Research Report

CONCEPTUAL AND MOTOR LEARNING IN MUSIC PERFORMANCE

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Abstract—*Are the mental plans for action abstract or specified in terms of the movements with which they are produced? We report motor independence for expert music performance but not for novice performance in a transfer-of-learning task. Skilled adult pianists practiced musical pieces and transferred to new pieces with the same or different motor (hand and finger) requirements and conceptual (melodic) relations. Greatest transfer in sequence duration was observed when the same conceptual relations were retained from training to transfer, regardless of motor movements. In a second experiment, novice child pianists performed the same task. More experienced child pianists showed transfer on both the motor and the conceptual dimensions; the least experienced child pianists demonstrated transfer only to sequences with identical motor and conceptual dimensions. These findings suggest that mental plans for action become independent of the required movements only at advanced skill levels.*

A long-standing question in motor learning is whether mental plans for action are specified in terms of the movements with which they are produced (cf. Bartlett, 1948). Although this question is addressed most often in the domain of skilled behavior, the answer may differ for early stages of motor learning (cf. Adams, 1987). Motor learning refers to changes—mental or physical—associated with practice or experience that provide the capability for producing skilled actions. We report here cognitive changes that occur for novice and experienced musicians as they learn to perform unfamiliar music. Music performance is a highly complex skill on many dimensions, including its conceptual structure (such as harmony and rhythm) and its motor requirements (such as hand and finger movements). We report motor independence in mental plans for music performances by expert musicians but not by novice musicians.

Transfer-of-learning tasks, in which movement control is learned in one situation and transferred to another, often provide insight into the contents of mental plans for actions (Schmidt & Young, 1987). Transfer of learning refers to a change in response on a novel task as a function of experience on a prior task. Experiments with key-pressing tasks have demonstrated transfer of learning between sequences that require different arm or finger movements, suggesting that abstract representations underlie sequence production (Cohen, Ivry, & Keele, 1990; Keele, Cohen, & Ivry, 1990). MacKay and Bowman (1969) demonstrated transfer between two languages in sentence production; bilingual speakers practiced reading a sentence aloud in one language (English or German) under speeded conditions, and then produced either a translation (same meaning) or a new sentence (different meaning) in another language. Only the translations were produced as quickly as the original practiced sentences, indicating that speakers' representations were abstracted from the particular articulatory movements used to produce the two languages.

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Overall, these findings suggest that mental plans for action are independent of the necessary motor movements, at least at fairly skilled levels of performance. However, several factors limit generalizations to domains such as music performance. First, novel (unfamiliar) tasks are often the object of experimental study, and generalizations to well-learned naturalistic tasks such as performing music may not hold. Second, music performance has different motor and structural requirements from other production domains. Hand and finger movements in piano performance frequently reach temporal limits under natural speeded conditions, and these movements are often correlated with abstract conceptual structures, such as how hand positions on a piano keyboard achieve particular harmonies (chords). Furthermore, pianists' hand and finger movements generate expressive nuances in timing and intensity that increasingly reflect the structure of a musical sequence the more familiar or well-learned the sequence (cf. Gabrielsson, 1999; Palmer, 1997). Thus, mental plans may reflect motor movements even more with increased skill because movements in music performance often correlate with abstract structural relationships.

Piano performance offers an excellent domain in which to contrast motor-specific and motor-independent representations in sequence production, because different melodies (pitch sequences) can be produced with the same sequence of hand and finger movements, and, conversely, the same melody can be produced with different hand and finger movements (e.g., by switching between hands). We used a transfer-of-learning paradigm to document how learning to perform one musical melody affects pianists' ability to perform another melody. Learning effects were measured under speeded performance conditions during transfer to melodies that contained the same or different motor requirements (hand and finger assignments) and the same or different conceptual requirements (pitch sequence). Transfer of learning between melodies that share or differ in motor movements and pitch structure should be informative about the role of motor-specific information in representations for sequence production.

We also investigated how sequence learning differs for novice and advanced performers. Although few studies of motor learning have addressed how mental plans for action change with expertise, a common belief is that independence from motor requirements is not acquired until advanced skill levels. In fact, teaching methods for beginner pianists often focus on hand and finger positions, whereas advanced methods focus more on conceptual or interpretive aspects of musical structure. We tested changes in the role of motor variables in sequence learning by contrasting transfer-of-learning effects in skilled adult pianists and novice child pianists, who performed the same task of learning novel melodies.

EXPERIMENT 1: SKILLED ADULT PIANISTS

The first experiment investigated the nature of sequence learning in skilled music performance. Skilled adult performers practiced a short musical sequence under speeded conditions and then performed a second sequence with the same or different motor (hand and finger) assignments and the same or different conceptual relations (pitch sequence). Evidence for whether sequence learning was based on motor or conceptual aspects was measured by the amount of transfer (change in total sequence duration) from the final training trial to the transfer trials. We predicted that greatest transfer would occur when both motor and conceptual factors were the same as in training trials, and no transfer would occur when both motor and conceptual factors were different from what they were in the training trials. Most important, we predicted positive transfer would occur when conceptual aspects were retained from training, regardless of whether the motor assignments were retained.

Method

Participants

Sixteen adult pianists from the Columbus, Ohio, music community participated. Participants had a mean age of 26 years and a mean of 18 years' piano performing experience (range of 10–38 years). Informed consent was obtained.

Materials and apparatus

Simple melodies that could be performed by beginners (Experiment 2) as well as experts (Experiment 1) were created. We constructed four sets of eight isochronous (constant-duration) sequences, each containing 12 quarter-note pitches notated in 4/4 time signature. Each stimulus set was composed in a different musical key (half were major and half were minor) so it would be distinguishable melodically. Four sequences in each set were notated in the treble clef. Two of these sequences were notated for the right hand and fingers, and two were notated for the left hand and fingers. In addition, two were based on one pitch sequence (melody), and two were based on a different pitch sequence. The remaining four sequences in each set were identical in all motor and pitch information, but were notated in the bass clef (in a different octave), to be visually distinguishable. Thus, each set of eight sequences contained all combinations of clef (treble, bass), hand and fingers (right, left), and pitch sequences (melody).

Participants performed on a computer-monitored Yamaha MX100 upright acoustic piano (2-ms resolution). Computer software determined key-press onsets and offsets and identified pitch errors by comparing the performance with the information in the notated musical score.

Design and procedure

The experiment used a 2 × 2 within-subjects design with independent variables of motor assignments (same or different hand and fingers, called *Msame* and *Mdiff*, respectively) and conceptual relationships (same or different pitch sequence, called *Csame* and *Cdiff*, respectively). The dependent variables were total sequence duration (onset of last tone minus onset of first tone) and percentage of pitch errors per sequence. The four conditions were ordered within an experimental session according to a Latin square design, with a different stimulus set assigned to each condition for each subject. Each stimulus appeared equally often in each condition across subjects. The following variables were balanced across subjects and conditions: whether the musical sequence was performed by the left or right hand, whether the sequence was notated in the treble or bass clef, and which stimulus set was assigned to each condition. Furthermore, hand and finger assignments for melodies were counterbalanced across both conditions and performers.

Participants completed the following procedure for each condition: They first performed a musical sequence slowly with a metronome (m.m. = 69 bpm) until no errors were made (to ensure that any errors under speeded conditions were not due to perceptual or reading errors); all participants performed the sequence without any errors within three pretraining trials. Then participants performed the same sequence 10 times, as quickly as possible. They then performed one of four related transfer sequences from the same stimulus set. Examples of training and transfer stimuli for the four conditions are shown in Figure 1. Depending on the condition, this transfer sequence differed from the training sequence in conceptual (melody) relations only (Cdiff-Msame), in motor (hand and finger) assignments only (Csame-Mdiff), in both conceptual relations and motor assignments (Cdiff-Mdiff), or in neither conceptual relations nor motor assignments (Csame-Msame; this condition yielded the original melody). The transfer sequences were distinguishable from the training sequences because they were notated in a different octave and clef. Participants performed the transfer sequence four times as quickly as possible. This procedure was repeated for each condition with sequences from a new stimulus set.

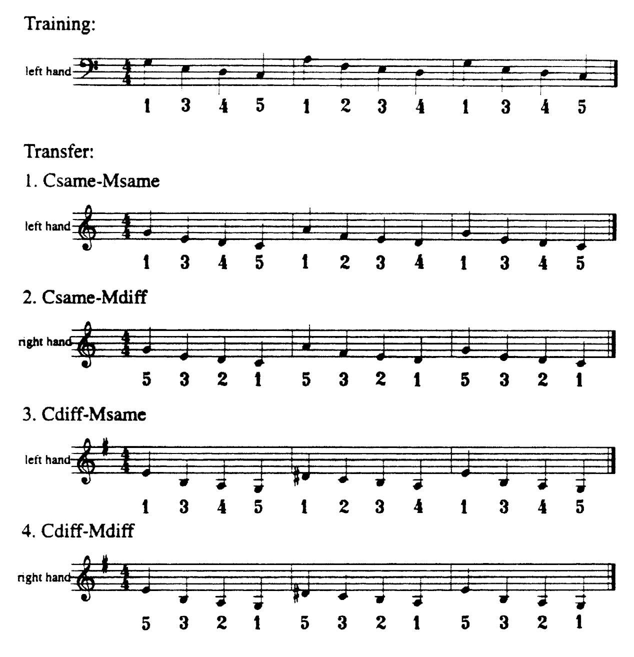

Fig. 1. Example of musical sequences used in the training and transfer conditions. The numbers indicate the fingering to be used, with 1 representing the thumb. Labels for the transfer conditions indicate whether the conceptual relations and motor assignments were the same as in the training sequence: Csame = same conceptual relations; Cdiff = different conceptual relations; Msame = same motor assignments; Mdiff = different motor assignments.

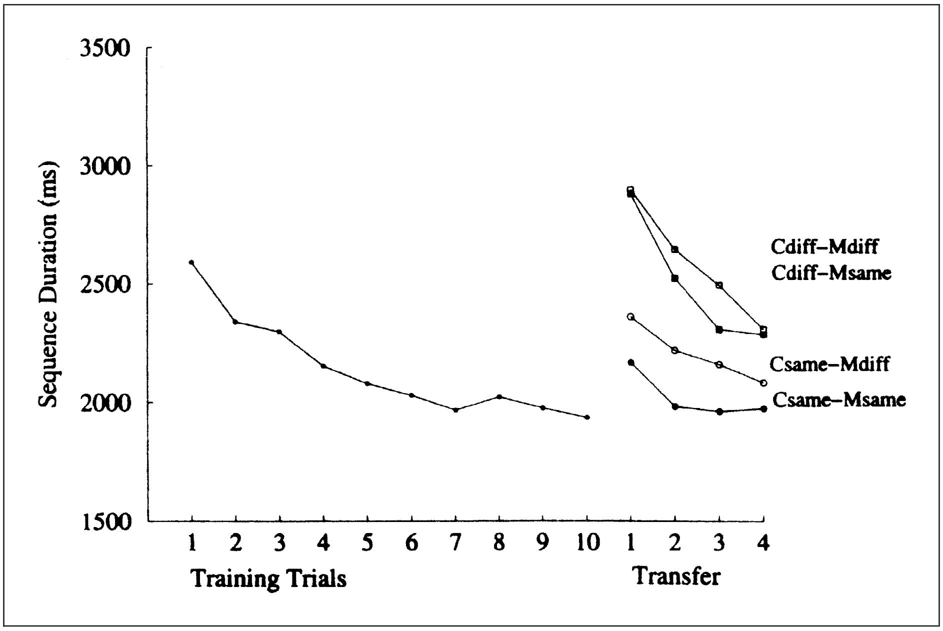

Fig. 2. Mean sequence durations in training and transfer trials for skilled adult pianists in Experiment 1. Labels for the transfer conditions indicate whether the conceptual relations and motor assignments were the same as in the training sequence: Csame = same conceptual relations; Cdiff = different conceptual relations; Msame = same motor assignments; Mdiff = different motor assignments.

Results

Sequence duration

Analyses of variance on the difference between the sequence duration of the last training trial (Trial 10) and the mean duration of the transfer trials (11–14) indicated significant effects of the conceptual condition, $F(1, 15) = 16.4$, $p < .01$, but not the motor condition. As shown in Figure 2, transfer was greatest when the conceptual melodic relationships were retained across sequences, regardless of whether the hand and finger movements remained the same.[1] Planned comparisons among all pairs of conditions supported these findings; the only significant differences were between the Csame-Msame and Cdiff-Msame conditions and between the Csame-Mdiff and Cdiff-Mdiff conditions ($p < .05$). "Perfect" transfer (no significant change in sequence duration between training and transfer) was obtained for the Csame-Msame condition only. There were no significant effects on amount of transfer due to pianists' musical experience or training, handedness, or hand assignments at transfer.

Errors

The percentages of pitch errors showed no significant differences between training and transfer trials; performance was close to perfect in all conditions (mean error = 3.0%). Thus, differences in sequence duration across conditions were not simply a function of a speed-accuracy trade-off.

1. Although performance on the first transfer trial was slower than performance on the first training trial in some conditions, this difference is probably an effect of practice gained during the pretraining trial (trials) at the slow tempo (to eliminate perceptual or reading errors), rather than a true negative transfer.

EXPERIMENT 2: NOVICE CHILD PIANISTS

Experiment 2 investigated the nature of sequence learning for novice child pianists, using the same transfer-of-learning paradigm as in Experiment 1. Although skilled pianists' representations for musical sequences are abstracted from the necessary hand and finger movements, novices may not yet have separated the abstract pitch relations from the motor movements that give rise to them. In Experiment 2, novice child pianists performed simplified musical sequences similar to those used in Experiment 1, under the same speeded conditions. As in Experiment 1, we predicted positive transfer when conceptual factors were the same from training to transfer. However, we also predicted positive transfer when motor (hand and finger) assignments were retained from training to transfer.

Method

Participants

Sixteen child pianists (mean age = 11.2 years) from the Columbus, Ohio, community participated. The pianists had a mean of 4.7 years of piano performing experience. The 8 pianists with the least amount of performing experience had a mean age of 10.5 years and a mean of 3.6 years' piano experience (range: 3–4). The 8 pianists with the most performing experience had a mean age of 11.9 years and a mean of 5.8 years' piano experience (range: 5–7). Parental consent was obtained in advance for all children.

Materials and apparatus

The stimulus materials from Experiment 1 were used; some were simplified (they were transposed to musical keys that contained fewer black keys or accidentals). The same apparatus was used as in Experiment 1.

Procedure

The procedure was similar to that of Experiment 1, except that the child participants played the first musical sequence at a slow rate without a metronome, until they could perform it without any errors (by the third trial). In addition, the children were told explicitly about the sequence to be performed (its key signature and starting hand position). These changes were introduced to make the task easier for the children. Total sequence duration and percentage of pitch errors were measured as before.

Results

Sequence duration

As shown in Figure 3, transfer was significant on both the motor and the conceptual dimensions. An analysis of variance on the difference between the sequence duration for the last training trial (10) and the mean duration of the transfer trials (11–14) indicated both a significant effect of motor condition, $F(1, 15) = 4.65$, $p < .05$, and a significant effect of conceptual condition, $F(1, 15) = 7.68$, $p < .05$. Planned comparisons supported these findings: There were significant differences between the Csame-Msame and Csame-Mdiff conditions and between the Csame-Msame and Cdiff-Msame conditions ($p < .05$). Thus, performance improved with both motor and conceptual similarity between musical sequences. "Perfect" transfer (no significant change in sequence duration from training to transfer) was obtained for the Csame-Msame condition only.

Errors

Percentages of pitch errors indicated performance was close to perfect (mean = 2.6%), with no differences across conditions. Thus, differences in sequence duration across conditions were not simply a function of a speed-accuracy trade-off.

Effects of musical experience

Although there were no effects of children's handedness alone or hand assignment at transfer, amount of piano experience (years of performing piano) did influence transfer in children's performances. Total sequence durations for the 8 least experienced pianists (3–4 years' piano experience) and 8 most experienced pianists (5–7 years) are shown in Figure 4. Differences between sequence duration on the last training trial and mean duration on the transfer trials indicated both a significant effect of motor condition and a significant effect of conceptual condition ($p < .05$) for the most experienced child pianists. In contrast, neither dimension had a significant effect for the least experienced children; transfer was obtained only for the same melody, produced with the same hand and finger movements. (The 95% confidence intervals indicated significant differences only between the Csame-Msame condition and all remaining conditions, $p < .05$.) The least experienced child pianists showed transfer of learning only to a particular instance of a sequence (Fig. 4a), whereas more experienced child pianists showed transfer to new sequences that were similar on either motor or conceptual dimensions (Fig. 4b).

GENERAL DISCUSSION

Musicians' transfer of learning across novel melodies indicates that as skill increases, mental representations for performance become

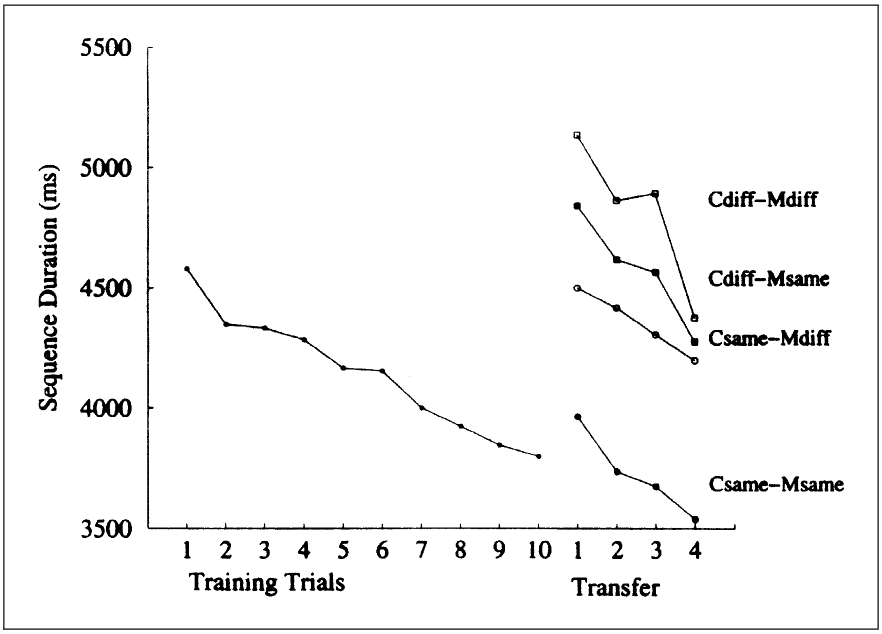

Fig. 3. Mean sequence durations in training and transfer trials for novice child pianists in Experiment 2. Labels for the transfer conditions indicate whether the conceptual relations and motor assignments were the same as in the training sequence: Csame = same conceptual relations; Cdiff = different conceptual relations; Msame = same motor assignments; Mdiff = different motor assignments.

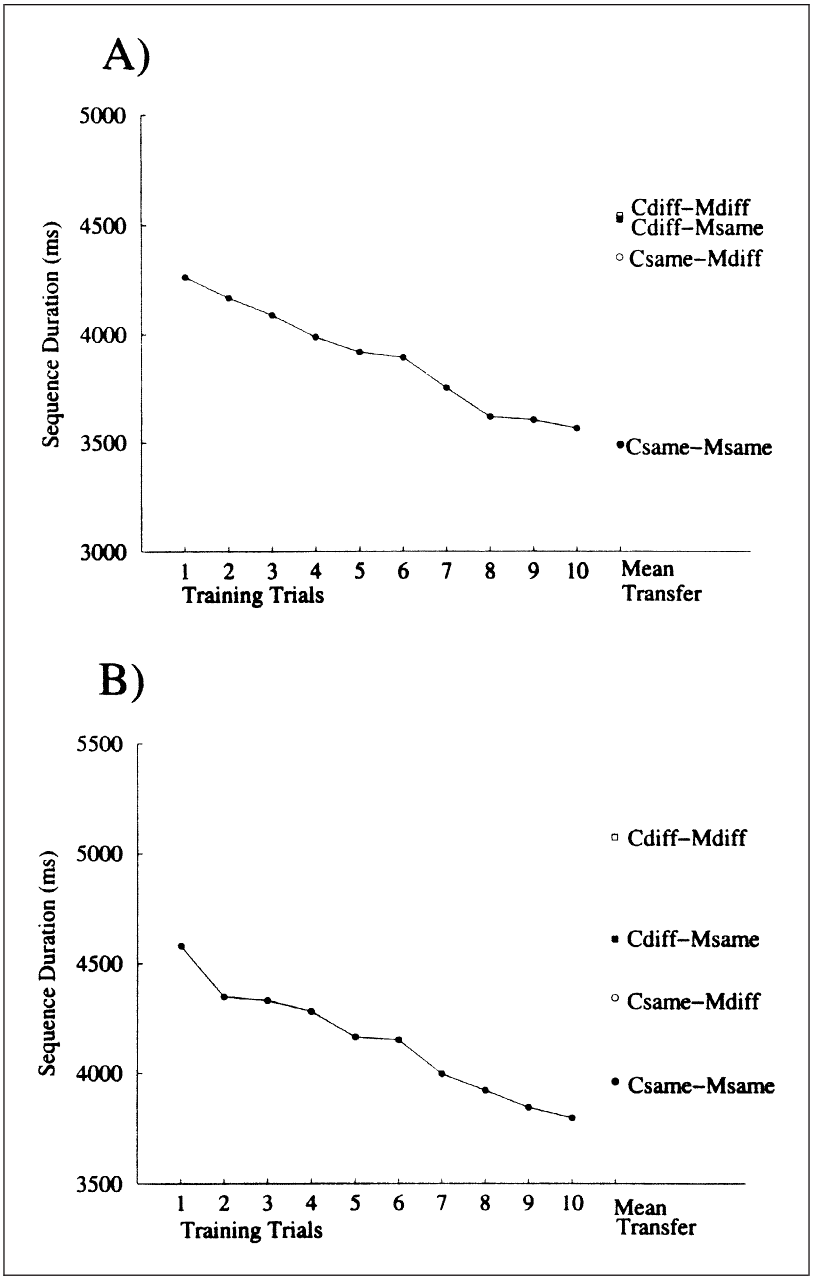

Fig. 4. Mean sequence durations of (a) the least experienced and (b) most experienced child pianists in Experiment 2. Labels for the transfer conditions indicate whether the conceptual relations and motor assignments were the same as in the training sequence: Csame = same conceptual relations; Cdiff = different conceptual relations; Msame = same motor assignments; Mdiff = different motor assignments.

dissociated from the movements required to produce a musical sequence; advanced performers' mental plans are based on abstract, conceptual pitch relations. These findings are consistent with evidence that conceptual (meaning) dimensions dominate articulatory movements in transfer tasks with speech (MacKay, 1987; MacKay & Bowman, 1969), and that conceptual (melodic) dimensions are independent of hand and finger movements in error patterns in piano performance (Palmer & van de Sande, 1993). In contrast to the results for skilled adults, the results for novice children showed transfer of learning that reflected the movements as much as the abstract pitch relationships. Thus, results of transfer tasks may not generalize from skilled to novice performers; compared with novice performers, skilled performers demonstrate more dissociation between abstract sequence dimensions and movements, and a lower weighting of the movement dimension.

Differences in sequence representations were found even within novice children's performances. More experienced child pianists (5–7 years of piano experience) showed both motor and conceptual transfer, but less experienced pianists (3–4 years) showed instance-based learning only (i.e., transfer occurred for the same musical sequence only). These findings suggest that the motor and conceptual dimensions become differentiated within a sequence representation as learning to perform progresses; only then are similarities across instances recognized in terms of those dimensions, resulting in transfer between different sequences. These findings are analogous to predictions of perceptual learning theories proposing that features of stimuli become discriminable as responses to those stimuli are learned (see Adams, 1987). Although some change in sequence representation may be maturational (the more experienced children were 1 year older on average than the less experienced children), age is not likely to be a main determinant, because differences were larger qualitatively between less and more experienced children than between children and adults. Findings of greatest change at early stages of learning are also consistent with the power law of practice (Newell & Rosenbloom, 1981), and with other music performance studies that indicate cognitive changes are largest at early stages of skill acquisition, independent of age of acquisition (Palmer & Drake, 1997).

Two issues raised by these findings include whether the motor transfer reflected hand movements, finger movements, or both and whether the task demands were too simple motorically for skilled pianists. The hand and finger movements were altered simultaneously in this study, to allow for stimulus melodies with simple fingerings that child novices could perform. Although further study is required to separate the role of hand and finger movements, three factors suggest that the motor transfer reflected primarily finger (not hand) movements: The amount of transfer was not affected by the hand used in the training conditions, by differences between hands within each transfer condition, or by the handedness of the pianists, for the experts or the novices. The second issue, that the task may have been simpler motorically for experts than for novices and therefore allowed more room for motor learning by novices, may account for the lack of motor effects in experts' performances. However, the novices' simplified musical sequences led to the same low error rates (2–3%) as the sequences performed by the skilled performers, suggesting that the task was of equivalent difficulty for the two groups. Extensions of this task to more complex music are needed.

Most important, these findings extend definitions of motor skills that combine cognitive and motor functions (Adams, 1987; Bartlett, 1948), indicating that mental plans for behaviors such as music performance become increasingly abstract and decreasingly motoric as skill increases. In contrast to previous transfer studies of motor learning that relied primarily on simple materials or unfamiliar tasks, studies of music performance utilize a naturalistic task that reflects complex stimulus structure. This fact, combined with the equivalence of task difficulty observed for the children and adults, offers compelling grounds for generalization of these findings to other motor domains. Finally, the greatest representational change in sequence learning was observed at relatively inexperienced skill levels. As Adams (1987) pointed out, investigators should have only a passing interest in behavior at its (highly skilled) asymptote; a scientific understanding of motor skills must be concerned with all levels of skill acquisition.

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