integration of the peripersonal space limits, as well for a complex sequential action involving the whole body. As we have seen that the seventh decade of life seems critical in the ability to preserve the temporal characteristics of movement during MI, future researchers should include older adults from a wider range of age to better characterize the effects of aging on MI accuracy.

Altogether, the studies that examined the effects of aging on the different dimensions of MI tended to show that the ability of older adults to mentally simulate movements is generally preserved but would depend to some extent on the level of the movements' constraints—in particular spatiotemporal and biomechanical—as well as on the age of the elderly.

Age-Related Changes During MI at the Brain Level

In healthy young adults, it has been repeatedly shown that first-person MI activates different regions of the sensorimotor system and that its efficiency as a training–rehabilitation technique is thought to come from this characteristic (Jackson, Lafleur, Malouin, Richards, & Doyon, 2003; Jeannerod, 2006; Malouin & Richards, 2010). It is thus important to identify whether the motor network is also engaged when older adults imagine movements.

The existing functional magnetic resonance imaging and transcranial magnetic stimulation studies on MI with older adults already shed some light on the neural underpinnings of MI in this population. First, during first-person MI of upper-limb and whole-body movements, it appears that older adults do recruit motor-related brain regions classically involved in mental simulation of movements. These regions include the premotor cortex, the supplementary motor area, subcortical structures such as the cerebellum and the basal ganglia (Nedelko et al., 2010; Zwergal et al., 2010), the inferior parietal cortex (Nedelko et al., 2010), the somatosensory and motion-sensitive visual cortices (Zwergal et al., 2010), and even the primary motor cortex (Hovington & Brouwer, 2010; Leonard & Tremblay, 2007). Second, the activity in most of these regions was found to be more prominent in elderly subjects compared with young controls (Nedelko et al., 2010; Zwergal et al., 2010). This greater activity could possibly reflect compensation mechanisms for age-related changes in the brain and help maintain performance in older adults, as it has been shown for actual execution of movements (see Seidler et al., 2010) as well as for tasks involving executive functions, episodic memory, or working memory (see Reuter-Lorenz & Park, 2010). However, future neuroimaging studies should control for MI compliance during the scanning process (e.g., by reporting concomitant measures of vividness or accuracy) to determine whether this age-related overactivity actually underlies good or poor MI ability, especially during the imagination of constrained movements. Third, the transcranial magnetic stimulation study of Leonard and Tremblay (2007) showed a lack of selectivity in the corticospinal excitability in elderly subjects (M age $= 62.0 \pm 6.0$ years) compared to young controls (M age $= 24.0 \pm 2.0$ years) during the execution and imagination of a cutting movement. More precisely, whereas a facilitation of the motor evoked potentials recorded in the main muscle involved in the task was observed in both groups, the older adults also displayed motor evoked potentials facilitation in another muscle less directly involved in the movement. This lack of corticomotor selectivity is in line with other findings showing a reduced ability to perform fine movements—which require a selective recruitment of muscles—with normal aging (see Krampe, 2002) and the fact that it is observed during both the executed and imagined conditions provides support for a cortical origin of this age-related change in motor control. Finally, Hovington and Brouwer (2010) studied how corticospinal excitability was modulated during first-person kinesthetic MI of a finger movement either triggered by a video or by verbal instructions, in young (M age $= 24.7 \pm 2.4$ years) and elderly (M age $= 67.2 \pm 7.0$ years) subjects. An increase in excitability during MI compared with rest was observed in both age groups. Furthermore, an interesting dissociation was shown between groups insofar as the level of corticomotor facilitation was higher for visually guided MI in the younger adults whereas it was greater for auditory-cued MI in the older adults. While this would need to be tested systematically, it is tempting to link this result with the age-related decrease in visual dominance found by Malouin, Richards, and Durand (2010). Indeed both findings argue for a reduction of the relative importance of visual information during first-person MI with aging.

Hence, although some age-related changes in the neural basis of MI have been shown, such as a greater brain activity and a lack of corticospinal selectivity, the sensorimotor system appears to be involved during MI performed by elderly subjects much as it is in younger ones. The functional significance of the brain activity during MI of unconstrained and constrained movements in older adults remains to be determined.

Toward Mental Practice in the Elderly

The results discussed in the previous sections of this review have revealed some age-associated alterations when imagining unusual–constrained movements as well as some age-related changes in brain activation during MI. However, it is important to emphasize that the ability to mentally simulate simple–usual movements—that we could term basic MI ability—is not altered with aging and that the older adults do engage the sensorimotor system during MI. Overall, these results suggest that it is viable to use MI as a tool to enhance motor performance in healthy older adults, as this approach has been found useful for other populations such as people with physical disabilities (see Dijkerman et al., 2010; Malouin & Richards, 2010; Schuster et al., 2011). With mental practice, motor training is less physically demanding; in fact, it has been shown that combining series of mental repetitions with a small amount of physical repetitions can provide similar benefits than physical repetitions alone (Pascual-Leone et al., 1995; Reiser, Busch, & Munzert, 2011). Such training regimen appears particularly relevant for older adults, as it makes possible to train also persons with less physical endurance or who fatigues quickly.

Yet, to date, results reported by the few studies that have specifically explored MI training in the elderly (Fansler, Poff, & Shepard, 1985; Hamel & Lajoie, 2005; Jarus & Ratzon, 2000; Linden, Uhley, Smith, & Bush, 1989; Surburg, 1976) are not really conclusive because only two have shown that it was advantageous to use mental practice, either alone compared with rest (Hamel & Lajoie, 2005), or combined with physical practice compared with physical practice alone (Jaruz & Ratzon, 2000). However, except in the Hamel and Lajoie's study, MI ability of the participants was not assessed in the studies, and it is possible that the subjects included in the other studies were not sufficiently able to imagine movements to benefit from MI training. Hence, in future work targeting mental practice in older adults, MI ability of the participants should be carefully assessed. For that purpose, the use of MI questionnaires as well as mental chronometry paradigms and hand-laterality tasks would be well suited. These tools have already been used, separately or in combination, to assess MI ability in several populations such as patients with stroke (e.g., Malouin, Richards, Durand, & Doyon, 2008a, 2008b; Sharma et al., 2009), Parkinson's disease (Heremans et al., 2011), or multiple sclerosis (Heremans, Nieuwboer, Spildooren et al., 2012). In particular, it has been shown that the combination of the KVIQ, a mental chronometry task, and a hand-laterality task, provides an extensive assessment of MI ability (Heremans, Nieuwboer, Feys et al., 2012). Another important challenge for future researchers will be to find the optimal ratio between mental and physical practice, depending on the action to perform and the level of fatigability of the targeted elderly subjects. Finally, MI compliance of the participants during mental practice should be controlled, for example by asking them to report the clarity an intensity of their images and sensations, but also by using more objective methods such as the recording of physiological measures from the autonomic system, as suggested by some authors (see Collet, Guillot, Lebon, MacIntyre, & Moran, 2011).

Considering the optimization of MI training with elderly subjects, the results discussed in this review help to provide some specific recommendations. First, because there are some age-related alterations in the mental simulation of constrained movements (Saimpont et al., 2009; Skoura et al., 2005), older adults should begin their mental practice with relatively simple movements and progressively integrate more difficult movements. Second, external cues could be used to facilitate MI and thus potentially optimize the training. Following the results of Hovington and Brouwer (2010) reported previously, it seems that auditory cues should be most suitable. However, the choice of visual or auditory cues could also depend on the modality of MI adopted. Indeed, in the study of Hovington and Brouwer (2010) where auditory cues facilitated more MI than visual cues, subjects were instructed to perform kinesthetic MI. In contrast, in the study of Heremans, Nieuwboer, Feys et al. (2012) in which visual cues were found more efficient than auditory cues, subjects performed visual MI. Hence, although further research would be needed to confirm this point, auditory cues could be more useful for kinesthetic MI whereas visual cues could be preferentially used for visual MI. Finally, as MI may be facilitated by adopting a posture congruent with the task (Saimpont et al., 2012) we suggest that the subjects' posture should be congruent to the movement to practice during MI training, to the extent possible.

Conclusion

Results from psychophysical studies show that, with aging, MI ability—as assessed by its vividness, temporal characteristics, and accuracy—is globally well preserved for simple movements but may be altered for difficult movements. Also, neurophysiological data indicate that older adults, much as younger ones, do recruit the motor system during mental simulation of movements. These findings provide support for the use of mental practice in the elderly population. It is important to underline that MI training is a no-cost, safe, and easy way to improve motor function. It appears especially advantageous for the elderly because it provides a unique opportunity to engage safely in training–retraining of actions while reducing physical demands and thus reach levels of performance beyond what can be achieved with physical practice alone. Novel applications of mental practice with the elderly definitely deserve more consideration in future research.

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