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EC PSYCHOLOGY AND PSYCHIATRY
Research Article

Electroencephalographic and Electromyographic Peculiarities of Motor and Ideomotor Finger Movement Task in Musicians and Novices

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Received: January 25, 2018; **Published:** May 15, 2018

Abstract

The production of voluntary movements by musicians often has many more elements contributing to the performance that is necessary to solve a given motor task. Nevertheless, only top musicians perform well by eliminating 'redundant degrees of freedom'. Mental motor imagery is the recognising tools of ability to learn how to move because motor imagery corresponds to a subliminal activation of the motor system, a system that appears to be involved not only in producing movements but also in imagining actions. Here we hypothesised that musical motor capacity is part of a broader sensorimotor integration characterised by fluency in the real motor task performance and precise imagination of motor task performance, where inhibition of redundant activation is reflected by increasing the brain alpha EEG and decreasing the muscles EMG power.

We aimed to study the association between fluency of fine motor task performance, its mental imagery and neurophysiological activity in novices, musically trained participants, and musical experts.

For this purpose musical performance ability level and fluency in timed finger-motor task performance were assessed in eighteen non-musicians, thirty musical students and in twelve top performers musicians.

Simultaneous monitoring the EEG, EMG were provided in (1) rest, (2) motor task performance and (3) imagination of motor task performance conditions. In all conditions, each trial had begun with eyes closed (EC) 60 s then eyes open (EO) 30 s with the presentation of a grey cross-eye fixation target.

These findings indicate that high musical performance abilities associate with the fluency of finger movement and increasing upper alpha EEG/forehead muscles EMG ratio during both actual motor task performance and either mental imagery of motor task. It allows concluding that alpha EEG /forehead muscles EMG ratio during the finger motor performance task could predict the motor capacity in a structure of musical ability.

These results have implications for musical performance training and rehabilitation. They indicate the utility of EEG and EMG for learning assessment in musicians. This study one more time validates expanded sensorimotor organisation in professional musicians, compared with musical students and non-musicians.

Keywords: *Explicit Self-Esteem; Implicit Self-Esteem; Self-Enhancement; Discrepant High Self-Esteem; Narcissism*

Abbreviations

EEG: Electroencephalogram; EMG: Electromyogram; MT: Motor Task; NM: Novices Group; TM: Trainings Musical Performance Group; MP: Musical Experts (Top Performers)

Introduction

The production of voluntary movements by musicians often has many more elements contributing to the performance that is necessary to solve a given motor task. Nevertheless, only top musicians perform well by eliminating 'redundant degrees of freedom' [1]. Context redundancy reflects the inefficiency of inhibitory processes of the sensorimotor coordination. Previous research has shown that redundant muscle inhibition leads to an increase in electroencephalographic (EEG) amplitude of the upper alpha frequency range [2,3], with simultaneous decrease in electromyographic (EMG) power of redundant muscle tension during fine motor performance providing an index of cortical "top-down" control [4-6]. In contrast, a decrease in alpha amplitude with simultaneous increase of forehead muscle tension indicate an increase in cortical activation [7,8]. Enhanced forehead muscle tone is also thought to be a sign of psychoemotional tension or mental stress [9,10]. Changes in alpha EEG and EMG power provide a mechanism to select relevant neuronal populations, although the relative contributions of these neurophysiological indices to musical performance ability remain unclear.

Recently it was demonstrated the efficiency of new educational and training approach aimed at increasing performance skills using mental motor performance [11]. In analogy, mental motor imagery is the recognising tools of ability to learn how to move because motor imagery corresponds to an activation of the motor system, which have been being involved not only in producing movements but also in imagining actions [12]. Here we hypothesised that musical motor capacity is part of a broader sensorimotor integration characterised by fluency in the real motor task performance and precise imagination of motor task performance, where inhibition of excessive activation is reflected by increasing the brain upper alpha EEG power and decreasing the muscles EMG power.

Aim

The aim is to study the association between fluency of fine motor task performance, its mental imagery and neurophysiological activity in novices, musically trained participants, and musical experts.

Fluency in timed finger-motor task performance was assessed in eighteen non-musicians, thirty musical students and in twelve top performers musicians.

Simultaneous monitoring the EEG, EMG were provided in (1) rest, (2) motor task performance and (3) imagination of motor task performance conditions. In all conditions, each trial had begun with eyes closed (EC) 60 s then eyes open (EO) 30 s with the presentation of a grey cross-eye fixation target.

These findings indicate that high musical performance abilities associate with the fluency of finger movement and increasing upper alpha EEG/forehead muscles EMG ratio during both actual motor task performance and either mental imagery of motor task. It allows concluding that alpha EEG/forehead muscles EMG ratio during the finger motor performance task could predict the motor capacity in a structure of musical ability.

These results have implications for musical performance training and rehabilitation. They indicate the utility of EEG and EMG for learning assessment in musicians. This study one more time validates expanded sensorimotor organisation in professional musicians, compared with musical students and non-musicians.

Materials and Methods

Participants

Eighteen novices (NM), thirty musically trained participants (TM) and twelve musical experts = high skilled musical performers – laureates of International competitions (MP) participated in the study. Table 1 presents the age, gender, and contribution to music education in compared groups. All study participants provided written informed consent, and the study was approved by the ethical committee of State Research Institute of Molecular Biology and Biophysics (Novosibirsk, Russia).

	Novices	Musically trained participants	Musical experts
n	18	30	12
Age, years M (SD)	27,6 (6,2)	24,3 (5,2)	29,4 (8,2)
Gender ratio (% of Female)	60,1	73,3	50
Length of musical practice, years M (SD)	2,3 (3,6)	15,4 (2,3)*	17,2 (5,5)*

***Table 1:** Mean characteristics of the three participant groups (SD in parentheses).*
**: Significant Group Difference*

The evaluation of musical abilities

Experts provided the evaluation of musical abilities in novices according to tests from Gifted and Talented Identification Handbook [13]. Musicians had performed two video reordered available cantilena and active music fragments (3 - 5 min length). Experts evaluated musical performance skills according to musical performance aptitude batteries [14]. The musical ability score comprises a rhythmic sense (Rhythm), an intonation sense (Intonation), and the ability to fluent perform music (Technique). We had collapsed the scores across every dimension of the instrumental performance ability.

Procedure

We had provided the simultaneous monitoring of the EEG, EMG in (1) rest, (2) motor task performance and (3) imagination of motor task performance conditions. In all conditions, each trial had begun with eyes closed (EC) 60s then eyes open (EO) 30s with the presentation of a grey cross-eye fixation target.

Fluency of the motor and ideomotor tasks performance

Timed motor performance task was as sequential finger movements (MT)- opposing each finger with the thumb in sequence, i.e. 'index, middle, ring, little' comprises a set [15]. Subjects reported how many sets both after the performance and after mental imagery (IT) they performed. Before task, the examiner gave verbal instructions while demonstrating the expected performance to ensure that the participant understood the instruction. Brief, untimed practice followed. After practising the examiner said, 'When I say "go", do the same thing as fast as you can until I stop you'. The fluency of MT and IT was computed as the number of sets per minute.

EEG and EMG recordings

The EEG was recorded monopolarly with a sampling rate of 720 Hz from Pz scalp electrode referenced to the left mastoid, ground at the right mastoid. Simultaneously EMG recorded from two bipolar electrodes placed on the forehead skin. The EEG data were analysed using WinEEG software (Mitsar Co., St. Petersburg, Russia). Eye-blink artefacts were removed using Independent Component Analysis, and then the recording was divided into 4.096-second-long epochs using a Hanning window (50% overlapped epochs). Only records showing an amplitude above 10 μV^2 were included in the analysis. EMG was recorded by two 1.6-cm Ag/AgCl surface bipolar electrodes fixed about 3 - 5 cm apart and placed on the forehead. The EMG signals were acquired with a 720-Hz sampling rate, amplified and filtered with 5 Hz high pass and 350 Hz low pass filters. We applied the usual approach to average the integrated EMG power (IEMG) in the signal over 100 ms [16].

EEG analysis

Analysis of EEG characteristics was carried out according to our previously published approach [17]. Briefly, individual alpha peak frequency and alpha frequency band limits were determined at every electrode site for every participant using data from the last 30s of EC and first 8s of EO conditions. Frequency bands that were decreased in power by more than 20% during the EO vs EC conditions were selected as individual alpha bands. Frequency showing the highest spectral amplitude within this band was identified as individual alpha peak frequency (IAPF). Lower and upper limits of the band (i.e. theta (TF) a113nd beta (BF) transition frequencies) were determined where EO curve crossed the EC curve closest to IAPF. The alpha amplitude suppression magnitude (ASM) in response to eyes open was measured as ASM = ln [(mean alpha power in EC condition - mean alpha power in EO condition) * 100%]/mean alpha power in EC condition). The alpha1 and alpha2 sub-bands were also adjusted: the alpha1 ranged from the lower limit to the individual alpha peak frequency, while the alpha2 ranged from the individual alpha peak frequency to the upper limit [18]. We had chosen the upper alpha-2 frequency range because its power increase is the marker of redundant brain and muscle activation [2,3].

Motor and the ideomotor task-related ratio of alpha -2-EEG and EMG power changes (reactivity) was defined according to the formula = mean ratio alpha-2-EEG power/integrated EMG power in rest divided to - alpha-EEG/EMG in MT(or IT) EC condition [18].

Statistic

A three-way repeated-measures ANOVAs were used to evaluate matching performances fluency, alpha EEG and EMG with factors of GROUP (3 levels: non-musicians, musically trained participants, and top professional musicians), TASK (3 levels: rest, motor performance and imagination of motor task performance), and VISION (2 levels: eyes closed and eyes open). Whenever necessary, Tukey HSD post-hoc test was performed. The level of significance was set at $p < 0.05$. Pearson's bivariate correlations were used to estimate intraobserver, interobserver, and test-retest reliability. A forward stepwise multiple regression analysis was used to determine if alpha-EEG/EMG variables under Motor and Ideomotor-tasking paradigms would predict scores in musical performance and finger motor fluency.

Results and Discussion

Group characteristics

As shown in table 1, groups did not differ in age, $t(60) = 0.099$, $p > 0.921$ and gender ratio, X2 (1, n = 60) = 1.864, $p > 0.397$, but period of musical practice in musically trained participants and top-musicians was longer than in novices , $t(60) = 8.697$, $p < 0.001$ (Table 1).

Fluency in motor and ideomotor task performance

Figure 1 displays the mean fluency in MT and IT in three groups. Fluency was highest in professional musicians vs musically trained participants and novices [$F(2, 176) = 12.23$, $p = 0.001$]. Fluency during imagined fingers movements was lower than during actual motor task in novices ($-t \leq 4.56$, $p \leq 0.02$). In TM group fluency in fluency of imagined motor task did not change, but skilled musicians demonstrated the fluency of IT higher than fluency of actual finger movement ($t \geq 7.72$, $p \leq 0.011$). As expected, musical performance abilities associated with fluency in motor task performance ($r = 0.83$, $n = 60$) in the whole sample (Figure 1).

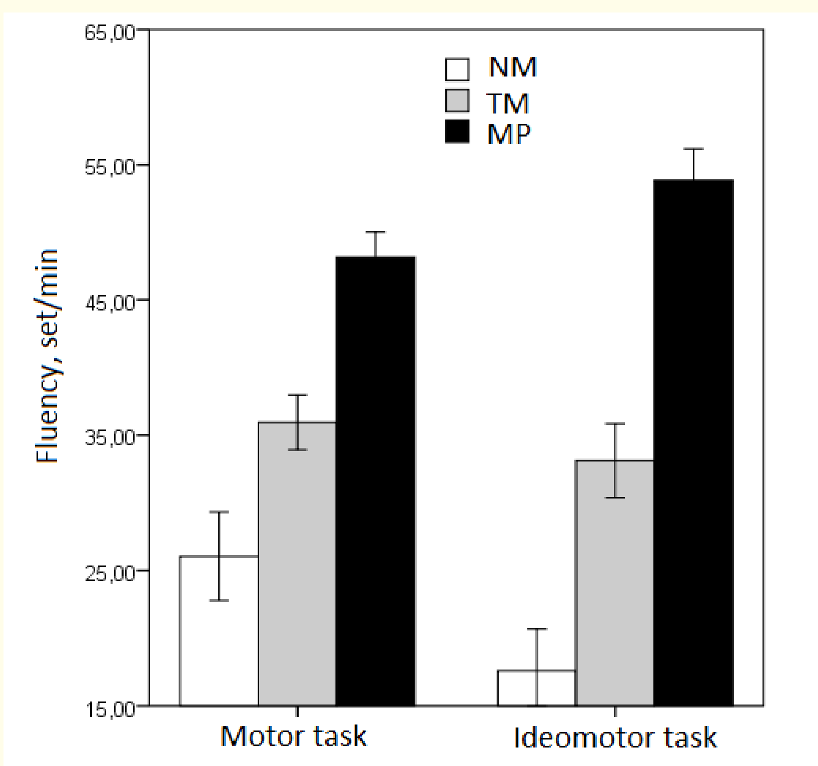

Figure 1: *Fluency (mean±2E) in motor and ideomotor tasks performance in groups of novices (NM), musical trainers (MT) and experts musicians (MP).*

Alpha-EEG/EMG ratio

In rest condition, there were no significant differences of alpha EEG and EMG power between novices, musically trained participants and professional musicians ($p > 0.05$). A main effect of GROUP was observed [$F(2, 58) = 81.23$, $p < 0.001$] for the ratio of alpha EEG/EMG during the actual motor task performance, that indicates greater increase of alpha-2 power and decrease of EMG in professional musicians ($t = 10.2$; $p = 0.001$) than in musically trained participants and non- musicians (Figure 2).

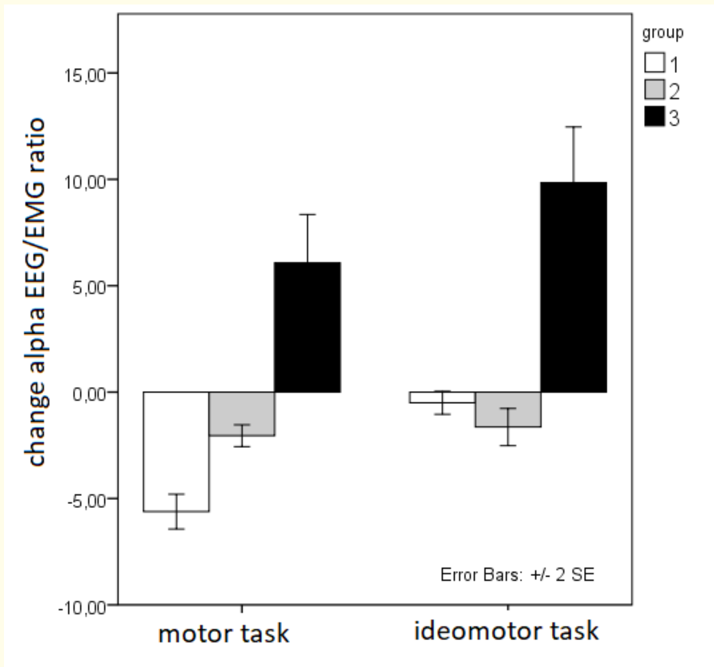

Figure 2: *Alpha-2-EEG/EMG ratio reactivity to motor and ideomotor task in groups of novices (NM), musical trainers (MT) and experts musicians (MP).*

Alpha-2-EEG/EMG ratio reactivity to motor and ideomotor task

Alpha-2-EEG/EMG ratio reactivity was entered into a 3 × 2 repeated-measures analysis of variance (ANOVA), with task category (motor vs ideomotor), and group (NM/TM/MP) as a between-participants factor. This analysis revealed significant main effects of the task [$F(1, 58) = 91.05$, $p < 0.001$] that demonstrated variable alpha-EEG/EMG reactivity to the motor and ideomotor task. The analysis also revealed a significant task by group interaction [$F(2, 58) = 25.39$, $p < 0.001$] (Figure 2). The alpha-EEG/EMG ratio during actual motor task performance does not change in musically trained participants and decreases in novices ($t = -5.9$, $p = 0.002$), but increased in musical experts. Interesting that this ration Alpha EEG/EMG ratio more increased in high professional musicians during ideomotor task performance did not change in musically trained participants and decreased in NM.

Correlation and multiple regression analysis

Change of alpha-EEG/EMG positively correlated with fluency of actual motor task performance in non-musicians ($r = 0.565$, $n = 18$; $p = 0.010$) and musically trained participants ($r = 0.73$; $n = 30$; $p = 0.009$) groups (Figure 2). In high skilled musicians, this correlation was absent (Figure 3).

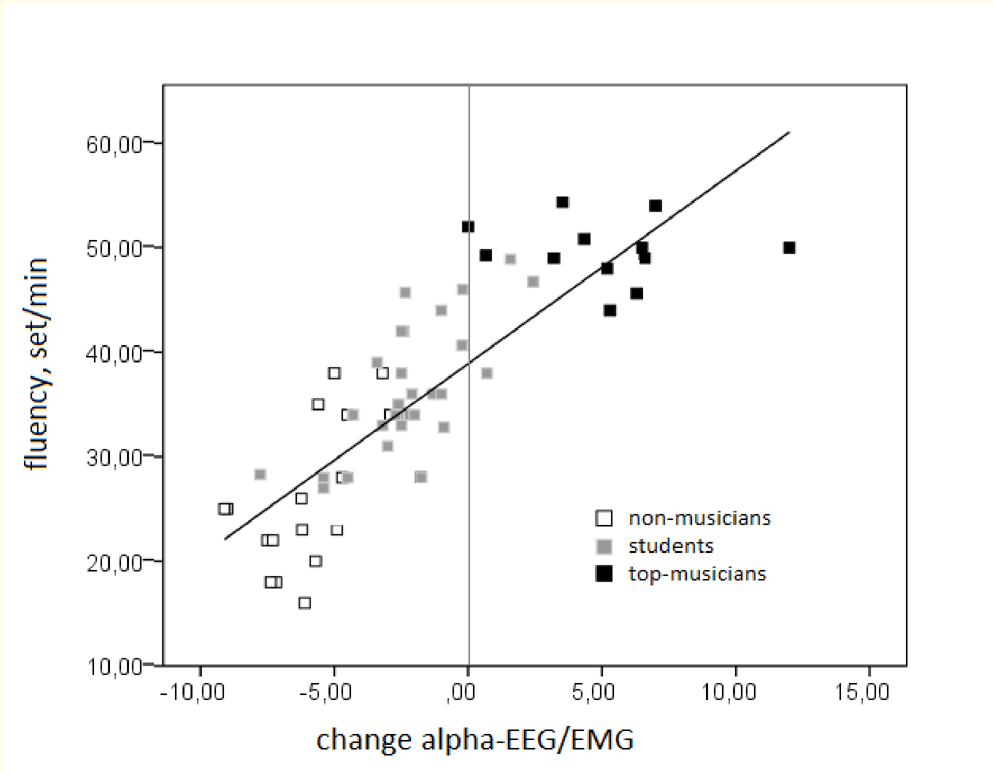

Figure 3: *Correlation between fluency in motor task performance and alpha-EEG/EMG reactivity.*

Dependent Variables	Steps	Predictors	Beta	$r_{partial}$	Adjusted r	F	p
Musical ability score	1	Musical practice length	0.875	0.875	0.861	49,988	0.001
	2	Alpha-EEG/EMG in rest condition	0.147	0.714	0.812	30,815	0.001
		Δ alpha-EEG/EMG in IT	-0.212	-0.481			0.001
Fluency of the finger movement	1	Musical practice length	0,677[a]	0,459	0,449	49,758	0.001
	2	Alpha-EEG/EMG in MT	0,718	0,515	0,498	49,988	0.001
		Δ alpha-EEG/EMG in IT	-0.340	-0.458			0.001
	3	Alpha-EEG/EMG in MT	1.0065	0.701	0.834	48.162	0.001
		Δ alpha-EEG/EMG in IT	-0.336	-0.485			0.001

Table 2: *Multiple stepwise linear regression analysis of the alpha-EEG/EMG and Δ alpha-EEG/EMG in the rest, the finger motor task (MT), and mental/ideomotor (IT) tasks as independent predictors of fluency and musical performance ability score.*

Discussion

This study one more time validates expanded sensorimotor integration in professional musicians, compared with musically trained participants and novices. Here we had explored the hypothesis that musical performance ability could be predicted by neurobiological markers of brain and muscles activation. From Bernstein's time it's well known that motor skill performance requires the need to overcome the numerous degrees of freedoms [19], Such complicated activity as musical performance needs acquisition of well-coordinated body movements, and the sequencing of movements inappropriate trajectories within the temporal demands of the task, mental imagery, and its physical constraints. On the one hand, our results support the theory that alpha oscillations as a basic top-down mechanism of neuronal inhibition [2,20,21] and thus may play a prominent role in the sensorimotor control and manual task performance. On the other hand, scalp EMG measurement itself could reflect the muscle activity involved in psychoemotional tension or mental stress [9,10,22] and characterise activation of redundant muscles not participating in the musical performance. Meanwhile, EMG activity is in reciprocal relation with EEG alpha power in the upper-frequency range [8]. So increasing upper alpha-EEG/EMG ratio could be interpreted as reflecting global inhibition of redundant cortical activation simultaneously with decreasing the excessive muscle activation and psychoemotional tension. Results of multivariate regression analysis demonstrated an association between alpha-EEG/EMG ratio with fluency in motor performance and musical practice length, that could be used in prediction of musical performance skill. Proposed characterisation of musical performance ability and fluency of finger movement via measurements of the ratio of alpha-EEG/EMG in rest condition and response to the motor task will potentially help more accurately pinpoint any musical abilities changes and development of the sensorimotor integration [23].

Conclusion

We consider that high musical motor capacity is part of a more comprehensive sensorimotor integration characterised by graceful movements, precise coordination and precise imagination of fine motor task performance with increased inhibition of redundant neural and muscles activation that reflected by brain alpha EEG and frontal muscles EMG power.

These findings indicate that high musical performance abilities associate with increasing upper alpha EEG/forehead muscles EMG ratio during both actual motor task performance and either mental imagery of motor task. It allows concluding that alpha EEG /forehead muscles EMG ratio during the finger motor performance task could predict the motor capacity in a structure of musical ability and so could be used as a feedback signal in Neurofeedback training of musical performance improvement and high level of sensorimotor coordination achievement.

These results have implications for musical performance training and rehabilitation. They indicate the utility of EEG and EMG for learning assessment in musicians. They also suggest learning strategies with a partial movement focus may be a beneficial strategy to support the development of sophisticated musical performance skills training and rehabilitation strategies focused on reacquisition of skills prior to performance reintegration.

Acknowledgements

We are acknowledging the contributions of our colleagues Anna Kondratenko (soloist and concertmaster of Macedonian Phylarmony) and Daria Melisova (PhD student of Schnittke Moscow State Institute for music) who are not included in the authorship of this paper.

Conflict of Interest

We declare absent of any financial or any conflict of interest exists.

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Volume 7 Issue 6 June 2018