Proceedings of the 7th Triennial Conference of European Society for the Cognitive Sciences of Music (ESCOM 2009) Jyväskylä, Finland
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Music-related motor skills in pianists: Predictors of skill acquisition in childhood and of maintenance in adulthood

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ABSTRACT

Background and Study Aims: Previous research on musical performance achievement has focused on the overall musical performance and on musical subskills. Two studies were conducted to identify predictors of motor skill acquisition in children pianists and of long-term development of motor skills in expert pianists in a relevant musical context.
Methods: Motor skills at the piano were assessed in standardized C major scale playing. For each participant, overall temporal unevenness of note onsets was calculated as the median of the mean standard deviations of inter-onset intervals of both hands and playing directions. Study 1: Motor performance was tested in 30 piano playing children. Information regarding (a) practice strategies, (b) participants' enjoyment of music, practice, and various subjects in school and (c) parental supervision of participants' practicing was collected using questionnaires. Study 2: Motor performance of 19 expert pianists was assessed twice within an average time interval of 27 months. Practice quantity and practice strategies were assessed by means of retrospective questionnaires.
Results: Study 1: Multiple regression analysis revealed a model predicting 68 % of the variance of performance values in children pianists, with the following parameters as predictors: duration of piano education, enjoyment of practice, frequency of technical exercise, enjoyment of the subject 'art' at school, frequency of parentally supervised practice, and enjoyment of music. Study 2: Stepwise linear regression revealed a model predicting 43 % of the variance of the motor skill development in expert pianists, with the practice time accumulated during follow-up as the only predictor.
Conclusions: Predictors of motor skill acquisition in children pianists are according to factors previously found to influence musical performance achievement. In expert pianists, maintenance of motor skills was strongly influenced by amount of practice.

I. INTRODUCTION

Musicians' sensorimotor coordination is highly complex and takes place at an extremely high level of spatio-temporal accuracy. Successful strategies for the acquisition and maintenance of sensorimotor coordination required for instrumental music performance are of interest to both instrumental teachers and expertise researchers. Previous research on musical performance achievement has focused on various target parameters such as on overall musical achievement (Davidson, et al. 1996; Ericsson, et al. 1993; Howe, et al. 1995; O'Neill, 1997; Sloboda & Davidson 1996; Sosniak, 1985; Williamon, et al. 2000) or on achievement in the musical sub-skills 'performing rehearsed music', 'playing from memory', 'playing by ear', 'improvising' (McPherson, 2005), or 'sight-reading' (Lehmann & Ericsson, 1993; McPherson, 2005; Kopiez & Lee, 2006; Kopiez, et al. 2006) or on manual coordination tasks (Ericsson, et al. 1993).

So far, little attention has been paid to the acquisition and long-term development of motor skills in musicians, in particular, of motor performance in relevant musical tasks. Objective quantification of motor performance in a relevant musical task, as required to investigate its acquisition and development, was previously carried out in professional pianists while they were playing standardized C major scales (Jabusch, 2006). Scale playing is one fundamental aspect of piano technique due to the fact that scales are basic elements of the musical architecture in classical music as well as in jazz, rock and pop music. The difficulty of temporal evenness in scale playing is one of the central aspects in the training of pianistic fluency. In C major scales played by professional pianists, Jabusch (2006) found a high degree of temporal evenness in the inter-onset intervals (IOI) using a Musical Instrument Digital Interface (MIDI)-based analysis method. This method has been shown to be a valid and reliable tool to investigate temporal evenness in scale playing of pianists (Jabusch, et al. 2004). The present paper reports on two studies that have been conducted to investigate (a) temporal evenness in scale playing of children pianists and biographical and behavioral predictors that are associated with the acquisition of this motor skill and (b) the long-term development of adult, professional pianists' temporal evenness in scale playing and its predictability by the pianists' practice habits.

II. METHODS

A. Motor performance test

The procedure of scale playing and analysis of temporal evenness was performed according to a protocol published previously (Jabusch et al. 2004). Scales were performed on a digital piano that was connected to a computer. For the test, sequences of 10 to 15 C major scales were played over two octaves (range: C3-C5) in both directions, inward and outward, with each hand separately. Fingering was according to the regular C major fingering. The tempo was standardized and paced by a metronome (Study 1: 80 beats per minute, two notes per beat, 375 ms per note; Study 2: 120 beats per minute, four notes per beat, 125 ms per note). Inter-onset intervals for all individual notes of the scales were analyzed using a researcher-developed software. Scale analysis was performed for each hand and in both directions separately. Mean standard deviations of inter-onset intervals (msdIOI) were calculated for all scales of each hand and playing direction. The msdIOI parameter was previously shown to be a reliable indicator of temporal evenness in pianists' scale playing (Jabusch et al. 2004). The median of the msdIOI values of both hands and playing directions (MIOI) indicated the overall temporal unevenness of note onsets for each participant.

B. Participants and Materials

Study 1: Thirty school-aged children participated in Study 1 (22 girls and 8 boys, aged between 8 and 17 years old, median age 13). All participants had been playing the piano for at least nine months prior to the study. Twenty-six participants took their piano lessons at the Hannover Music School, four participants were taking lessons at the Hannover University of Music and Drama. Informed consent was obtained by all participants and their parents.

Scale playing performance was investigated in each child by means of the abovementioned procedure. Using questionnaires, biographical information was collected including the child's history of practicing (practice amount and content), details of piano lessons, subjects' attitudes towards music and practice, their subject preferences at school, and the extent to which their parents supervised their practice. Subjective ratings (e.g. of frequencies or of enjoyment) were encoded on corresponding 5-point scales. The questionnaire was completed with the assistance of a single researcher. Parents of the younger subjects were asked to assist in the answering of questions (Jabusch et al., 2007).

Study 2: Nineteen pianists were recruited for participation in Study 2 (12 men, 7 women). Thirteen pianists were piano students at the Hanover University of Music and Drama, six pianists had already graduated. At the beginning of the study, the pianists were aged between 19 and 39 years (mean: 28 years; standard deviation: ± 6 years). They had started to play the piano between the age of 3 and 9 years (6 ± 2 years).

Scale playing performance was investigated twice in each pianist, with an average time period of 27 months between both performance tests (referred to as baseline test and follow-up test in the following sections). Pianists were informed about the follow-up test only at the time of the invitation to participate in the follow-up test. This was done to avoid any bias in participants' practice habits (e.g. practice with focus on scale playing) during the follow-up period due to their knowledge of the study. After the baseline test, participants reported their current daily practice time, their accumulated life practice time and their age at commencement of piano playing. After the follow-up test, they reported their current daily practice time and their total practice time accumulated during the follow-up period. Additionally, they completed a questionnaire in which they documented information about their practice habits applied during the follow-up period such as changes of scale practice activities, the percentage of practice time spent with technical exercises and the application of special strategies for scale practicing such as playing in rhythms or with special articulations (Jabusch et al., 2009).

Statistical tests: For both studies, Pearson correlations were calculated to reveal associations between interval-scaled variables and Spearman rank correlations for ordinal-scaled variables. Stepwise Multiple Regression Analyses were used to assess predictability. Within-group performance results before and after follow-up were compared using the *t* test for paired samples in Study 2. Between-group differences of groups with different practice habits were analyzed by *t* tests for independent samples. The two-tailed level of statistical significance was set at $p < .05$.

III. RESULTS

A. Study 1

Children pianists began to play piano between the age of 5 and 12 years (median: 7 years) and the duration of their piano education was between 9 months and 12 years (median: 5 years). The median daily practice time was .5 hours (range: 0.2 to 3.5), and the median total life practice time was 559 hours (range: 88 to 8700). In the performance test, all children were able to play the scales according to the protocol. MIOI indicated the overall temporal unevenness of note onsets for each participant. A low score for MIOI denotes a low level of unevenness in the scales (high temporal onset precision), while a high score for MIOI denotes a high level of unevenness (low temporal onset precision). The median of the MIOI values was 20.8 ms (range: 16.0 to 31.9). A correlation was observed between the motor performance values MIOI and the daily practice time ($r = -.45$; $p < .05$), the total life practice time ($r = -.46$; $p < .05$) and the duration of piano education ($r = -.41$; $p < .05$). Stepwise multiple regression analysis revealed a model predicting 68 % of the variance of MIOI values, with the following six items of the questionnaire as predictors: duration of piano education (30 %), enjoyment of practice (10 %), frequency of practicing technical exercises (9 %), enjoyment of the subject visual arts at school (7 %), frequency of parentally supervised practice (6 %), and enjoyment of music (6 %) (Jabusch et al., 2007).

B. Study 2

At the time of the baseline test, pianists had been playing the piano for 21 ± 6 years (mean ± standard deviation), their total life practice time was 21,600 ± 10,900 hrs. MIOI values of the baseline tests (MIOI-1) ranged between 6.9 and 13.6 ms (10.2 ± 1.8 ms). After a period of 27 ± 8 months, the follow-up tests were conducted and the resulting MIOI values (MIOI-2) were between 8.1 and 15.9 ms (10.6 ± 1.9 ms). No within-group difference was observed between MIOI values of the baseline test and the follow-up test (MIOI-1 vs. MIOI-2: $t = -1.4$, $df = 18$, $p = .18$, [two-tailed]). Within the follow-up period, participants had an average daily practice time of 3.3 ± 1.8 hrs and reported

an increase of total life practice time of 2800 ± 1800 hrs. In the following sections, the difference of performance values before and after follow-up is termed MIOI-d (MIOI-d = Median of the differences of msdIOI of both hands and both playing directions (Test 2 minus Test 1)). MIOI-d values were between -1.5 and 2.6 ms (0.3 ± 1.2 ms). A correlation was found between MIOI-d and the total practice time accumulated in the follow-up period (Pearson r = -.68, p = .001) and with the average daily practice time during the follow-up period (Pearson r = -.60, p < .01). All pianists with a daily practice time of at least 3.75 hours maintained or improved their temporal onset precision in scale playing within the follow-up period. Stepwise multiple regression analysis revealed a model predicting 43 % of the variance of MIOI-d, with the practice time accumulated during the follow-up period as the only predictor. None of the parameters related to the quality of practice (i.e. change of the daily practice time; amount of scale practicing during the follow-up period; relative practice time spent with technical exercises) were identified as significant predictors. Furthermore, MIOI-d did not significantly correlate with any of these parameters. None of the outcome measures (MIOI-d; MIOI-2) differed significantly in pianists who had applied special strategies for scale practicing such as playing in rhythms or with special articulations compared to those who had not applied these strategies (Jabusch et al., 2009).

IV. DISCUSSION

The aim of Study 1 was to investigate children pianists' motor skills in a relevant musical context and to identify biographical predictors of the acquisition of these motor skills. According to expectations, variables that determined the amount of time children spent at the instrument significantly correlated with temporal fine motor precision. Moreover, the duration of piano education was a predictor for temporal fine motor precision. These findings coincide with various publications that related the number of years of practice with instrumental achievement (e.g. Ericsson et al. 1993, Sloboda & Davidson 1996, McPherson 2005). The frequency of technical practice, a predictor of fine motor precision explaining 8 % of the variance in the temporal onset precision, can be classified as one type of deliberate practice according to the definitions described by Ericsson et al. (1993). External and internal motivational factors were frequently described as influential factors for musical development. Sloboda & Davidson (1996) emphasized the necessity of external motivation developing into internal self-motivation by the early teenage years as a prerequisite to sustain the commitment required to persist with musical instrument learning. In the present study, the frequency of parentally supervised practicing represents an external motivational factor that turned out to be a predictor of temporal fine motor precision. The predictors enjoyment of practice, enjoyment of music, and enthusiasm for the subject visual arts at school may represent internal motivational factors not only for making music but additionally for a further artistic disposition.

Study 2 was conducted to investigate the long-term development of music-related motor skills in professional pianists and to investigate which elements of piano practice have an influence on this development. Within-group comparison revealed no improvement of performance within the follow-up period for the selected motor task. This may lead to the interpretation that practice activity within the follow-up period was necessary to maintain participants' performance level, i.e. to avoid deterioration of scale playing abilities. Practice activities in experts with the purpose of maintenance of performance have already been described in other domains. For example, elite swimmers have measurable decreases in their muscle metabolism if they do not train for 48 hours (Ericsson et al. 1993). The important role of practice in the maintenance of skills in older musicians has been described by Krampe & Ericsson (1996). In order to detect determinants in the practice habits which might predict the development of temporal evenness in scale playing, we retrospectively recorded the quantity of practicing and investigated several qualitative parameters connected to the practicing of scales. As one may expect, the development of performance results during the follow-up period correlated with the practice time accumulated during that period. To our surprise, regression analysis revealed a model that predicted 43 % of the variance of the performance development during the follow-up period with the variable 'practice time accumulated between test 1 and test 2' as the only predictor. No parameter specifying the content of practicing or strategies of scale practicing served as a predictor for the performance development or correlated with the development of performance during the follow-up period. It is possible that the strategies chosen as variables for qualitative analysis of practice might not be sufficient to describe those elements of practicing that are crucial for the development in scale playing. Another explanation for this finding might be the homogeneous study sample of pianists: baseline tests revealed MIOI-1 values of 10.2 ± 1.8 ms which indicate a high and homogeneous level of performance quality. Finally, it is possible that different practice strategies may be successful in different pianists depending on the individual practice biographies at the piano.

V. CONCLUSIONS

We conclude that the *acquisition of motor skills in children* pianists cohered with factors previously found to influence musical achievement at the instrument, even with the focus on a selected motor task. External and internal motivational factors accounted for 29 % of motor performance variances. In contrast, *maintenance of expert pianists' motor skills* was strongly influenced by practice quantity. A minimum daily practice time of 3.75 hours was sufficient to allow successful maintenance of motor skills in the selected motor task in professional pianists.

ACKNOWLEDGMENT

Many thanks to all participating children pianists and adult pianists who generously contributed their time and enthusiasm to this project.

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