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Review article

Two hands, one brain, and aging

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ABSTRACT

Many activities of daily living require moving both hands in an organized manner in space and time. Therefore, understanding the impact of aging on bimanual coordination is essential for prolonging functional independence and well-being in older adults. Here we investigated the behavioral and neural determinants of bimanual coordination in aging. The studies surveyed in this review reveal that aging is associated with cortical hyper-activity (but also subcortical hypo-activity) during performance of bimanual tasks. In addition to changes in activation in local areas, the interaction between distributed brain areas also exhibits age-related effects, i.e., functional connectivity is increased in the resting brain as well as during task performance. The mechanisms and triggers underlying these functional activation and connectivity changes remain to be investigated. This requires further research investment into the detailed study of interactions between brain structure, function and connectivity. This will also provide the foundation for interventional research programs towards preservation of brain health and behavioral performance by maximizing neuroplasticity potential in older adults.

Contents

Abbreviations: BOLD, blood-oxygen-level dependent; CC, corpus callosum; CRUNCH, compensation-related utilization of neural circuits; DLPFC, dorsolateral prefrontal cortex; DMN, default mode network; dMRI, diffusion magnetic resonance imaging; DTI, diffusion tensor imaging; EEG, electroencephalography; FC, functional connectivity; fMRI, functional magnetic resonance imaging; GTNA, graph theoretical network analyses; HARDI, high angular resolution diffusion imaging; M1, primary motor cortex; OA, older adults; PET, positron emission tomography; PMd, dorsal premotor cortex; S1, primary somatosensory cortex; SII, secondary somatosensory cortex; SMA, supplementary motor area; SPL, superior parietal lobule; SUCAS, age-related subcortico-cortical activation shift; TMS, transcranial magnetic stimulation; VL Nc, ventrolateral thalamic nucleus; VPL Nc, ventral posterolateral thalamic nucleus; YA, young adults.

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1. Introduction

Many tasks of daily life have a bimanual signature, such a dressing yourself, tying shoelaces, lifting and carrying objects, eating, or typing an email. However, despite their abundance in daily life, bimanual coordination skills have been studied much less intensively than unimanual skills. Equally, in the context of motor learning paradigms, most research has been done on adaptation and sequencing tasks, primarily performed by a single limb (King et al., 2013). However, as a subfield of study in movement control and neuroplasticity, bimanual coordination is generating increasing interest from various scientific disciplines, such as movement sciences, neurosciences, clinical neurology, and neurorehabilitation (Swinnen and Gooijers, 2015). This interest stems from the unique control principles found in bimanual tasks (Kelso et al., 1979; Swinnen, 2002) that cannot necessarily be inferred from the study of unimanual movement. Examples are the preference to activate the homologous muscle groups across both limbs simultaneously or to move in the same direction in extrinsic space with both limbs (Serrien et al., 1999; Swinnen et al., 1997a,b, 1998a, 2001). Because of this underuse of bimanual tasks, our understanding of the neural basis of bimanual coordination is still fragmentary and basic knowledge about the functional contribution of brain areas constituting the bimanual motor network is incomplete at best (Swinnen, 2002; Swinnen and Wenderoth, 2004). Here, we discuss this bimanual motor network and how it is affected by aging to pave the way for future research.

1.1. A useful clinical tool

Because many bimanual skills develop spontaneously during childhood, we consider them as easy and take them for granted. However, these skills hide a considerable behavioral complexity and depend on sophisticated neural architecture. This becomes critically apparent when incurring a temporary dysfunction of one arm after an injury or when confronted with chronic consequences of stroke, leading to hemiparesis of one side of the body. As such, restoring or improving bimanual skill is a critical target for neurorehabilitation intervention (Lewis and Byblow, 2004; Reinkensmeyer et al., 2016; Stinear and Byblow, 2004; van Delden et al., 2012). Clinical tests such as the Purdue Pegboard Test (Desrosiers et al., 1995a; Tiffin and Asher, 1948) or the TEMPA test (Desrosiers et al., 1995b) are used to assess bimanual coordination. Moreover, clinical test batteries such as the Katz Index of Independence in Activities of Daily Living (Katz et al., 1970) or the Unified Parkinson's Disease Rating Scale (UPDRS; Movement disorder society task force on rating scales for Parkinson's disease, 2003) often include bimanual tasks to measure performance capabilities. Sometimes bimanual skills can even become critical tools to characterize prominent clinical expressions of disease. For example, research on Parkinson's disease has demonstrated that freezing episodes can be triggered during performance of simple bimanual cyclical tasks (Nieuwboer et al., 2009; Vercruysse et al., 2014). This temporary disruption of movement is a kinematic and neural signature of Parkinson's disease that is very similar in the upper and lower limbs (i.e., freezing of gait). Such endeavors open up avenues for investigating the neural underpinnings of upper limb freezing episodes in these patients, using medical imaging techniques in constrained environments that are less optimal for the study of lower limb movements (Vercruysse et al., 2014). More generally, bimanual skills constitute a critical marker of functional independence across the lifespan and in patients recovering from neural insults.

1.2. A tool with potential benefits for the promotion of healthy aging

As bimanual coordination is a meaningful tool to diagnose, assess, and rehabilitate patients, a research effort towards improving our basic understanding of the neural control of bimanual coordination across the lifespan should be encouraged. Bimanual coordination is particularly critical in the older population, because moving both hands in an organized way in both space