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Biographic and behavioral factors are associated with music-related motor skills in children pianists

June T. Spector [a,b], Raymond Yong [c], Eckart Altenmüller [c], Hans-Christian Jabusch [d,*]

[a] Department of Environmental & Occupational Health Sciences, University of Washington, 4225 Roosevelt Way, Suite 100, Seattle, WA 98105, USA
[b] Department of Medicine, University of Washington, 4225 Roosevelt Way, Suite 100, Seattle, WA 98105, USA
[c] Institute of Music Physiology and Musicians' Medicine, Hannover University of Music, Drama and Media, Emmichplatz 1, 30175 Hannover, Germany
[d] Institute of Musicians' Medicine, University of Music Carl Maria von Weber, Leubnitzer Straße 17 b, 01069 Dresden, Germany

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ABSTRACT

This study aimed to identify biographical and behavioral factors associated with children pianists' motor skills using an objective assessment of a music-relevant motor task. Motor skills at the piano were assessed in 30 children pianists by measuring temporal unevenness in standardized scale playing using musical instrument digital interface (MIDI)-based scale analysis. Questionnaires were used to collect detailed information about the amount of time playing the piano, practice characteristics, attitudes toward music and practice, and the environment of music and practice. Associations between performance values and variables from the questionnaire were investigated using multivariable linear regression. A higher number of years playing the piano, more frequent parental involvement in the child's practice, more frequent practice of technical exercises, and greater enjoyment of practice and of the visual arts were associated with better motor performance. In addition to cumulative experience and aspects of practice, extrinsic motivational factors (e.g., parental interest) and intrinsic motiva-

* Corresponding author. Address: Institute of Musicians' Medicine, Dresden University of Music Carl Maria von Weber, Leubnitzer Straße 17 b, 01069 Dresden, Germany. Tel.: +49 351 6475220; fax: +49 351 64752229.
E-mail addresses: spectj@u.washington.edu (J.T. Spector), raymond@raymondyong.com (R. Yong), eckart.altenmueller@hmtm-hannover.de (E. Altenmüller), jabusch@hfmdd.de (H.-C. Jabusch).

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tional factors (e.g., an artistic disposition) were associated with better performance on a musically-relevant motor task in children pianists.

1. Introduction

Instrumental music performance is one of the most complex of human accomplishments. Instrumental musicians must develop a high level of fine motor skill and coordination to achieve the spatio-temporal accuracy required for this complex task (Kopiez, 2004). A model of the development of such skills has been proposed by Gagne (2003) and adapted to the development of musical skills specifically by McPherson and Williamon (2006). In this model, natural abilities in intellectual, creative, socio-affective, and sensori-motor domains serve as a starting point in the developmental process of learning and practicing. This process is catalyzed by intrapersonal, environmental, and chance factors to yield superior performance and skills. Natural abilities are characterized in this model as genetic in origin and may manifest as parents or other family members of children pianists who have gravitated toward piano playing and developed superior musical skills. Intrapersonal catalysts include motivation to seek challenges and constantly improve through high quality and lengthy interactions with music. These intrapersonal factors may also include a willingness to frequently practice difficult technical exercises, a positive attitude toward music, practice, and art, and a desire to attend concerts. Environmental catalysts may include the family's involvement in music and practice and support for attending concerts, which children do not necessarily have the means to accomplish by themselves. The developmental process includes high quality practice, such as deliberate practice, over a long period of time. A detailed understanding of these factors is of interest to both researchers and instrumental teachers.

Previous research has focused on biographic and behavioral factors associated with musical performance achievement in children, music students, and expert musicians. Studies in children have focused on young concert pianists (Sosniak, 1985), children in their very first year of piano study (O'Neill, 1997), and musically-gifted school children (Sloboda & Howe, 1991). Consistent with Gagné's and with McPherson's and Williamon's model, certain practice-related, environmental, and intrapersonal factors have been reported to contribute to musical performance achievement in children. These factors include: total time playing the instrument (McPherson, 2005; Sloboda & Howe, 1991); frequency of technical practice (McPherson, 2005; Sloboda & Howe, 1991); parental support and involvement (Davidson, Howe, Moore, & Sloboda, 1996; Howe, Davidson, Moore, & Sloboda, 1995; McPherson, 2009; O'Neill, 1997; Sosniak, 1985); and frequency of listening to music (Davidson et al., 1996; Howe et al., 1995).

To date, assessment of music performance achievement in research studies has relied largely on subjective measures of performance. Overall musical achievement has been assessed using the results of auditions and examinations at music schools (Davidson et al., 1996; Howe et al., 1995), ratings by instrumental teachers (Ericsson, Krampe, & Tesch-Römer, 1993; Sloboda & Howe, 1991; Williamon & Valentine, 2000), and competition results (Sosniak, 1985). Musical achievement has also been assessed through observation of musical sub-skills, including performance of rehearsed music, playing from memory, playing by ear, improvising, and sight-reading (McPherson, 2005). A large number of studies in adults have used objective methods, such as musical instrument digital interface (MIDI) techniques, to assess music achievement. These objective methods have been used to assess acquisition and maintenance of expert performance (Ericsson et al., 1993; Jabusch, Alpers, Kopiez, Vauth, & Altenmüller, 2009; Krampe & Ericsson, 1996), sight-reading (Kopiez, 2006; Lehmann & Ericsson, 1993), and other musical sub-skills. There are, however, few published studies using similar objective methods in children (Brotz, 1992; Frewen, 2009).

In the present study, we aimed to assess the relationship between motor performance, using validated objective methods, and biographical factors in children pianists. A comprehensive set of biographical factors, selected based on Gagné's and on McPherson's and Williamon's model of skill development (Gagne, 2003; McPherson & Williamon, 2006), was assessed using a standardized questionnaire rather than interview methods (Davidson et al., 1996; Howe et al., 1995; McPherson, 2005; Sloboda & Howe, 1991).

Motor performance was measured using MIDI-based scale analysis, which has been shown to be a valid and reliable tool to investigate temporal unevenness in playing in pianists (Jabusch, Vauth, & Altenmüller, 2004). The practice of scales is relevant for pianists and piano students because scales are basic elements of the musical architecture in classical music as well as in jazz, rock, and pop music. Consequently, scale playing is a fundamental aspect of piano technique. Playing scales requires finger cross-over maneuvers, which are considered to be the main difficulties in scale playing (Breithaupt, 1912). The achievement of temporal evenness in scale playing is a central goal in the training of pianistic fluency (Dichler, 1948; Neuhaus, 1993). Professional pianists have been reported to display a high degree of temporal evenness in C major scale playing (Jabusch, 2006). MIDI-based analysis of C major scale playing has been successfully used to study the effect of practice on the long-term development of adult pianists' motor skills (Jabusch et al., 2009; van Vugt, Jabusch, & Altenmüller, 2013a).

We hypothesized that practice-related, intrapersonal, and environmental factors shown to facilitate overall musical skill development are associated with fine motor precision in a musically-relevant context in children pianists. Specifically, we hypothesized that increased practice and frequency of technical practice, greater motivation, and parental involvement are associated with increased fine motor precision. Preliminary results of this research have been published by Jabusch, Yong, and Altenmüller (2007).

2. Methods

2.1. Participants

Thirty-three school-aged children who were taking piano lessons at the time of the study were recruited to participate from the Hannover music school and the Hannover University of Music, Drama and Media. Potential participants were included in the study if they were able to play C major scales on the piano over two octaves with both hands separately. Piano teachers at both institutions were informed about the project and actively supported participation of their students. No financial compensation was offered for participation. Informed consent was obtained by all participants and their parents. The study was performed in accordance with relevant institutional and national regulatory standards.

Three children were found not to be able to play scales according to the protocol and were excluded from the study. The final study sample was 30 children (22 girls and 8 boys, aged 8–17 years, median age 13). Participants had been studying piano for at least nine months prior to the study (median 5 years, range 9 months to 12 years) and took lessons once a week. Participants started playing the piano at a median age of 7 (range 5–12) years and reported practicing from three to seven days per week, with a median daily practice time of 30 min (range 10 min to 3.5 h). The median total life practice time was 559 (range 88–8697) hours. Total life practice time was strongly correlated with total years playing the piano [Spearman's $\rho(28) = 0.70$, $p < .001$] and weekly practice time [Spearman's $\rho(28) = 0.80$, $p < .001$]. Further details of participant characteristics are shown in Table 1.

2.2. Assessment of biographical factors

A self-administered questionnaire was developed that sought information on the pianistic and musical history and attitudes of participants. A single researcher was present to give clarifications when uncertainties arose in the questions, and parents of the younger participants were asked to assist in the answering of questions. The questionnaire included questions on the following topics:

Table 1
Participant characteristics and Spearman correlations with MIOI where applicable ($N = 30$).

Participant characteristic	Median (IQR) or *n* (%)	Spearman's ρ (*p*-value)[a]
Gender		
Male	8 (27%)	
Female	22 (73%)	
Total years playing the piano	5 (3, 6.5)	−0.40 (.03)
Total life practice hours	559 (362, 1129)	−0.43 (.02)
Frequency of practicing technical exercises		0.02 (.92)
Never	2 (7%)	
Seldom	3 (10%)	
Sometimes	5 (17%)	
Often	11 (37%)	
Very often	9 (30%)	
Attitude toward practice[b]		−0.27 (.15)
Sometimes likes to practice	8 (27%)	
Often likes to practice	19 (63%)	
Always likes to practice	3 (10%)	
Frequency of parental involvement in practice		−0.18 (.34)
Never	4 (13%)	
Seldom	5 (17%)	
Sometimes	6 (20%)	
Often	11 (37%)	
Very often	4 (13%)	
Parents play the piano		
No	18 (60%)	
Yes (one parent[c])	12 (40%)	
Attitude toward music[d]		−0.33 (.07)
Somewhat likes	2 (7%)	
Likes	9 (30%)	
Likes very much	19 (63%)	
Frequency of attending classical music concerts		−0.44 (.01)
Never	3 (10%)	
Less than once a year	6 (20%)	
A few times a year	11 (37%)	
Once every few months	9 (30%)	
Once a month or more	1 (3%)	
Enjoyment of art_{rel}[e,f]	0.91 (0.83, 1.36)	0.20 (.32)

IQR = Inter-Quartile Range.
[a] Correlation of participant characteristic with MIOI.
[b] No participants reported never or seldom liking to practice.
[c] No participants reported that both parents play the piano.
[d] No participants reported enjoying music not at all or not much.
[e] Four values missing.
[f] Enjoyment was rated on a scale of 1–5 (1 represents the highest level of enjoyment), and scores were normalized by dividing the score by the mean score for all school subjects to yield a relative (rel) enjoyment value.

demographics, total length of time playing the piano, practice characteristics, attitudes toward music and practice, and the environment of music and practice, including attitudes toward school subjects.

To assess total life practice times, participants were asked to indicate the amount of average daily practice time for different age segments (each of two years' duration) since the start of piano playing. Total life practice times were calculated by summing total practice durations during these age segments. Interviews have previously been shown to be a reliable method for the calculation of cumulative practice time. Lehmann & Ericsson compared retrospective estimates of cumulative practice time with cumulative practice time from participants' practice diaries and found an estimation error of 10–15% (Lehmann & Ericsson, 1998). Bengtsson et al. found a high test–retest reliability for the

assessment of practice times in professional pianists using interviews; for interviews conducted at baseline and one year later, reliability coefficients of childhood, adolescent, and adult reported practice times were 0.81, 0.86, and 0.95, respectively (Bengtsson et al., 2005).

Responses to questions addressing attitudes (e.g., attitude toward practice) were assessed using 5-point Likert scales. For questions addressing enjoyment of school subjects (e.g., visual arts, mathematics, sports), children rated their enjoyment using a scale of 1–5 (where 1 represents the highest level of enjoyment). Non-musical and non-artistic school subjects were assessed to allow for normalization of ratings: scores were normalized by dividing the score by the mean score for all school subjects to yield a relative enjoyment value.

2.3. Assessment of temporal unevenness in scale playing using MIDI-based scale analysis

The procedure of scale playing and analysis of temporal unevenness was performed according to a previously published protocol (Jabusch et al., 2004). Scales were performed on a digital piano (Kawai MP 9000) that was connected to a computer, and performances were recorded and converted to MIDI-files using commercially available music editing software (Musicator Win, v. 2.12). Sequences of 10–15 C major scales were played over two octaves (range: C3-C5) in both directions, inward and outward, with each hand separately. Participants were asked to play in legato-style. Fingering was according to the regular C major fingering: 1, 2, 3, 1, 2, 3, 4, 1, 2, 3, 1, 2, 3, 4, 5 (fingers 1–5 refer to thumb, index, middle, ring, and little finger, respectively). The tempo was standardized and paced by a metronome (80 beats per minute, two notes per beat, resulting in desired inter-onset intervals of 375 ms). Inter-onset intervals for all individual notes of the scales, except the very last note of each scale (upward note c2, downward note c), were analyzed using researcher-developed software. The standard deviation of inter-onset intervals represents the temporary unevenness of key strokes and was previously reported to be a precise indicator of pianists' motor control as well as its impairment in pianists with movement disorders (Jabusch et al., 2004). Scale analysis was performed for each hand and in both directions separately. Median standard deviations of inter-onset intervals (medsdIOI) were calculated for all scales of each hand and playing direction. To assess participants' scale playing performance, regardless of their handedness, we collapsed performance data of both hands and both playing directions using protocols analogous to those previously reported (Jabusch et al., 2009; van Vugt, Treutler, Altenmüller, & Jabusch, 2013b). The median of the medsdIOI values of both hands and playing directions (MIOI) indicated the overall temporal unevenness of note onsets for each participant. A low MIOI score corresponds to a low level of temporal unevenness in scales (greater fine motor precision), while a high score denotes a high level of temporal unevenness between the notes of the scales (lesser fine motor precision).

2.4. Statistical analyses

Descriptive statistics were used to summarize biographical characteristics. Spearman rank correlation coefficients were calculated to assess correlations between biographical variables and MIOI values. The Shapiro–Wilk test indicated that age, attitude toward practicing, total years of piano playing, parental involvement in practice, frequency of attending classical music concerts, and MIOI were normally distributed. Other variables were not normally distributed. For consistency, we used Spearman rank correlations.

Multivariable linear regression was used to estimate adjusted associations of biographical variables with MIOI. Questionnaire variables that were hypothesized to be associated with MIOI based on the theoretical framework described above and on previously reported factors that were found to be related to musical achievement in general, as well as relevant potential confounders, were selected *a priori* as variables to include in the linear regression model. Variables included in the regression model, and total life practice hours, are shown in Table 1. We included gender in the regression model, but we did not adjust for age, as age was strongly correlated with total years of piano playing [Spearman's $\rho(28) = 0.73$, $p < .001$]. The variable attitude toward music, which was not significantly correlated with enjoyment of the school subject music, was included in the regression model. The relative rating for the enjoyment of the school subject music was not included in the regression model

because it exhibited a borderline correlation with that of the enjoyment of the school subject art [Spearman's $\rho(26) = -0.34$, $p = .09$], indicating that pupils with greater enjoyment of the school subject art relative to other subjects tended to have lesser enjoyment of the school subject music. The relative rating for the enjoyment of the school subject music also exhibited a borderline correlation with the frequency of parental supervised practice [Spearman's $\rho(28) = -0.32$, $p = .09$], indicating that pupils with greater enjoyment of the school subject music relative to other subjects tended to have more frequent parental supervision of practice.

Years playing the piano and relative enjoyment of visual arts as a school subject were coded as continuous variables in the multivariable regression model. Variables for which bivariate descriptive analyses suggested an approximate linear relationship with MIOI, and an underlying interval scale could be reasonably assumed, were coded as continuous variables (frequency of parental involvement in practice, attitude toward practice, frequency of attending classical music concerts). Other variables were coded as categorical variables (gender, frequency of technical practice, whether parents play the piano, attitude toward music). *p*-values less than .05 were considered statistically significant. All analyses were performed using STATA 11 (StataCorp. College Station, TX).

3. Results

3.1. Reliability of performance values in children pianists

To assess the reliability of the performance parameter (MIOI) in children pianist participants, we divided all recorded MIDI data into two groups. Recordings with even numbers of scales were divided half. In recordings with uneven numbers of scales, the scale in the middle position of the recording was included in the first group. We calculated the MIOI values of the first (MIOI-1) and second group of scales (MIOI-2) played by each child. The intraclass correlation for MIOI-1 and MIOI-2 values was 0.91, indicating that scale playing performance values were highly consistent throughout the performances.

3.2. Scale playing performance (MIOI) and correlations with participant characteristics

The median MIOI was 19.19 ms (IQR 17.54–22.39). Correlations between independent variables and MIOI are shown in Table 1. There was no significant correlation of MIOI with age [$\rho(28) = -0.24$, $p = .20$]. There was also no significant difference in MIOI for boys ($M = 20.77$, $SD = 3.61$ ms) and girls ($M = 19.63$, $SD = 3.09$ ms), $t(11.9) = 0.79$, $p = .45$, $d = 0.34$. A lower MIOI score (greater fine motor precision) was significantly correlated with increased years playing the piano and with increased total life practice hours as well as with increased frequency of attending classical music concerts. There was a borderline correlation between lower MIOI scores and more favorable attitudes toward music.

3.3. Associations of participant characteristics with MIOI in the multivariable linear regression model

Results of the linear regression analysis are shown in Table 2. There was a decrease in mean MIOI of 0.81 ms for every additional year of piano playing (95% CI −1.44, −0.17). A higher frequency of parental involvement in the child's practice was associated with better (lower) MIOI scores ($\beta = -1.19$; 95% CI −2.02, −0.36). Increasing enjoyment of practice was associated with better (lower) MIOI scores ($\beta = -2.09$; 95% CI −3.77, −0.41), and more frequent practice of technical exercise was associated with better MIOI scores [$F(4, 12) = 4.61$, $p = .02$]. More enjoyment of the school subject art (greater values of enjoyment of art correspond to less enjoyment) was strongly associated with better MIOI scores ($\beta = 3.58$; 95% CI 1.08, 6.09). The R^2 and adjusted R^2 for the multivariable linear regression model were .86 and .72, respectively.

Table 2
Participant characteristics in the multivariable linear regression model of MIOI ($N = 26$[a]).

Participant characteristic	β Coefficient (95% CI)[b]	*p*-value
Gender (ref. male)	0.32 (−2.07,2.72)	.77
Female		
Total years playing the piano	−0.81 (−1.44, −0.17)	.02
Frequency of practicing technical exercises (ref. never)		.02
Seldom	6.31 (−1.48, 14.10)	
Sometimes	1.64 (−4.66,v7.95)	
Often	−0.60 (−7.45,6.25)	
Very often	−0.33 (−6.78,6.13)	
Attitude toward practice	−2.09 (−3.77, −0.41)	.02
Frequency of parental involvement in practice	−1.19 (−2.02, −0.36)	.01
Parents play the piano (ref. no)		
Yes (one parent)	−0.92 (−3.26,1.42)	.41
Attitude toward music (ref. somewhat likes)		
Likes	−3.59 (−8.75,1.56)	.15
Likes very much	−4.35 (−9.17,0.47)	
Frequency of attending classical music concerts	0.21 (−1.04,1.47)	.72
Enjoyment of art_{rel}[c]	3.58 (1.08,6.09)	.01

CI = Confidence Interval.
[a] Four unique values missing (4 enjoyment of art).
[b] β coefficient of participant characteristic in multivariable linear regression model of MIOI, adjusted for all other variables in the Table. For categorical variables, the β coefficient represents the mean change in MIOI compared to the reference category.
[c] Enjoyment was rated on a scale of 1–5 (1 represents the highest level of enjoyment), and scores were normalized by dividing the score by the mean score for all school subjects to yield a relative (rel) enjoyment value.

4. Discussion

In this study of biographical and behavioral factors associated with children pianists' motor skills, a higher number of years spent at the instrument, environmental factors (e.g., more frequent parental involvement in the child's practice), and intrapersonal factors (e.g., greater enjoyment of art, positive attitude towards practice) were associated with better temporal fine motor precision. These findings are consistent with previous reports of factors associated with musical performance achievement. However, to our knowledge, this is one of the first studies to use an objective measure of a musically-relevant motor task to evaluate motor skills and associated factors in children.

Age and gender were not significantly associated with fine motor precision in our study. The children in our study were older (aged 8–17, median age 13) than children in previous studies that have examined the relationship between age, gender, and motor performance. Frewen reported increased keyboard performance accuracy with increased grade level in children in kindergarten through fourth grade (approximately 9 years of age) (Frewen, 2009). In a study of children aged 7–11, decreased piano performance accuracy was associated with younger age and male gender, and this finding was hypothesized to relate to aspects of early motor development (Brotz, 1992). However, our findings suggest that for slightly older children, such as those in our study, age and gender are not related to music-related motor performance.

We observed an association of better temporal motor precision with a higher total number of years playing the piano and with a higher number of total life practice hours in the correlation analysis. Furthermore, the number of years at the piano appeared to be significantly related to temporal precision in the regression model. In our study, there was also a strong correlation between total life practice time and total years playing the piano. These observations are in keeping with McPherson's and Williamon's model of skill development through practice over a long period of time and with previous studies that have related the number of years of practice with instrumental achievement (McPherson, 2005; Sloboda & Howe, 1991). This concept is also supported by studies in other domains, ranging from chess players to sports professionals (Charness, Krampe, & Mayr, 1996; Ericsson et al., 1993).

Higher frequency of practicing technical exercises was correlated with better temporal motor precision, and this variable was a significant predictor of temporal motor precision in the regression analysis. Technical exercises can be classified as a type of deliberate practice, as defined by Ericsson et al., and deliberate practice has been reported to be associated with greater expert musical performance achievement (Ericsson et al., 1993). The frequency of technical practice has been reported to contribute to musical performance achievement in children in previous reports (McPherson, 2005; Sloboda & Howe, 1991). A willingness to practice difficult exercises may be categorized as an intrapersonal catalyst of musical skill development in McPherson's and Williamon's model (McPherson & Williamon, 2006). This motivational factor, together with a positive attitude toward practice, is likely related to more frequent practice of technical exercises.

There was a significant association between a more positive attitude toward practice and better motor performance in the regression analysis. A more positive attitude toward practice is an indicator of intrinsic motivation. Children who reported enjoyment of their practice may be more likely to engage, over time, in the kind practice that is widely thought of as being an essential part of musicianship and effective learning. According to Ericsson et al., deliberate practice is comparatively low in inherent enjoyment (Ericsson et al., 1993). Lehmann reported that musicians' subjective enjoyment levels of the different practice-related activities were different; for example, the study of new repertoire was regarded as more enjoyable than problem spot practice (Lehmann, 2002). It is possible that high enjoyment ratings for musical practice in general help children to overcome less enjoyable moments during practice (Austin, Renwick, & McPherson, 2006).

Lehmann argues that quality and quantity of practice, rather than innate talent, largely explains individual differences in performance in non-experts (Lehmann, 1997). In McPherson's and Williamon's model, natural abilities are characterized as genetic in origin and could manifest as multiple family members who have gravitated toward piano playing and developed superior musical skills. We did not find a significant relationship between parents playing the piano and better temporal motor precision. Although we have no information about the innate talent of participants, our finding is consistent with Lehmann's argument.

The correlation between practice time and performance in our study was stronger than correlations reported in certain prior studies of non-experts (Lehmann, 1997). Further, in a previous study in children, aspects of effective practice, including self-regulation, were reported to be low (McPherson & Renwick, 2001). The stronger correlation between practice time and performance observed in our study may be explained by greater proportions of effective practice time exhibited by children in our study compared to the general population of piano-playing children. Two-thirds of children in our study reported practicing technical exercises often or very often. Half of participants reported parental involvement in practice, which may enhance the effectiveness of practice (Lehmann, 1997).

More frequent parental involvement in the child's practice was associated with better motor performance. Studies have consistently shown that various forms of parental support or encouragement are associated with a greater likelihood of musical achievement in children (Davidson et al., 1996; O'Neill, 1997; Sloboda & Howe, 1991; Sosniak, 1985). Family involvement in practice, and support for attending classical music concerts, may serve as environmental catalysts for musical skill development, according to McPherson's and Williamon's model (McPherson & Williamon, 2006). Sloboda et al. emphasized the importance of the development of extrinsic motivation, which includes parental involvement, into intrinsic self-motivation by the early teenage years as a prerequisite to sustain the commitment required to persist with musical instrument learning (Sloboda & Davidson, 1996). Further study is needed to determine whether children with better motor performance at early ages, which may reflect successful extrinsic motivation, go on to develop strong intrinsic self-motivation and persistence with musical instrument learning.

Our results suggest that factors that may influence intrinsic motivation, such as attending classical music concerts or general enjoyment of the arts, are associated with motor performance. These factors may also be characterized as intrapersonal catalysts of musical skill development per McPherson's and Williamon's model (McPherson & Williamon, 2006). Intrinsic motivation has been described by Ericsson et al. as a key component of deliberate practice (Ericsson et al., 1993). In addition, audiovisual perception in the live experience of classical music concerts may facilitate the acquisition of music by observation and imitation through the previously described observation–execution system that links

visual and auditory perception to motor performance (Haslinger et al., 2005). Artistic disposition in a child might determine the extent of creativity and imagination brought to the practice of their instrument. An artistic disposition, as well as enjoyment of practice, may therefore positively affect a child's likelihood of engaging in deliberate practice.

4.1. Strengths and Limitations

Strengths of this study include the use of an objective, validated measure of motor performance that is relevant in the musical setting. This study also has several important limitations. First, the study is relatively small in size, and a lack of statistical significance in some of the effect estimates in the regression analysis may reflect a lack of study power. This issue may have been exacerbated by *a priori* coding of some variables as categorical variables in the regression model. These results should be confirmed in a larger study. Second, although a structured questionnaire was used, this questionnaire has not yet been validated, and the possibility of recall bias is present.

5. Conclusions

Years of piano playing, as well as external and internal motivational factors, were associated with temporal fine motor precision in children pianists. Although this study focused on a selected music-relevant motor task, results are consistent with previous studies of factors that influence musical achievement on the piano. Approaches that encourage and support a child's motivation to persist in musical instrument playing may contribute to improved music-related motor performance. Similar principles may also apply to other motor-intensive activities.

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