IS MUSICAL TRAINING REFLECTED BY SACCADIC EYE MOVEMENT?

Wilfried Gruhn
Friederike Litt
Annette Scherer
Till Schumann
Eva Maria Weiß
Musikhochschule (University of Music) Freiburg, Germany

Christine Gebhardt
Blick Labor, Brain Research Unit, University of Freiburg, Germany

ABSTRACT

Musicians who practice from notation and sight read every day perform a special training for their eye movements and can, therefore, be differentiated from non-musicians. If this difference can be exhibited it is questioned whether this difference remains stable over the life span. 115 subjects of three age groups (36 pupils M =11.5 years, 41 university students M = 23,1 years, 38 adults 55,6 years) – 57 musicians and 58 non-musicians – were measured with respect to their saccadic eye movements (overlap and anti gap paradigm). An infra-red beam helmet (Express Eye) was used to collect data for the reaction time of pro and anti saccades, mean distribution, percentage of express saccades, correction time, and percentage of direction errors. Data were analyzed separately for each age group and served as factors for fixation and voluntary control. These data were also controlled by general intelligence (Raven's Advanced Progressive Matrices, APM), music aptitude (Gordon's Advanced Measures of Music Audiation, AMMA), handedness, and a sight reading test. In general, there is an obvious advantage for musicians with respect to voluntary control and fixation although not all parameters show a significant difference. A slight, but robust interaction between musical training and saccadic reaction time has been confirmed.

1. INTRODUCTION

In course of the debate on cognitive transfer effects on music, many investigations focused on the relation between music and intelligence. According to Gardner's theory of multiple intelligences music aptitude or talent can be seen as one intelligence amongst others (Gardner 1985; 1999) or it can be interpreted as a performance of special intelligence on a lower level of general intelligence when g factor is positioned at the top and specific abilities on the bottom of a hierarchical structure of the intelligence pyramid. In this context, mental speed has been introduced as a robust indicator of cognitive intelligence (Saring & v.Cramon 1980; Galley 1999). Consequently, it has been investigated whether it possibly interacts with music achievement (Gruhn, Galley, & Kluth 2002).

In previous experiments, two paradigms of saccadic eye movement, the overlap and anti-gap task, have been broadly investigated as an indication for dyslexia (Fischer 1999; Biscaldi et. al. 2000), as an effect of Alzheimer and Huntington Disease (Currie et al. 1991), and in schizophrenia (Rosse et al. 1993; Sereno et al. 1995). Furthermore, oculo-motor anomalies have also been reported for children with Attention Deficit and Hyperactivity Disorder, ADHD (Mokler, 2002). Saccadic eye movements have also been investigated in music while subjects (trained musicians and amateurs) sight read music (Kinsler & Carpenter 1995).

Along with these studies, an immediate connection between attention and saccadic eye movement – especially express saccades – is obvious. All modalities of attention have an impact on the oculo-motor system (Kimmig 1986). Namely the overlap task provides a strong factor for attention because fixation (F factor measured by reaction time in pro-saccades) which is characterized by a voluntary suppression of saccades, and the rate of express saccades determine processes in frontal lobe which are engaged in attention. On the other hand, mean reaction time, correction time and the rate of corrections for direction errors in anti-gap tasks indicate voluntary eye control (V factor). Both factors are truly influential on music performance. Therefore, it seems reasonable to observe these factors and find out how these tasks are performed in musicians and non-musicians.

2. EXPERIMENT

2.1 Subjects

Controlled, voluntary eye movement and fixation follows a highly complex mental process with many brain areas involved. Most of the measured parameters show a significant age effect. Visual acuity has been fully developed up to age 8 to 9. Then, fixation and reaction time still improve up to 20 years followed by a decline over age. Therefore, we observed three samples of age representing three different stages of development. Altogether, 115 subjects volunteered in the study: 36 high school students (mean age = 11,5 years, 18 m, 18 f) consisted of 21 musicians who had an ongoing instrumental training for at least four years and 15 students without any musical training. The next group was comprised of 41 university students (mean age = 23,1 years, 16 m, 25 f) consisting of 21 music majors from the Freiburg Music Academy and 20 non music students. Finally, 38 adults participated (mean age = 55,6 years, 22 m, 16 f), 15 professional musicians and 23 adult patients of the Blick Labor Freiburg with no special musical training.

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2.2 Method

To measure F and V factors over age, two paradigms were applied. In the *overlap paradigm*, a peripheral stimulus is added to a central fixation point. The task is to immediately move the eyes to the peripheral stimulus. For the *gap paradigm*, a gap is placed between central and peripheral stimuli. Furthermore, a pro-saccade and an anti-saccade task was performed. In the pro task, eyes follow the peripheral stimulus, whereas for the anti task subjects were asked to move their eyes into the opposite direction (voluntary motion control). Mean reaction time, distribution of reaction time, rate of express saccades, rate of direction errors and reaction time for corrections in the anti-gap task were recorded during a series of 100 trials each (pro overlap and anti gap). The average reaction time, i.e. the distance between stimulus perception and motor reaction, is about 200 ms. Extremely short reaction within a span of 80 – 135 ms are called express saccades and function as a strong indicator for fixation control.

Measurements were taken individually using a helmet with an integrated infra-red diode and two photo sensors directed toward both edges of the cornea. A small laser pointer on top of the helmet projects the stimuli on a screen in front of the subjects. While moving their eyes the infra-red beam is reflected depending on the shift of the eyes. For each subject, the sensors have to be calibrated very precisely. Subjects were placed in a quiet and darkened room and performed both tasks after a short verbal instruction. Additionally, every subject performed several tests in a separated session: an intelligence test (Raven's Advanced Progressive Matrices, APM, group testing), a music aptitude test (Gordon's Advanced Measures of Music Audiation, AMMA, group testing), the Edinburgh Inventory for Handedness, and a sight reading test (Etude by M.Wright) using a six point rating scale as individual tests. The collected data were statistically analysed by Spearman correlation ranks, U-test by Mann & Whitney, and a MANOVA for all variables of the tests.

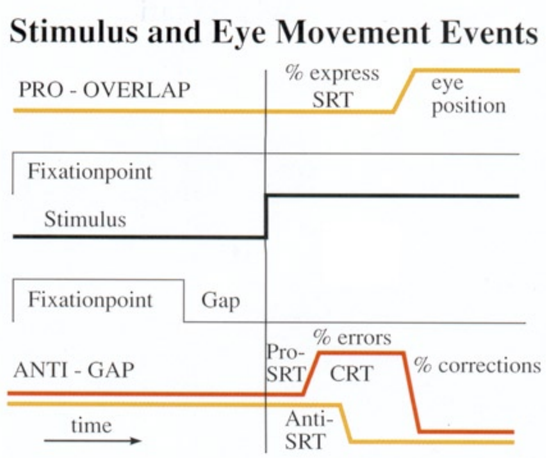

Figure 1: General design of pro-overlap and anti-gap tasks. Saccadic reaction time (SRT) and correction reaction time (CRT), rate of express saccades and errors are measured. Moving up of the eye position line refers to a stimulus jump to the right, moving down means to the left (© Blick Labor Freiburg).

3. RESULTS

As expected reaction times over all groups and ages perform two distinct peaks, one at about 120 ms (= express saccades) and the other at about 140-150 ms. However, this is only evident for the anti-gap task. Fixation and voluntary control as measured by reaction time of pro-overlap and anti-gap tasks show a clear age effect. Up to age 20 reaction time diminishes in both groups, musicians and non-musicians, but deteriorates with growing age In general there is no striking significant distinction between the music groups. Only high school students (fig. 2) exhibit a significant difference between musicians and non-musicians for the amount of express saccades ($p = .039$), whereas university students only show a slight tendency in the amount of direction errors (anti-gap pro errors $p = .068$). However, adults differ significantly in their anti-gap reaction time ($p = .055$) and the rate of their direction error corrections ($p = .016$). For these parameters, musicians exhibit higher rates of corrections and shorter reaction times.

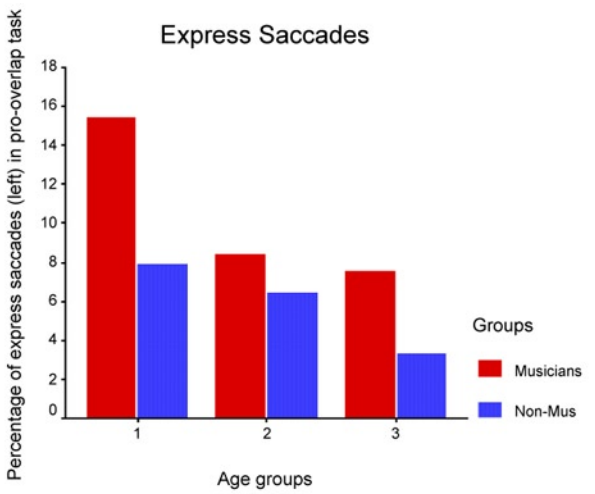

Figure 2: Distribution of express saccades performed by musicians and non-musicians of three age groups
(* = significance level $p < .05$).

A multivariate analysis of variance for all variables (pro-overlap: mean reaction time, distribution, rate of express saccades; anti-gap: mean reaction time for pro and anti saccades, rate of direction errors, mean reaction time for corrections, rate of corrections) with musical activity and age as independent factors demonstrates that only age has a significant impact on the means of all variables.

However, if we extract the best performances in sight reading and AMMA of musicians from all groups, we find them always above the means of the non-musicians in their particular age group. This is also reflected by figures 3.1 and 3.2, which present the scatter plots with regression lines differentiating between both music groups.

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However, a clear distinction between musicians and non-musicians is reflected by conspicuous divergences in the oculo-motor tasks. Non-musicians produce significantly more standard deviations (p = .007) in their voluntary control data in anti-gap tasks where frontal components are involved than musicians. In other words, musicians have a stronger voluntary control at their disposal. On the other hand, neither music aptitude, nor handedness, nor general intelligence show any effect on the performance of either one of the oculo-motor variables.

Figure 3.1: Scatter plot of mean reaction time for pro-overlap tasks at left moves by musicians and non-musicians.

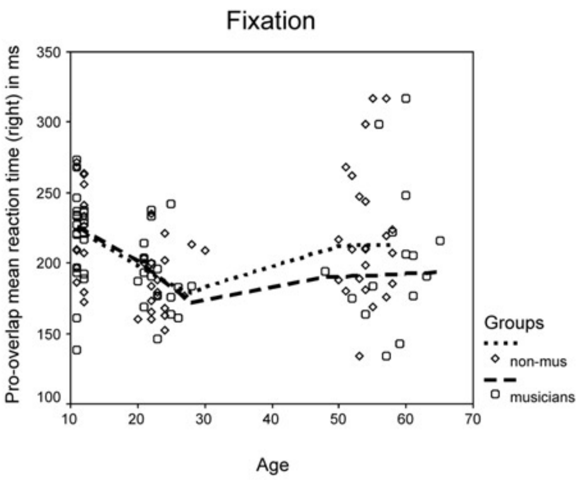

Figure 3.2: Scatter plot of mean reaction time for pro-overlap tasks at right moves by musicians and non-musicians.

4. DISCUSSION AND CONCLUSIONS

As indicated by the data from this study, there is a remarkable tendency that subjects who are trained in music do better in those tasks where frontal areas are involved and spontaneous reaction time is essential. In general, musicians perform higher speed: their reaction time is shorter, they also produce more express saccades, and are more successful in their correction of direction errors. It is also reasonable that even the best musicians in our study are stronger in voluntary eye control and more stable in their fixation. This is likely because of their daily music training which calls for high concentration, controlled fixation, attention and voluntary control.

The fact that only very few parameters show a significant difference between musicians and non-musicians is due to a very broad distribution within each group. Mainly the high school students who declared themselves as musicians with at least four years of instrumental training cannot always be seen as strongly musically trained. Many of them performed extremely poorly in sight reading. Their mean daily practice time is 30 minutes and varies between 5 and 90 minutes. Therefore, we especially looked at the best performers of each group and compared them to the mean of the non-musicians of their peers who exhibited a clear differentiation.

The results of this study generally confirm findings of an earlier study (Gruhn, Galley, & Kluth 2002) where oculo-motor data were collected from a continuously accelerated running and jumping spot paradigm and interpreted as an indicator of mental speed. In the former study only young children participated who were musically engaged in manifold ways, and their data were referred to those of a large population of peer without any music. It could be demonstrated that all subjects with music as an intervening variable exceeded their peers in mental speed significantly.

Although this study does not exhibit as strong data as the former, it is yet evident that stronger F and V factors in musicians are reflected by data that indicate fixation (such as mean reaction time of pro-saccades and rate of express saccades) and voluntary control (such as mean reaction time of anti-saccades, correction time and rate of direction errors). Additionally, it is likely that musicians tend to perform on a higher level of mental speed.

This might indicate that mental speed can be seen as a very general measure for cognitive potential which functions as a necessary prerequisite for the development of specific aptitudes. But it could also support the idea that general factors like concentration power, reaction time, voluntary control, and gross and fine body motion control may be enhanced by music practice which, then, would support the theory of transfer effects.

However, neither this nor the former study can decide about the causal link between music aptitude and achievement on the one side and cognitive factors like mental speed on the other. The data of our study make it more likely to assume that musical and cognitive abilities develop independently. However, both faculties seem to rely on general abilities that coincide in mental speed, fixation, and voluntary control factors which can be measured by eye movement. The conclusion that musicians are superior in their oculo-motor capacities is not supported by this study.

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