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Research report

Preservation of perceptual integration improves temporal stability of bimanual coordination in the elderly: An evidence of age-related brain plasticity

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HIGHLIGHTS

- How auditory and/or visual stimuli affect bimanual coordination in the elderly?
- Both auditory and audio-visual stimuli enhance stability of coordination in the elderly.
- Attentional and sensorimotor-related neural activations are increased in the elderly.
- Perceptual integration of auditory stimulations is preserved in the elderly.

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ABSTRACT

Despite the apparent age-related decline in perceptual-motor performance, recent studies suggest that the elderly people can improve their reaction time when relevant sensory information are available. However, little is known about which sensory information may improve motor behaviour itself. Using a synchronization task, the present study investigates how visual and/or auditory stimulations could increase accuracy and stability of three bimanual coordination modes produced by elderly and young adults. Neurophysiological activations are recorded with ElectroEncephaloGraphy (EEG) to explore neural mechanisms underlying behavioural effects. Results reveal that the elderly stabilize all coordination modes when auditory or audio-visual stimulations are available, compared to visual stimulation alone. This suggests that auditory stimulations are sufficient to improve temporal stability of rhythmic coordination, even more in the elderly. This behavioural effect is primarily associated with increased attentional and sensorimotor-related neural activations in the elderly but similar perceptual-related activations in elderly and young adults. This suggests that, despite a degradation of attentional and sensorimotor neural processes, perceptual integration of auditory stimulations is preserved in the elderly. These results suggest that perceptual-related brain plasticity is, at least partially, conserved in normal aging.

1. Introduction

Aging seems to be characterized by inevitable decline in perceptual-motor performance, as proved by slowness in reaction times and movement times and by decreased accuracy and fluency when the elderly perform psychomotor tasks [1–3]. One obvious example of this effect can be found in bimanual coordination which is continuous rhythmical movements of the upper limbs [5–8]. Experimentally, temporal accuracy and stability of a bimanual coordination can be explored with a synchronization paradigm that requires to tap right and left index fingers in synchrony with a required timing pattern specified by a stimulation. In healthy adults, two modes of coordination are proved to be accurate and stable: the so-called inphase coordination relates to simultaneous movements of homologous muscle groups and antiphase coordination mode corresponds to alternated activation of homologous muscle groups. The inphase coordination mode is characterized by greater stability than antiphase one [9,10]. Intermediate coordination modes are harder to perform, as proved by their low accuracy and stability without learning [11,12].

Most of the studies investigating the effect of aging on bimanual coordination reveal a significant degradation of bimanual

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coordination but inconsistent results can be found in the literature. For instance, Serrien and collaborators require young adults and older participants to produce inphase and antiphase coordination by doing flexions and extensions with their elbows in accordance with an auditory stimulation at 1 Hz [13]. Results suggest that upper-limb performance is resistant to age-related deficits for both inphase and antiphase coordination modes. Using a visual stimulation, Lee and collaborators asked young and older participants to realize the inphase and antiphase coordination modes with two slide carriages at 1 and 2 Hz. Results indicate that, whatever the frequency, elderly produce lower temporal stability than younger participants for both the inphase and antiphase coordination modes [14]. Bangert and collaborators require young and older participants to perform continuous coordination (circle drawing) and discrete tasks (inphase and antiphase tapping fingers) at 0.8, 1 and 1.2 Hz in synchrony with a visual stimulation. They found that age-related deterioration of movements is particularly found for the antiphase discrete tapping. The elderly produced antiphase coordination less stably than the younger participants (no difference for inphase) [15]. Using an auditory stimulation, Wishart and collaborators asked young and older participants to produce bimanual inphase and antiphase coordination modes at different frequencies (0.5, 1, 1.5, 2 Hz) [8]. They found that antiphase is less stable for elderly but only when the required movement frequency is high (beyond 1.5 Hz). It is possible that the differences between these results refer to the type of coordination (discrete tapping or continuous coordination) or to the required frequency of the coordination (from 0.5 Hz to 2 Hz). But one other possible explanation of the apparent discrepancy between these results relates to the sensory modality of the stimulation available to produce the required coordination.

Firstly, auditory sensory modality seems to induce greater improvement on motor performance than visual modality. Previous results of Fraisse [16] proved that auditory stimulation gives rise to faster unimanual reaction times than visual stimulation in healthy adults. More recently, Repp and Penel [17] suggest an auditory dominance on unimanual sensorimotor synchronization to rhythmic stimuli. As regard to bimanual coordination, Ronsse and collaborators compared visual and auditory augmented feedback to learn intermediate coordination mode. They found an improvement of the temporal stability of a new coordination produced with auditory augmented feedback in young adults [18]. One possibility to improve the accuracy and stability of intermediate coordination is to synchronize fingers tapping with environmental information such as stimulation pacing or augmented visual feedback in young adults [19] and the elderly [20]. Debaere and collaborators tested the learning of bimanual coordination with and without augmented visual feedback in young adults. They demonstrated that augmented visual feedback facilitates this new learning and showed that different neural pathways are used when individuals practice a bimanual coordination task with and without visual feedback. Wishart and collaborators asked elderly people to produce intermediate coordination with visual feedback. They showed that with visual feedback, the older adults were able to acquire the new bimanual coordination as revealed by significant improvements in measures of accuracy and stability. However, no study has compared the effect of visual and auditory sensory modalities of a stimulation to improve stability of a bimanual coordination in the elderly.

Secondly, recent behavioural research in young adults suggests that the combination of both visual and auditory modalities can enhance unimanual sensorimotor synchronization to rhythmic stimuli [21] and to learn a new bimanual coordination mode [22]. Moreover, when young and older participants are required to respond as fast as possible to auditory, visual or audio-visual sensory stimuli, results show that audio-visual information accelerates unimanual reaction times compared to unisensory auditory, even more in the elderly than in young adults [23–25]. The effect of the combination of two sensory modalities on motor behavior suggests that the brain integrates incoming sensory information as a patterned fashion in order to adapt outgoing motor commands. The process is called multisensory integration (MI) [26,27].

Thirdly, neural mechanisms by which MI operates can be investigated with ElectroEncephaloGraphy (EEG) which measures the level of desynchronization and synchronization within local neuronal populations, capturing respectively the level of neural activation and deactivation of underlying cortical areas [28–31]. A recent review of neural correlates of MI [32] reveals that MI is associated to desynchronization in alpha frequency band (8–12 Hz), desynchronization in beta band (13–30 Hz) and synchronization in the gamma band (30–80 Hz) which reflect respectively activations of attentional (Deiber, Calbara, Ibanez, & Hauert, 2001), sensorimotor [29–31] and perceptual processes [34–36]. Investigating these activations is particularly interesting in the context of aging because the age-related decline observed in bimanual coordination can be associated with a reduction of attentional capacity especially for complex motor tasks [14,37,38]. Age-related alteration of bimanual coordination may also be due to an alteration in sensorimotor processes. More particularly, aging induce a lengthening of motor programming [39,40]. Alteration of bimanual coordination can also be attributed to degraded perceptual processes due to relative alteration of brain areas responsible for sensory integration or sensory organs themselves [41,42].

On this basis, the aim of the present study is: (1) to compare the effects of auditory and visual stimulations to improve the accuracy and stability of the bimanual coordination in the elderly compared to younger adults; (2) to investigate the possible effects of the combination of both sensory modalities on the produced coordination modes and (3) to test whether the behavioural effects are associated to additional neural activations related to sensorimotor, attentional and perceptual processes in the elderly.

2. Methods

2.1. Participants

Twenty volunteers participated in the study, including 10 young adults (eight women; 22.8 ± 1.68 years of age) and 10 elderly participants (eight women; 67.7 ± 6.58 years old). Most of young adults were students and most of elderly were recruited from club of retired teachers. All participants were right-handed, as assessed by the Edinburgh Handedness Inventory [43] (Older adults = 96 ± 8.43; Young adults = 87.32 ± 14.68). All participants were non-musicians. General cognitive functions of the elderly were assessed using the Mini-Mental State Examination [44] (maximum score = 30; MMSE = 27.8 ± 2.09). Individuals with a score less than 24 were excluded from the study, resulting in the replacement of one elderly. None of participant reported cognitive, sensory, motor or neuropsychological deficits. Participants had corrected-to-normal vision and hearing. All participants signed an informed consent before beginning the study. The study was in agreement with the University guidelines and the ethical standards laid down in the declaration of Helsinki.

2.2. Materials

One computer (X86 architecture and Windows XP Operation System) delivered visual instructions and visual pictures and/or auditory tones stimuli with Presentation software version 0.81 (Neurobehavioural Systems Inc., Albany, CA). This computer was connected via a PS2 port to a keyboard with two red-colored 'Ctrl'