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Effects of Melodic Structure and Meter on the Sight-reading Performances of Beginners and Advanced Pianists

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ABSTRACT

We explored how the melodic structure (that can determine the fingering) and the meter would affect visual encoding (i.e., fixation measured by an eye tracking device), visuo-motor coordination (i.e., eye-hand span), and the execution (i.e, mistakes, stuttering) in the beginner's sight-reading performances in comparison to the advanced pianist's. Eighteen students—9 beginners and 9 advanced pianists—sight-read simple melodic scores, consisting of the step-wise, the skip-wise, or the combined structure written in 3/4, 4/4, or 5/4. Results indicated that the melodic structure affected the beginner's encoding and execution. The combined structure had the beginners spend more time in saccade (rather than in fixation) and stutter more often than the step-wise or the skip-wise structure. The meter, on the other hand, affected the advanced pianist's visuo-motor coordination and execution. The complex meter (i.e., 5/4) resulted in the advanced pianist's shorter eye-hand span than a simple meter (i.e., 3/4, 4/4), in line with Chang (1993), and more rhythm errors than 4/4 meter. The beginner's sight-reading was less efficient than the advanced pianists in visual encoding, in visuo-motor coordination, and in execution. Nonetheless, the beginners could read 0.52 notes *ahead* of what was being played regardless of the meter or the melodic structure of the score.

I. INTRODUCTION

Sight-reading literature has focused mostly on experts (Chang, 1993; Furneaux & Land, 1999; Goolsby, 1994; Lehmann & McArthur, 2002; Sloboda, 1977; Truitt, Clifton, Pollatsek, & Rayner, 1997; Wurtz, 2009), and it is still unknown what happens when beginners try sight-reading a simple music score. The purpose of the present study was to obtain empirical evidence of the basic cognitive processes involved in the beginner's sight-reading performance. In particular, we explored how the melodic structure (that can determine the fingering) and the meter would affect the visual encoding (i.e., fixation measured by an eye tracker), the visuo-motor coordination (i.e., eye-hand span), and the execution (i.e, mistakes, stuttering) in the beginner's sight-reading in comparison to the advanced pianist's.

We predicted that an advanced pianist's performance would be superior to the beginners in the visual encoding, the visuo-motor coordination, and the execution. Based on Chang (1993), the advanced pianists would sight-read scores written in a simple meter better than those in a complex meter due to their long-term exposures to simple-meter pieces. The beginners would not be affected by the metric structure due to their limited exposures to any score but by the melodic structure. More specifically, the beginners would perform "step-wise" structures (i.e., moving adjacent fingers) better than "skip-wise" structures (i.e., moving non-adjacent fingers), and they would perform either of these structures better than "combined" structures (i.e., mixture of moving adjacent and non-adjacent fingers).

II. METHOD

A. Participants

Participants were 18 graduate and undergraduate students. Of those 9 had less than 1 year of musical training beyond 8-12 (M = 9.22, SD = 1.09) years of classroom music instruction ("the beginners") and 9 had 11-20 (M = 16.22, SD = 4.06) years of keyboard training in addition to 9-12 (M = 11.56, SD = 1.01) years of classroom music instruction ("the advanced"). They received either a course credit for the first author's lectures or a small gift as an incentive.

B. Materials

1) For warm-up. Three graphic scores and one score with the staff notation were prepared. The first graphic score consisted of 18 filled squares (depicting quarter notes) arranged in such a way that only adjacent fingers were supposed to move. The second graphic score consisted of 7 unfilled rectangles (depicting half notes) arranged such that either every other finger (i.e., 1, 3, 5) or the two outer fingers (i.e., 1, 5) were supposed to move. The third graphic score consisted of a combination of 5 unfilled rectangles and 8 filled squares arranged in such a way that the opening pattern (i.e., a half note followed by the two quarter notes with step-up motions) was arranged into sequences (Figure 1a). The third graphic score was converted into the staff notation (Figure 1b) as the fourth warm-up material. Only quarter notes, quarter rests, and half notes were used for the warm-up. The graphical notations were created by using Microsoft Excel 2000, and the staff notation was created by Finale 2003.

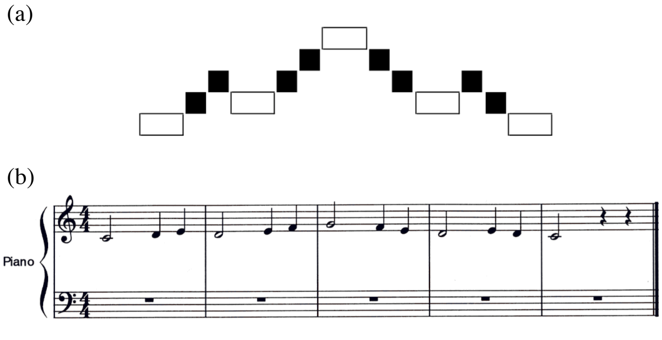

Figure 1. The third (a) and the fourth (b) warm-up materials.

2) For practice. One score, consisted of 8 measures in 4/4 meter, was prepared for a practice trial by using Finale 2003. In addition to the aforementioned rhythm notations, eighth notes were introduced.

3) For trials. For the actual sight-reading materials, we first prepared three melodies in C major on the treble staff. The first melody mostly consisted of a step-wise motion requiring a player to move adjacent fingers within 5 scale tones ("step-wise" melody, Figure 2a). The second melody mostly consisted of a skip-wise motion requiring a player to move every other finger within 5 scale tones ("skip-wise" melody, Figure 2b). The third melody consisted of both step-wise and skip-wise motions requiring mixed fingerings as well as shifting the hand position within 9 scale tones ("combined" melody, Figure 2c). We then arranged each melody into three metrical structures: a 24-measure-long 3/4-meter piece (see Figure 2a), a 24-measure-long 4/4-meter piece (Figure 3a), and a 25-measure-long 5/4-meter piece (Figure 3b). Thus, total of nine melodies (i.e., 3 structures × 3 meters) were prepared for the experiment. The scores were created by using Finale 2003.

Figure 2. The first 4 measures of the three types of melodic structures written in 3/4 meter: step-wise (a), skip-wise (b), and combined (c).

4) Stimuli for an experiment. The actual stimuli used for each experiment were created as Microsoft PowerPoint 2001 slides. The graphical and staff notations were converted to bmp files to be imported into slides. One set of stimuli consisted of 12 slides: four slides for verbal cues, four slides for warm-up materials (i.e., 3 graphical and 1 standard notations), one slide for the practice material, and three slides for the experimental trials. To identify the presentation timing of each of the three trial materials, beeping sound was added only to these trials. Because there were 18 different combinations and orders of the three trial slides based on the aforementioned nine melodies, 18 PowerPoint files were created.

C. Apparatus

The experimental stimuli were presented through a display (FlexScan S170, Eizo) controlled by a Windows XP computer. Eye movements were recorded by means of a baseball-cap-style eye tracker (ST-560, Nac) and a digital videocassette recorder (DSR-11, Sony). Each participant sight-read the material on an electric piano (Clavinova CLP-170, Yamaha). The sound output of the piano was connected to the analogue input of the digital videocassette recorder (DSR-11), so that the timing of eye movements and that of the sound produced on the piano could be synchronized. To obtain data from the video- and the audio-recordings, the digital information was imported to a Mackintosh G3 computer by means of Final Cut Express HD (Apple, Ver. 3.5.1).

Figure 3. The first 4 measures of the step-wise melody written in 4/4 (a) and in 5/4 (b).

D. Procedure

Each participant was assigned randomly to one of 18 experimental stimuli, such that the nine target materials (i.e., 3 structures × 3 meters) would be sight-read in the counter-balanced manner. During the warm-up, the beginners were given a quick instruction for how to read and play a melody on the piano with one hand by reading patterns (rather than individual notes) through graphic and staff notations (see Figure 1). The participants were allowed to use whichever hand they preferred for the task. They were also told in advance that the two of the three melodies they would be sight-reading later consisted of five adjacent pitches, just like what they saw in the warm-up, but that one of the melodies consisted of nine pitches and they would need to move their hand position. The advanced pianists also went along with the same warm-up materials without detailed instruction. After the warm-up, the participants became equipped with the eye tracker.

Once the eye tracker was calibrated, the participants were asked not to move their heads or the position of the piano bench. Prior to the practice trial, the participants were informed that the length of the practice material was about one-third of the trial materials. Also, they were instructed to play the melody in their comfortable tempo and to try not to stutter even when they made mistakes. Furthermore, the participants were told that they could stop sight-reading if they felt it was too difficult to continue. For the practice, the beginners were given 1-min preview time, during which they were allowed to sing the melody or to move their fingers, but the piano lid was closed by the experimenter, so that they could not touch any keys. The advanced pianists were instructed to begin sight-reading as soon as the score was presented. The beginners were allowed to review the same practice material as many times as they wanted before moving on to the trials.

During the experimental trials, the beginners were given 3 min to study the score before each trial in the way they did for the practice trial, whereas no preview time was given to the advanced pianists. During both the practice and the experimental trials, the experimenter stayed away from the participant once the score was presented. During the experimental trials, the experimenter did not communicate with the participant.

E. Data Analysis

1) Eye movements. As a measure for the visual encoding, we examined the fixations while each participant was sight-reading the second line (9-16 measures) of each score, located in the center of the display, showing the eye-tracking markers most clearly and reliably. Of the two eye-tracking markers per participant, we used the more clearly recorded one. If both eyes were tracked equally well, then we used the one that was the same as the participant's handedness. The locations of the eye-tracking markers were identified frame by frame (i.e., 1/30 s). If the eye-tracking marker stayed at the same location for 2 or more frames, we identified it as a fixation, otherwise, as a saccade. We obtained *the proportion of fixation* by dividing the number of "fixation" frames by the total number of frames during the target portion of each score. We also obtained *the mean number of frames per fixation* for the target portion of each score.

2) Eye-hand span. As a measure for the efficiency of the visuo-motor coordination, we examined *the eye-hand span* ("EHS"), expressed as the number of notes between the note fixated and the note played (e.g., Furneaux & Land, 1999; Sloboda, 1977). To obtain EHS, we first numbered all the notes (including rests) with integers (i.e., 1, 2, 3, etc.) from left to right on the target portion (9-16 measures) of each score. We then measured the distance between the note number being fixated in *one frame after* the beginning of the produced sound (identified in the wave form on Final Cut Express HD) and the note number being played. By doing so, we managed to avoid mistaking the beginning of saccade for fixation. If the fixated location was somewhere between two notes, then we identified that location by adding .5 to the note number on the left side. If the eye-tracking marker did not exist in the target frame (perhaps, because of looking somewhere outside the score), we assumed that the participant was playing the note based on the last information obtained from the score; we went back to the frame where we could locate the eye-tracking marker just before the current sound production, and calculated the distance by subtracting the note number being played from the note number being fixated at that location. We obtained this distance when each note in the target portion of each score was being played, and identified EHS for each piece by calculating the mean distance between the note being fixated and the note being played.

3) Errors. As a measure for the quality of the execution, we used three types of errors: *pitch errors*, *rhythm errors*, and *stuttering* (i.e., destruction of flow by reviewing one or more notes). *Pitch errors, rhythm errors*, and *stuttering* were evaluated for each note (including a rest) on each score. For pitch errors, if the participant played a wrong key, skipped/added a note, or played more than two or more tones at a time, it was identified as an error. *The proportion of pitch errors* was calculated for each score for each participant by dividing the number of errors by the total number of notes. For rhythm errors, either a shorter or a longer duration than the note on the score was identified as an error. *The proportion of rhythm errors* was calculated for each score for each participant by dividing the number of mistakes by the total number of notes. For *stuttering*, if the participant played the target note more than once, then the number of additional tones played for that particular note was recorded. *The total number of stuttering* for each score was used for analysis.

4) Statistical analysis. Because data for some measurements were not normally distributed, we used a permutation test (Good, 1994; Roff, 2006), which allows us to test significance of difference against the distribution based on the current sample rather than a known distribution under particular assumptions (e.g., normal distribution). Unlike conventional non-parametric tests, which convert interval data into ordinal ones, permutation tests can maintain the original data. According to Roff (2006), results of a permutation test with two or more independent variables (e.g., permutation two-way ANOVA) can be unreliable. Therefore, we used permutation *t*-tests for all comparisons with Bonferroni's correction for the level of significance (α). Since the present study was exploratory, the overall α for each comparison was set at .10. The number of iterations per test was 2000.

III. RESULTS

A. Effects of Musical Training on the Overall Performance

Overall, the advanced pianist's performances were superior to the beginners (*ps* < .0005), as predicted. The proportion of fixation was greater during the advanced pianist's (*M* = .88, *SD* = 0.09) than during the beginner's (*M* = .79, *SD* = 0.08) sight-reading performance. The advanced pianist's EHS (*M* = 1.73, *SD* = .80) was longer than the beginner's (*M* = 0.52, *SD* = 0.43). The advanced pianists (*M* = .01, *SD* = 0.02 on pitch; *M* = .02, *SD* = 0.06 on rhythm) made much fewer errors than the beginners (*M* = .06, *SD* = 0.05 on pitch; *M* = .19, *SD* = 0.21 on rhythm). The beginners (*M* = 2.74, *SD* = 3.81) stuttered more often than the advanced pianists (*M* = 0.22, *SD* = 0.57). One measure—the mean number of frames per fixation—did not reveal significant differences between the beginners (*M* = 10.82, *SD* = 3.15) and the advanced pianists (*M* = 11.12, *SD* = 3.39).

B. Effects of Meter

We conducted three multiple comparisons for each dependent variable per sample (Bonferroni's correction, subset's α = .034). The meter affected the advanced pianist's sight-reading performances, as predicted. More specifically, the advanced pianist's EHS for the scores written in 5/4 meter (*M* = 1.26, *SD* = 0.59) appeared to be shorter than those written in 3/4 (*M* = 1.90, *SD* = 0.82) or in 4/4 (*M* = 2.03, *SD* = 0.75); they were approaching significant (*ps* = .085 and .043, respectively). The advanced pianists made more rhythm errors in sight-reading the scores in 3/4 (*M* = .03, *SD* = 0.08) or in 5/4 meter (*M* = .03, *SD* = 0.07) than those in 4/4 meter (*M* = .00, *SD* = 0.00), both of which were significant (*ps* < .0005). Similar effects were observed in the beginner's rhythm errors. The beginners also made more rhythm errors for the scores written in 3/4 (*M* = .23, *SD* = 0.23) or 5/4 (*M* = .24, *SD* =

0.19) than those in 4/4 (*M* = .11, *SD* = 0.07), but these differences were not significant (*ps* = .225 and .192, respectively).

C. Effects of Melodic Structures (Fingering)

We conducted three multiple comparisons for each dependent variable per sample (Bonferroni's correction, subset's $\alpha = .034$). The melodic structure affected only the beginner's sight-reading performances, as predicted. The proportion of the beginner's fixation appeared to be smaller in the combined (*M* = .74, *SD* = 0.08) than in the step-wise (*M* = .81, *SD* = 0.07) or in the skip-wise (*M* = .81, *SD* = 0.07) structure; they were approaching significant (*ps* = .076 and .089, respectively). On the other hand, the melodic structure affected the beginner's execution. The beginners stuttered more often in the combined (*M* = 5.67, *SD* = 5.14) than in the stepwise (*M* = 0.89, *SD* = 0.74) or in the skip-wise (*M* = 1.67, *SD* = 1.83) structure (*ps* = .004 and .032, respectively).

IV. DISCUSSION

Results of the present study revealed that the sight-reading processes could be investigated with beginners as well. The beginner's sight-reading was less efficient than the advanced pianists in visual encoding, in visuo-motor coordination, and in execution. Nonetheless, the beginners could read 0.52 notes ahead of what was being played regardless of the meter or the melodic structure of the score. The beginners stuttered more often when they were sight-reading the combined structure than either the step-wise or the skip-wise structure. Since their errors were not affected by the melodic structure, the beginner's stuttering may have resulted from their lacking confidence rather than from their correction of errors.

The present study re-confirmed the negative effect of complex meter on the advanced pianist's sight-reading (Chang, 1993). It is surprising that the lesser exposure to complex meter in general could shorten the advanced pianist's EHS and increase rhythm errors even for a simple melodic score.

The present study demonstrated that beginners could sight-read simple melodic scores on the piano with minimal information about relations among structural cues on the staff notation, fingering, and hand position on the keyboard. The use of graphic notations, proven as effective in children's understanding of music (e.g., Adachi, 1992, 2012; Adachi & Chino, 2004), may also be effective in the adult beginner's introductory piano instruction. How the adult beginners improve their sight-reading skills through such an instruction is worthy of another study.

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