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Motor and mental training in older people: Transfer, interference, and associated functional neural responses

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ABSTRACT

Learning new motor skills may become more difficult with advanced age. In the present study, we randomized 56 older individuals, including 30 women (mean age 70.6 years), to 6 weeks of motor training, mental (motor imagery) training, or a combination of motor and mental training of a finger tapping sequence. Performance improvements and post-training functional magnetic resonance imaging (fMRI) were used to investigate performance gains and associated underlying neural processes. Motor-only training and a combination of motor and mental training improved performance in the trained task more than mental-only training. The fMRI data showed that motor training was associated with a representation in the premotor cortex and mental training with a representation in the secondary visual cortex. Combining motor and mental training resulted in both premotor and visual cortex representations. During fMRI scanning, reduced performance was observed in the combined motor and mental training group, possibly indicating interference between the two training methods. We concluded that motor and motor imagery training in older individuals is associated with different functional brain responses. Furthermore, adding mental training to motor training did not result in additional performance gains compared to motor-only training and combining training methods may result in interference between representations, reducing performance.

1. Introduction

The ability of humans to acquire new motor skills is important throughout life. However, during normal aging, atrophy affects the human brain, including regions central to motor learning (Jernigan et al., 2001; Liu et al., 2003; Raz et al., 2005). Thus, learning new motor skills may become more difficult with advanced age and may rely on partially different neurophysiological processes compared to younger individuals (Sawaki et al., 2003; Seidler et al., 2010). This is supported by studies showing that older individuals have qualitatively different brain activation patterns compared to young individuals when performing simple movements (Calautti et al., 2001; Hutchinson et al., 2002; Ward and Frackowiak, 2003) or more complex coordination tasks (Heuninckx et al., 2005). A more widespread activation pattern has been found involving bilateral motor brain regions (Sharma and Baron, 2014) as well as non-motor brain regions (Zapparoli et al., 2013), indicating a need for extra resources and higher level of processing, possibly reflecting a compensatory process in order to maintain performance levels (Heuninckx et al., 2005; Heuninckx et al., 2008; Ward and Frackowiak, 2003). Notably, how these marked differences influence motor learning in aging is still not well understood. Some suggest that the aging brain has a different ability to respond to training (Sawaki et al., 2003), whereas others have suggested that, even though the rate of learning may be slower, motor memory storage and retrieval functions are preserved (Smith et al., 2005).

Motor training is not the only alternative to learning motor skills. Motor imagery training, also known as mental training, has also been shown to be an efficient strategy for acquiring new motor skills (Nyberg et al., 2006; Olsson et al., 2008a) or improving already skilled actions (Olsson et al., 2008b). The ability to mentally represent actions, such as sequential finger movements, appears to be preserved through older adulthood (Caçola et al., 2013), but a greater temporal difference between executed and mentally simulated movements has been observed with older people being faster during motor imagery of the action compared with the actual execution of the action (Personnier et al., 2010). Similar to motor execution, brain activity during motor imagery appears to be more widespread in older individuals with an

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overall shift towards a more bilateral motor cortex appearance (Sharma and Baron, 2014) and over-recruitment of non-motor regions (Zapparoli et al., 2013).

The aim of this study was to investigate performance gains and associated underlying neural networks after motor, mental, and combined motor and mental training in older individuals. We also wanted to examine whether adding mental training to motor training results in additional performance gains. We previously showed that performance improvements following either motor or mental training for a finger-tapping task in young individuals rely on partially different neural systems (Nyberg et al., 2006; Olsson et al., 2008a) with no additional performance gain by adding mental training to motor training. Given that motor learning is possible even at older ages (Voelcker-Rehage, 2008), we hypothesized that the underlying neural networks would be broadly similar as in our previous study (Olsson et al., 2008a), with motor training resulting in a representation in the premotor cortex and mental training resulting in a representation in the secondary visual cortex.

A second aim was to examine the specificity of motor learning in older individuals. Seidler (2007) suggested that transfer and motor acquisition are distinct processes and that the transfer of learning remains intact in old age. In young individuals, we found that transfer following 6 weeks of finger-tapping training was limited to those who performed a combination of motor and mental training (Olsson et al., 2008a). Considering that motor learning is still intact, though slower, in older individuals (Daselaar et al., 2003), we hypothesized that the effects of training would be similar to what young individuals experience after a shorter length of training (Nyberg et al., 2006) with a general facilitation of tapping performance reflected by increased performance in an untrained motor task regardless of training method.

2. Method

2.1. Participants

A total of 56 healthy older participants, including 30 women (mean age 70.6 years, standard deviation [SD]=5.2, range 60–81 years), were recruited via local advertisement. Background characteristics are presented in Table 1. Participants provided written informed consent prior to the start of the study and were compensated with 500 SEK for their participation. Exclusion criteria included extensive experience playing a musical instrument or other tasks requiring finger motor skills, low cognitive functioning, or having metallic non-removable objects in the body. None of the participants reported any psychiatric illness or undergone brain or heart surgery. All participants reported being generally healthy. Self-reported handedness and the Edinburgh Handedness Scale (Oldfield, 1971), which creates a laterality index ranging from positive 100 (strongly right-handed) to negative 100 (strongly left-handed), were also collected during pre-test. We did not use any specific cut-off in the present study, but we used the index to quantify the participants' handedness. Two participants had an Edinburgh Handedness Scale score that contradicted their self-reported handedness. One participant reported being left-handed but was right-handed according to the scale (score=25). The other participant reported being right-handed but was left-handed according to the scale (score=−23). Both of these subjects performed within 1SD of the sample mean on the motor performance tasks and, therefore, were included in the study. All other participants scored >75. The Montreal Cognitive Assessment (MOCA) was used to assess adequate cognitive functioning. It has been suggested that a MOCA score of 26 and higher should be considered normal compared to about 22 for people with Mild Cognitive Impairment and about 16 for people with Alzheimer's disease (Nasreddine et al., 2005). The lowest MOCA score by a participant in this study was 20. Thus, we cannot exclude the possibility that we may have some participants with mild cognitive impairments in our sample (Nasreddine et al., 2005). It must be stressed that a MOCA score is only a screening measure and cannot be utilized for diagnostic purposes. All participants were assessed to have an efficient level of cognitive functioning for the purpose of this study. The Regional Ethical Review Board in Umeå approved this study (dnr 08-094M).

2.2. Procedure

In the pre-test session, participants were given standardized instructions that each finger on the left hand represented a single digit number, with the index finger as 1 and the little finger as 4. They were then told to sequentially tap a five number sequence as fast and accurately as possible using four adjacent keys on the keyboard for as long as the sequence appeared on a computer screen (30 s). Thus, the number of sequences one could produce was unrestrained during the 30 s the sequence appeared on the screen. While tapping, the hand was covered by a cardboard box. Two different sequences were used (Olsson et al., 2008a): A=2 3 1 4 2 and B=2 4 1 3 2. Sequence A was presented for 30 s, then a 30 s rest (five Xs displayed on screen), followed by sequence B. This procedure was repeated three times. In the pre-test and post-test sessions, as well as during motor training, all finger-tapping exercises were presented and recorded using E-Prime 2.0 (Psychology Software Tools, Inc., USA). The total numbers of correctly tapped sequences for each sequence (A and B separately) were used as measures of motor performance. Scores were calculated using an automated syntax; the few cases of obvious systematic errors (e.g., tapping the right sequence but on the wrong keys) were corrected manually by a researcher unaware of the training condition to which participants were assigned.

Following the pre-test session, participants trained twice a week for 6 weeks (Olsson et al., 2008a). Participants trained in groups (maximum of four individuals in one group) in a dedicated room at Umeå University Campus. Participants were randomized to train on one of the two sequences (A or B), resulting in one trained sequence and one untrained sequence for each participant. The purpose of the untrained sequence, which was only performed in the pre/post and scanning sessions, was to enable the investigation of possible transfer effects. The participants were

Table 1
Background characteristics of the motor training group, mental training group, and combined motor and mental training group.

	Motor group (n=18)	Imagery group (n=19)	Combined group (n=19)	Statistics
Age, years	70.3 (4.4)	70.2 (6.3)	71.1 (5.1)	F=0.2, p=0.861
Education, years	15.2 (4.4)	13.2 (5.1)	14.4 (5.4)	F=0.7, p=0.492
Female sex	56%	58%	47%	χ^2 (2)=0.47, p=0.789
Edinburgh Handedness index	87.89 (33.0)	99.47 (2.3)	98.47 (4.9)	F=2.1, p=0.132
MOCA[a] score	24.83 (1.7)	24.00 (2.5)	24.05 (2.0)	F=0.9, p=0.413

Note: data are presented as mean (SD) unless otherwise noted. [a]Montreal Cognitive Assessment.