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Research Report

Q6 Brain network connectivity associated with anticipatory postural control in children and adults

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A B S T R A C T

Internal models provide a coherent framework for understanding motor behavior. Examples for the use of internal models include anticipatory postural adjustments (APAs), where the individual anticipates and cancels out the destabilizing effect of movement on body posture. Yet little is known about the functional changes in the brain supporting the development of APAs. Here, we addressed this issue by relating individual differences in APAs as assessed during bimanual load lifting to interindividual variation in brain network interactions at rest. We showed that the strength of the connectivity between three main canonical brain networks, namely the cingulo-opercular, the fronto-parietal and the somatosensory-motor networks, is an index of the ability to implement APAs from late childhood (9- to 11-year-old children). We also found an effect of age on the relationship between APAs and coupling strength between these networks, consistent with the notion that APAs are near but not yet fully mature in children. We discuss the implications of these findings for our understanding of learning disorders with impairment in predictive motor control.

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1. Introduction

When an individual manipulates an object, one hand often holds the object and the other performs voluntary manipulative movements. To remain stable, the postural hand needs to attenuate the perturbations of the moving hand. This is implemented through a repertoire of anticipatory postural adjustments (APAs) that prevent perturbations caused by voluntary movements in advance. The best example of APAs during bimanual actions is the one provided by the bimanual load lifting paradigm (Hugon, Massion, & Wiesendanger, 1982; Massion, Ioffe, Schmitz, Viallet, & Gantcheva, 1999). In this paradigm, the participant holds an object in the postural hand. When the object is unexpectedly lifted by an external force, the postural hand is destabilized (imposed unloading; Fig. 1A). Inversely, when the participant lifts the object with its own hand, the destabilization of the postural arm is greatly attenuated (voluntary unloading; Fig. 1B). This is due to a decrease of the postural force (Diedrichsen et al., 2003) and to the inhibition of muscle flexors of the postural arm that intervenes dozen milliseconds before lifting (Massion et al., 1999). Hence, APAs are clear illustrations for the use of predictions from internal models to cancel out the destabilizing effect of movement on body posture (Diedrichsen et al., 2003). As such they have always been considered a central feature of the neuroscience of movement (Bernstein, 1967).

APAs emerge early in life. Children as young as 2- to 4-years old already demonstrate some anticipation of the weight of the object during the voluntary lift (Eliasson et al., 1995; Schmitz, Martin, & Assaiante, 1999). Infants in their first year of life are even already able to implement APAs to maintain their posture stable during reaching or in response to predictable external perturbations (Cignetti, Zedka, Vaugoyeau, & Assaiante, 2013; de Graaf-Peters, Bakker, van Eykern, Otten, & Hadders-Algra, 2007; van Balen, Dijkstra, &

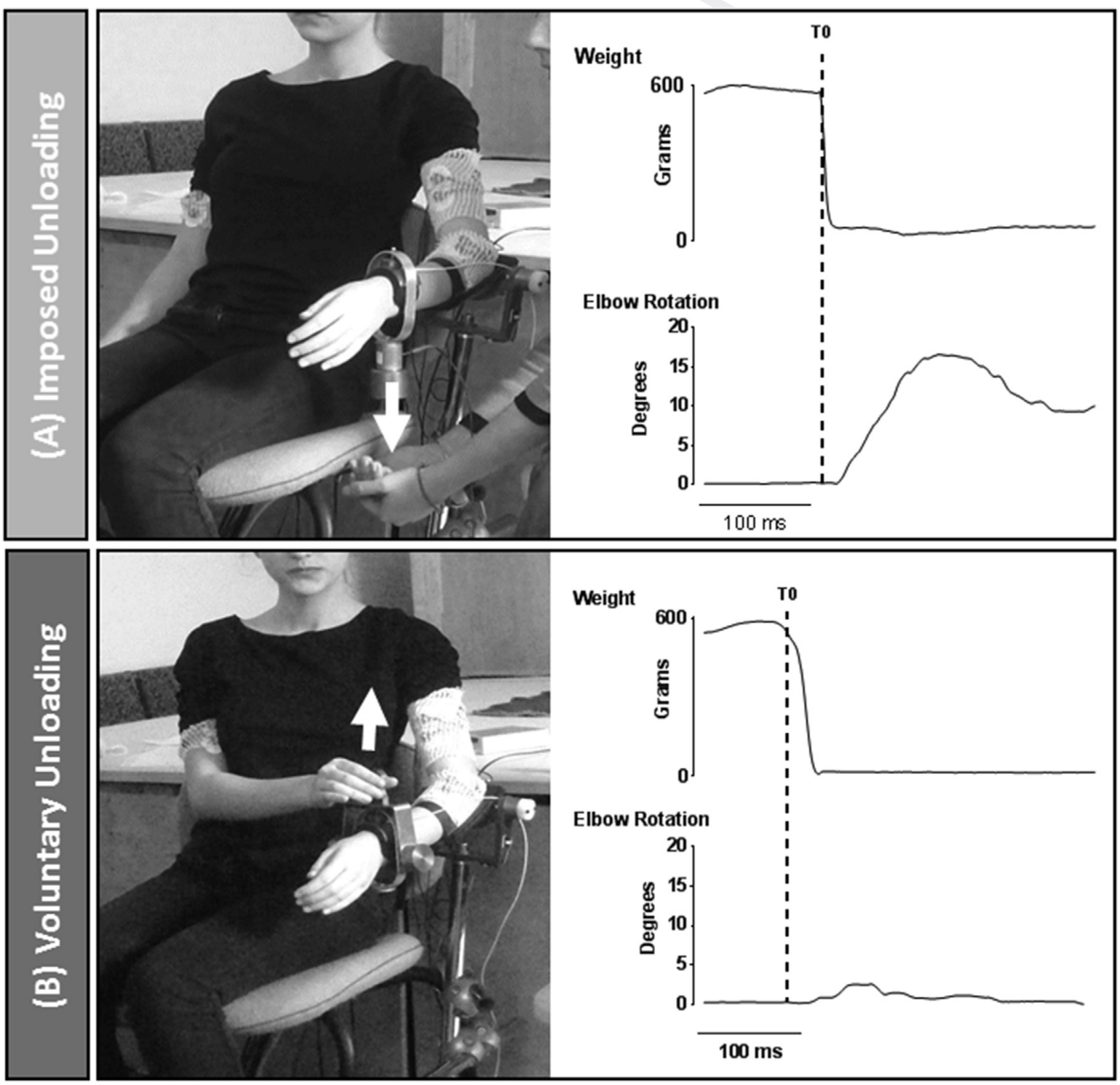

Fig. 1 – Experimental set-up of the bimanual unloading task. (A) During imposed unloading, the load is released by the experimenter switching off the magnet (T0), which induces the (reflex) flexion of the forearm. (B) During voluntary unloading, the subject lifts the load attached to the forearm (T0). Forearm flexion is reduced in this condition due to anticipation.

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