Immature cerebro-cerebellar interaction for timing motor control in children

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E-Poster

Introduction:

In human motor systems neuroscience, most of the knowledge is established based on the data obtained from adult's brain. Yet, little is still known how the human central motor system develops. Physical education teachers and coaches of young athletes empirically know that there are sensitive or critical periods when the most important motor skills have to be acquired and refined before puberty starts. For example, childhood, especially the age between 7 to 12 years, is thought to present favorable conditions for the development of coordination, and thus coordination abilities should be intensively trained particularly at this age (Hirtz and Starosta, 2002). Despite this belief, neuronal basis that defines this age is widely veiled. In the present study, we focus on a coordination ability to generate movements at precise timings in synchronization with external cues.

Methods:

We scanned brain activity with functional magnetic resonance imaging while 22 right-handed healthy children (8-11 years) and 22 young adults (18-23 years) actively performed continuous extension-flexion movements of their right wrists in synchronization with 1 Hz sounds. Since the pace was regular and one could predict the timing, we asked the participants to keep generating the movements at the exact timings of the sounds. We measured the movements with a goniometer and evaluated the timing of generated movements. We also scanned their brain activity while an experimenter passively moved their wrists in synchronization with the sounds. Both children and adults could perform the movements at the pace of 1 Hz, but the variance of movement timing was significantly greater in children than in adults ($p < 0.001$). Then, we examined interaction term (adults, children x active, passive) to identify neuronal substrates that allow adult's accurate performance. Next, we performed correlation analysis to depict neuronal substrates associated with the degree of accurate performance in adults. Finally, we conducted functional connectivity analysis to identify brain regions where the activity shows stronger functional coupling with the activity in the hand section of the left primary motor cortex (M1). To depict significant brain regions in each analysis, we used voxel-wise threshold of $p < 0.001$ and evaluated significance of brain activations in terms of spatial extent of the activations in the entire brain (cluster-wise threshold $p < 0.05$ corrected).

Results:

When we examined the interaction term, we found that the cerebellar vermis activated exclusively in the case when adults actively performed the movements (Fig. 1). Thus, the vermis activity was involved not in the sensory processing of afferent inputs but in the active control of the movements, which was lacking in children. Correlation analysis revealed significant negative correlation between the variance of movement timing and the vermis activity only in adults ($r = -0.69$, $p < 0.001$; Fig. 2), meaning that the activity was greater in adult participants who showed higher accuracy of timed movements. Thus, the vermis activity likely participates in the active control process that allows accurate timed movements in adults, which is still immature in children (Fig. 2B). Finally, functional connectivity analysis showed that the adult's vermis activity showed stronger functional coupling with the M1 activity when compared with children (Fig. 3), indicating that cerebro-cerebellar interaction in motor domain (Coffman et al., 2011; Grodd et al., 2001) is still immature in children.

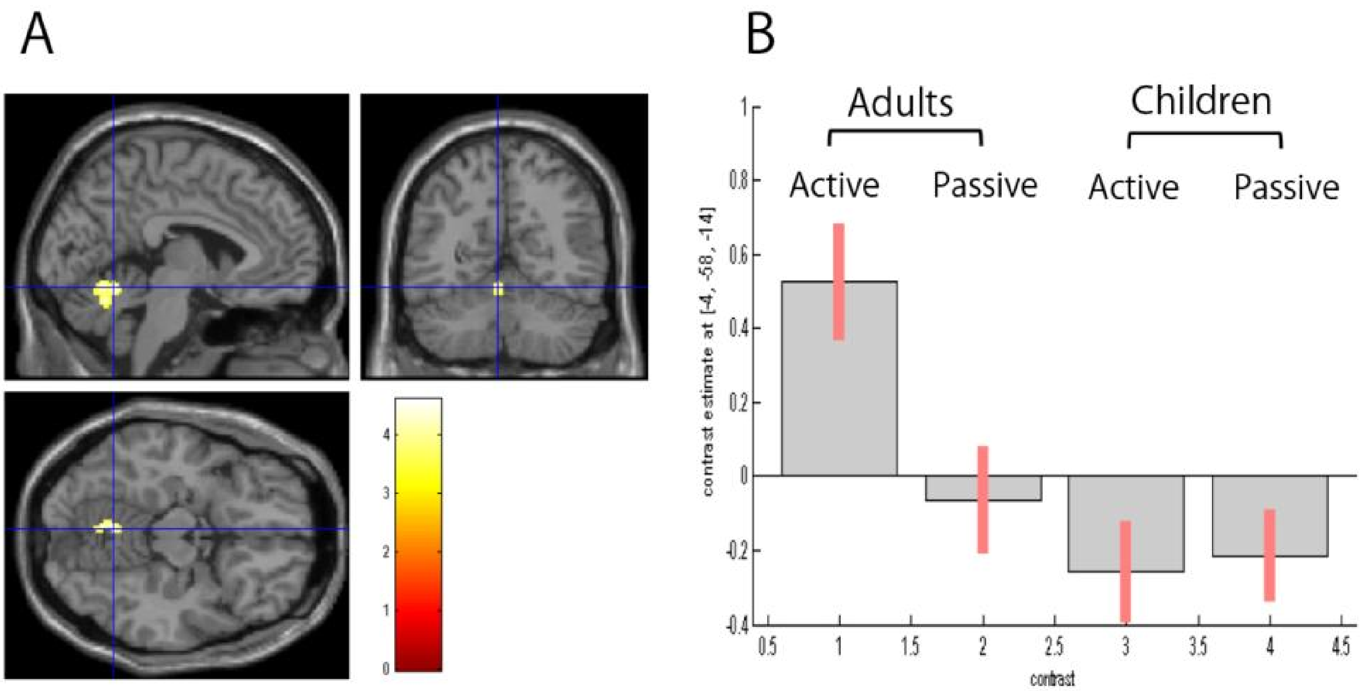

Figure 1 The cerebellar vermis exclusively active when adults actively performed the timed movements (A) and its contrast estimate (B)

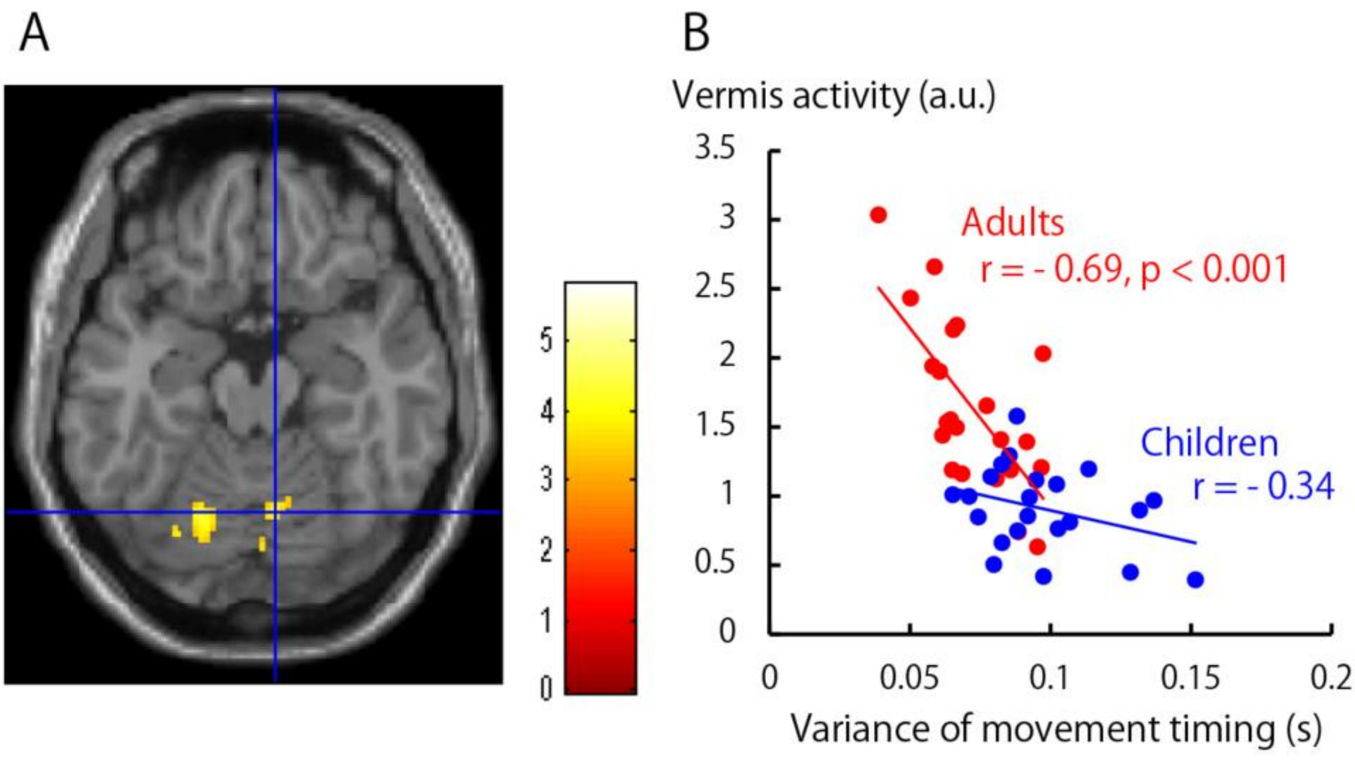

Figure 2 The cerebellar vermis activity showing negative correlation with the variance of movement timing in adults (A), which was not observed in children (B)

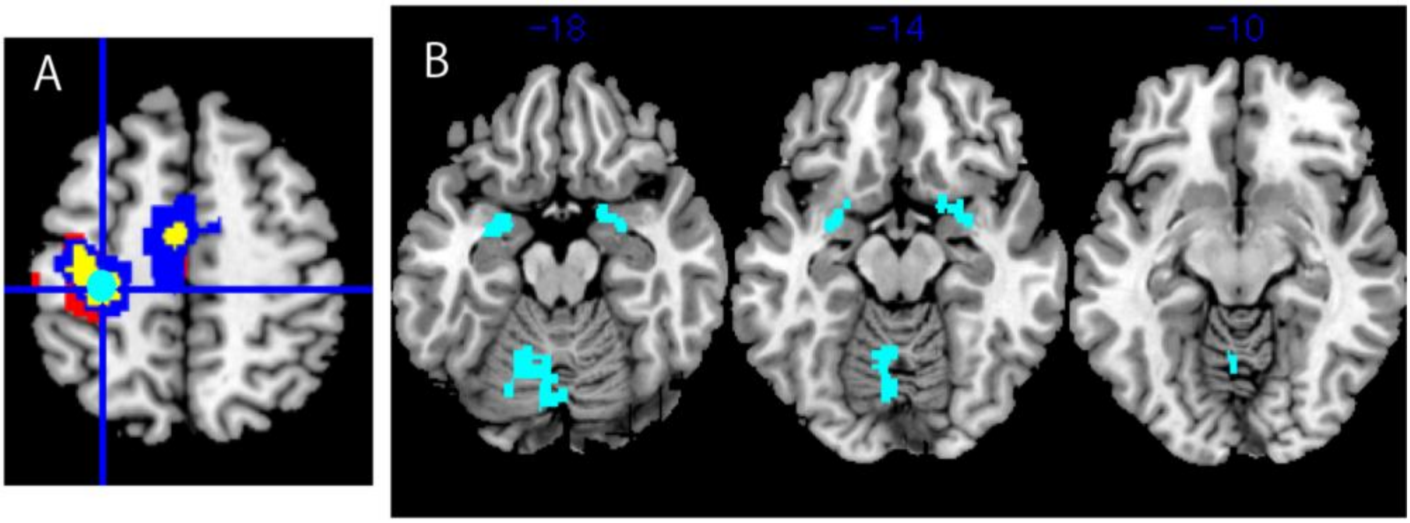

Figure 3 The cerebellar vermis showing stronger functional coupling with the left M1 activity (A) in adults when compared with children (B)

Conclusions:

The cerebro-cerebellar interaction in motor domain is in still immature state of development for children at the age between 8 to 11 years. This immaturation appears to make them difficult to keep implementing a motor response at a precise timing. Hence, this age is not the best age for timing motor control, but shaping the cerebro-cerebellar interaction at this age through coordination training may benefit later success in motor control.

Imaging Methods:

BOLD fMRI

Lifespan Development:

Normal Brain Development: Fetus to Adolescence [1]

Motor Behavior:

Motor Behavior Other [2]

Poster Session:

Poster Session - Monday

Keywords:

Cerebellum
Development
FUNCTIONAL MRI
Motor
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Plasticity

[1|2]Indicates the priority used for review

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Please indicate which methods were used in your research:

Functional MRI

For human MRI, what field strength scanner do you use?

3.0T

Which processing packages did you use for your study?

SPM

Provide references in author date format

Coffman, K.A. (2011), 'Cerebellar vermis is a target of projections from the motor areas in the cerebral cortex', Proceedings of the National Academy of Sciences of the United States of America, vol. 108, no. 38, pp. 16068-16073
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