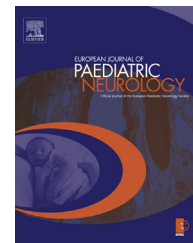




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fMRI assessment of neuroplasticity in youths with neurodevelopmental-associated motor disorders after piano training



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ABSTRACT

Background: Damage to the developing brain may lead to lifelong motor impairments namely of the hand function. Playing an instrument combines the execution of gross and fine motor movements with direct auditory feedback of performance and with emotional value. This motor-associated sensory information may work as a self-control of motor performance in therapeutic settings.

Aims: The current study examined the occurrence of neuronal changes associated to piano training in youths with neurodevelopmental-associated hand motor deficits.

Methods: Functional magnetic resonance imaging responses evoked during a finger tapping task in a group of ten youths with neuromotor impairments that received individualized piano lessons for eighteen months were analyzed. Functional imaging data obtained before and after the piano training was compared to that obtained from a similar group of six youths who received no training during the same period of time.

Results: Dynamic causal modeling of functional data indicated an increase in positive connectivity from the left primary motor cortical area to the right cerebellum from before to after the piano training.

Conclusions: A wide variability across patients was observed and further studies remain necessary to clarify the neurophysiological basis of the effects of piano training in hand motor function of patients with neurodevelopmental motor disorders.

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1. Introduction¹

Neurodevelopmental disorders arise from injury to the developing brain that often results in lifelong motor impairments and disabilities. Infantile cerebral palsy (CP) in particular, with a prevalence of 1.5–3 cases per 1000 live births,^{1,2} constitutes the most common neurodevelopmental disorder associated to motor impairments. Non-progressive damage to the brain before birth or during childhood causes neural connections to be formed in abnormal ways leading to motor impairments and potentially also to different degrees of sensory and cognitive impairment and often epilepsy.³ Despite the advances in obstetric and neonatal care the prevalence of CP has not decreased, partly due to an increasing number of low birth-weight children especially in developing countries.

Clinical management of motor impairments in CP includes typically orthopaedic surgery to tackle malfunctioning mechanics, use of orthotic devices, task-specific intensive therapy,⁴ physical therapy (stretching and flexibility exercises) and speech therapy.³ Therapy based in auditory feedback and music has also been used in the rehabilitation of gait patterns^{5–7} and whole body movements⁸ in patients with CP. Fewer studies have investigated the therapeutic effects of music and musical instruments in the rehabilitation of hand motor deficits in cerebral palsied patients.⁹ Impairment of hand functions are widespread and varied in these patients,¹⁰ depending on the extension of neuronal damage.^{11,12} In other clinical populations music-supported therapy has been successful in improving motor functions, for example in stroke patients.^{13–16} Improvement of motor functions by playing in a MIDI piano and/or electronic drum set was accompanied by neuronal changes in cortical motor areas.^{17,18}

The potential therapeutic effects of piano playing in youths with motor disabilities of neurological origin and no previous musical education was addressed in a study that compared hand motor function before and after piano training in ten patients with CP and eight participants with neurodevelopmental disorders.¹⁹ Participants received individualized piano lessons 30–45 min long in a MIDI keyboard twice a week and for eighteen months. Hand motor functions were measured with Box&Block test,²⁰ by assessing the hand gripping force and by measuring the regularity of key stroking between the fingers. The latter was assessed via the MIDI piano, by measuring the time interval between sequential strokes with neighboring fingers. A less variable key stroking movement of the fingers (i.e. smaller standard deviation of the time interval between consecutive key strokes) is indicative of a more regular movement. Improvement in hand motor skills, expressed in terms of an increase in the regularity of finger strokes (Fig. 1), was especially noticeable in patients with CP.

In a recent study⁹ ten adult CP patients received therapeutic instrument music performance training by playing in a keyboard. Also here examination of the pressing force exerted by the hand fingers on the keys, measured also with a MIDI interface, indicated improvement of hand function.

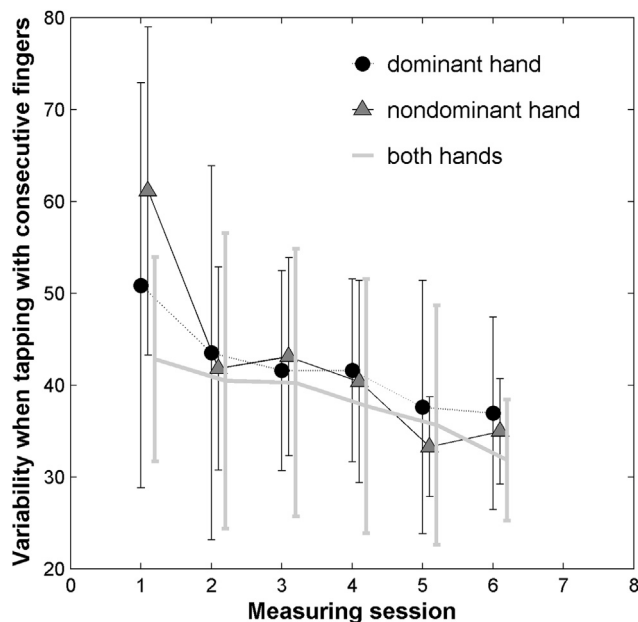


Fig. 1 – Standard deviation of the time interval between sequential key strokes measured in different experimental sessions. Data collected when playing in a MIDI piano with the dominant (black circles), non-dominant (gray triangles) and both (gray thick line) hands. Participants were youths diagnosed with CP or other types of neurodevelopmental disorders, all experiencing impairment of motor function of at least one hand. The average values presented were calculated across participants. Lower values indicate less variability in the time interval between consecutive key strokes, on average, and therefore indicate more regular finger movement. Figure adapted from Ref. ¹⁹.

Learning to play an instrument involves not only the repetition of different movements but also the coordination of hands and fingers. This requires integration of multimodal (sensorimotor, visual, auditory) information and the recruitment of a multitude of brain areas.^{21–23} Furthermore, the immediate auditory feedback received while playing the piano stimulates the patient to correct his own performance. Playing an instrument has therefore several ingredients that can trigger and/or promote brain plasticity.²⁴

Piano practice was shown to promote plasticity in sensorimotor cortex in healthy subjects without previous musical experience.²⁵ After weeks of practice, similar activation patterns were elicited by auditory stimulation alone and by performing a motor task alone. The strong interaction built between the auditory and motor modalities was supported further by the fact the activations observed took place without the need for the participant to be attentive.

Furthermore, interaction between the auditory and motor systems can be observed already after learning short piano sequences in musically naïve subjects.²⁶ Activations of the frontoparietal motor-related network were observed in musically naïve subjects after being simply presented to the short sequence they had learned and without having to move their hands. No activation occurred when a musical sequence

¹ fMRI: functional magnetic resonance imaging, CP: cerebral palsy, M1: primary motor cortex, CBL: cerebellum, GLM: general linear model; DCM: dynamic causal modeling.

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