Cognitive Processes during Piano and Guitar Performance: An Eye Movement Study

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ABSTRACT

The purpose of this study is to clarify the cognitive processes during music performance, namely how the players view the music and make the fingers move. This paper focuses on preview time (hand eye span) in piano and guitar playing. Two experiments were conducted, one was for piano and the other was for guitar. In both experiments, musical score was presented on a computer screen, and subject was required to play the instrument fluently. The music pieces were well-known piece, unknown piece and difficult piece, and all were single melody music. The basic characteristics of eye movements during piano and guitar playing were analyzed. Also, the preview times were estimated using relation between eye tracking data and finger movement data. The preview for the music was observed in all experimental conditions for both instruments, but the preview times were different among subjects, music pieces, and trial numbers. The preview times were longer in the higher skill subjects than in the beginner skill subjects. Also, the preview times were longer for difficult pieces than for easier pieces. The results suggested that skill level of performers, difficulty of music pieces and knowledge for music pieces were crucial factors which influenced the preview time.

I. INTRODUCTION

When we run, throw a ball, ride a bicycle, or play a piano, we are engaged in the performance of a type of human skill called motor skills. The capacity of human beings to learn new motor skills, and develop them over short and long time scales is central to human achievement.

Motor Learning has been a central interest since the birth of psychology, and also music performance is one of very interesting subjects of cognitive psychology, since it requires perceptual and motor coordination (McLeod, 1990), which is basic and important ability for activities of our daily lives.

Music performance has been widely studied by various methods (Sloboda, 1985; Gabrielsson, 1999). However, there are few studies of eye movement during music performance, though eye movement data give us good evidences regarding information processing in music playing.

The purpose of this study is to clarify the cognitive processes during music performance, namely how the players view the music and make the fingers move. This paper focuses on preview time (hand eye span) in piano and guitar playing.

II. METHODS

Two experiments were conducted, one was for piano (Experiment A) and the other was for guitar (Experiment B). We have developed two experimental systems for each experiment. In both experiments, musical score was presented on a computer screen, and subject was required to play the instrument fluently. The music pieces were well-known piece, unknown piece and difficult piece, and all were single melody music.
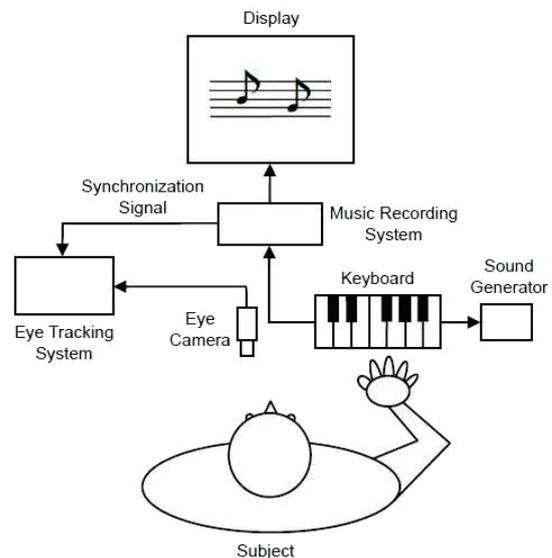
Figure 1. Experimental apparatus for piano playing.

A. Experiment A: Piano Playing

In the experiment A, the eye movements and finger movements during piano playing were measured simultaneously by an eye tracking system and a MIDI keyboard system. One male and two female subjects participated, and each one has had beginner skill, intermediate skill, and advanced skill for piano playing.

1) *Apparatus.* The experimental apparatus consists of a computer, display, MIDI keyboard and sound generator for music recording system, and a video eye tracking system (NAC Image Technology Inc., EMR8B-NL). Finger movement data and eye tracking data were synchronized by digital signals transmitted by the music recording system at the start of each trial. The apparatus is shown in Figure 1.

2) *Tasks.* Music was presented on a computer screen, and subject was required to play a piano (MIDI keyboard) fluently. The pieces were as follows:

- Well-known piece: A famous Japanese children's song "Yuyake Koyake" composed by S. Kusakawa (C major, two-four time, 16 measures).
- Unknown piece: A melody based on a solfege music (C major, two-four time, 16 measures).
- Difficult piece: A melody based on a solfege music (A minor, two-four time, 16 measures, with several accidentals and syncopations).

Well-known piece and unknown piece were assumed to be easier pieces.

3) *Subjects.* The following 3 subjects participated.

- Subject A: 22 years old, male, beginner skill level.
- Subject B: 19 years old, female, intermediate skill level.
- Subject C: 22 years old, female, advanced skill level.

These subjects were classified into 3 levels according to interviews about their backgrounds prior to the experiment. They were all naïve to the purposes of the experiment.

4) *Experimental design.* Before the experiment, we explain the task to the subjects, and let them play practice music to familiarize them with the equipment and apparatus. Next, subjects performed the well-known piece, unknown piece and difficult piece for 5 times, respectively.

Figure 2. Experimental apparatus for guitar playing.

B. Experiment B: Guitar Playing

In the Experiment B, the eye movements and finger movements during guitar playing were measured simultaneously by an eye tracking system and a motion analysis system. Three male subjects participated, and each one has had beginner skill, intermediate skill, and advanced skill for guitar playing.

1) *Apparatus.* The experimental apparatus consists of a computer and display for music display system, motion cameras and computer for a video motion analysis system (Shin Osaka Shokai Co., Dynas3D/G), and a video eye tracking system (NAC Image Technology Inc., EMR8B-HM). Finger movement data and eye tracking data were synchronized by digital signals transmitted by the music display system at the start of each trial. The apparatus is shown in Figure 2.

2) *Tasks.* Music was presented on a computer screen, and subject was required to play a guitar fluently. The pieces were as follows:

- Well-known piece: A famous American children's song "Grandfather's Clock" composed by H. Work (C major, four-four time, 16 measures).
- Unknown piece: A melody based on a solfege music (C major, four-four time, 16 measures).
- Difficult piece: A melody based on a solfege music (A minor, four-four time, 16 measures, with several accidentals and syncopations).

Well-known piece and unknown piece were assumed to be easier pieces.

3) *Subjects.* The following 3 subjects participated.

- Subject D: 42 years old, male, beginner skill level.
- Subject E: 37 years old, male, intermediate skill level.
- Subject F: 19 years old, male, advanced skill level.

As well as Experiment A, these subjects were classified into 3 levels according to interviews about their backgrounds prior to the experiment. Subject F was a winner of local guitar competition. They were all naïve to the purposes of the experiment.
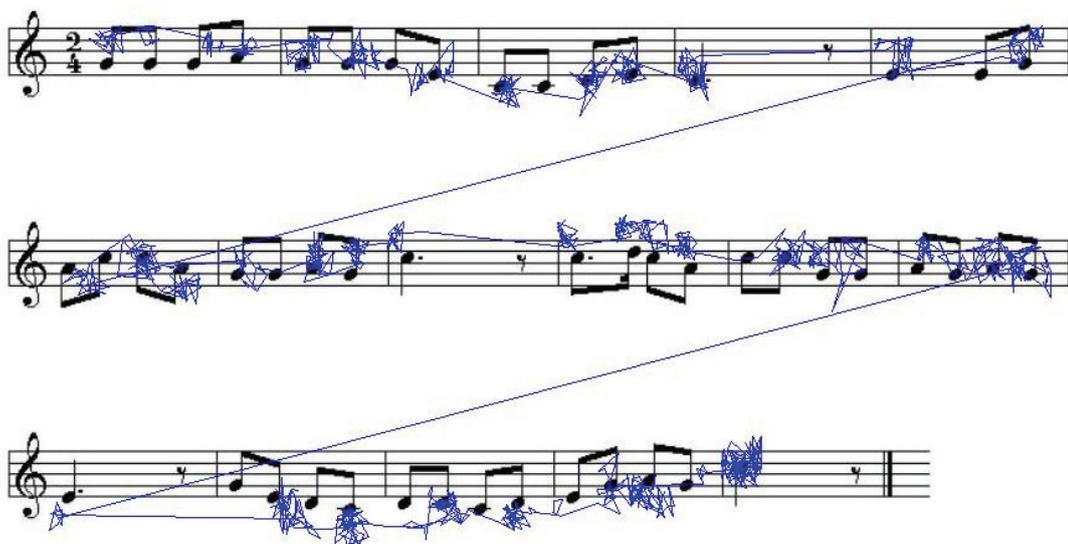
Figure 3. Eye movement data during piano playing for well-known piece.

4) *Experimental design.* Before the experiment, we explain the task to the subjects, and let them play practice music to familiarize them with the equipment and apparatus. Next, regarding subject D, he performed the well-known piece for 3 times and unknown piece for 6 times, instead of playing the difficult piece. The other subjects (subject E and F) performed the well-known piece, unknown piece and difficult piece for 3 times, respectively.

III. RESULTS

A. Experiment A: Piano Playing

Eye movement data during piano playing were obtained from the eye tracking system. The example is shown in Figure 3. The basic characteristics of eye movements were analyzed, and fixation points corresponding to the tones were estimated. On the other hand, finger movement data were acquired from the MIDI data recorded by the music recording system.

Then, the preview times were estimated using relation between eye tracking data and finger movement data. In this study, the preview time was defined as the difference between eye fixation time and finger movement time for corresponding note. The preview times were varying widely during music performance as shown in Figure 4. Therefore, the means of preview time for each piece were calculated. The mean preview times by music are shown in Figure 5, and the mean preview times by subject are shown in Figure 6.
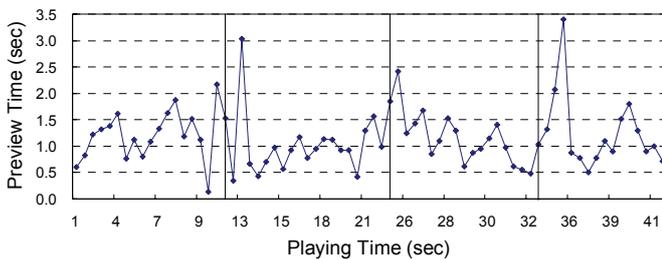
Figure 4. Preview time during piano playing. The vertical lines mean the beginning of next staves.
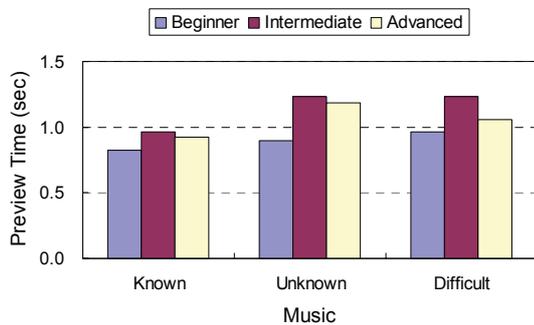
Figure 5. Mean preview times by music.
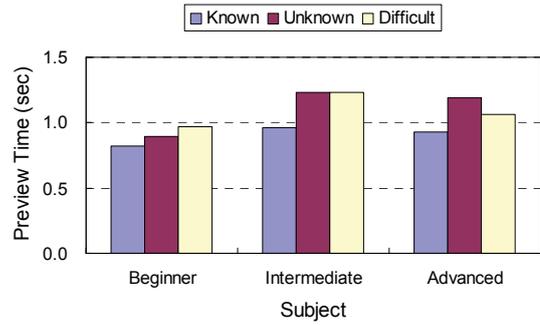
Figure 6. Mean preview times by subject.

The preview for the music was observed in all experimental conditions, but the preview times were different among subjects and music pieces. The following results are observed:

- As shown in Figure 4, the preview time at the beginning of stave was longer than the other part of stave.
- As shown in Figure 5, the mean preview times of unknown piece and difficult piece were longer than those of well-known piece.
- As shown in Figure 6, the mean preview times of intermediate skill level subject and advanced skill level subject were longer than those of beginner skill level subject.

B. Experiment B: Guitar Playing

As well as Experiment A, eye movement data during guitar playing were obtained from the eye tracking system, and the basic characteristics of eye movements were analyzed, and fixation points corresponding to the tones were estimated. On the other hand, finger movement data were acquired from the video motion analysis system. Then, the preview times were estimated using relation between eye tracking data and finger movement data.

In Experiment B, the means of preview time for each piece were calculated, and the transitions by trial were drawn in the graphs. The transitions of mean preview times for well-known piece, unknown piece, and difficult piece are shown in Figure 7, 8, 9, respectively.
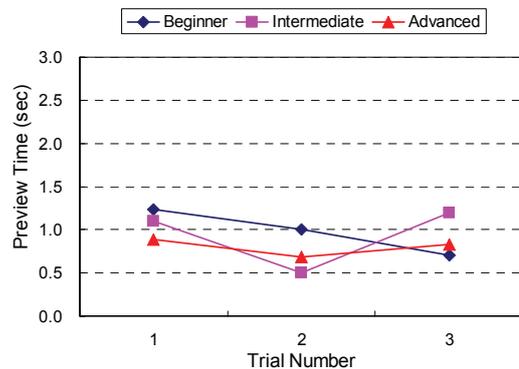
Figure 7. Transitions of mean preview times for well-known piece.
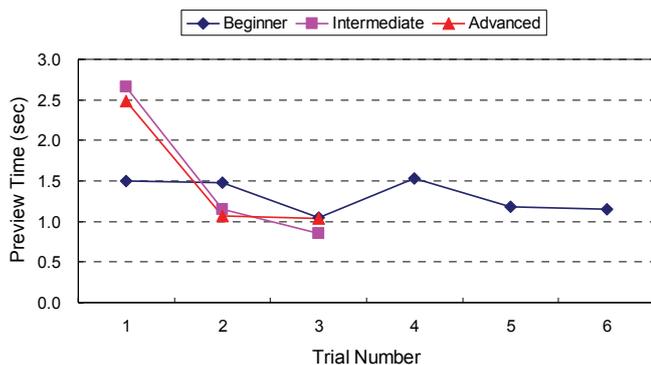
Figure 8. Transitions of mean preview times for unknown piece.
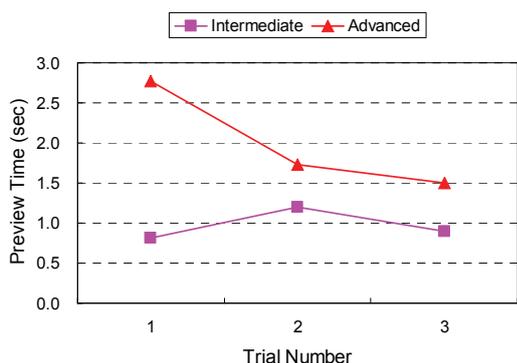
Figure 9. Transitions of mean preview times for difficult piece.

As well as Experiment A, the preview for the music was observed in all experimental conditions, but the preview times were different among subjects, music pieces and trial numbers. The following results are observed:

- As shown in Figure 7, the mean preview times for well-known piece did not differ among subjects.
- As shown in Figure 8, the mean preview times of intermediate skill level subject and advanced skill level subject were much longer than those of beginner skill level subject in the first trial for unknown piece, but they declined after the second trial.
- As shown in Figure 9, the mean preview times of advanced skill level subject were much longer than those of intermediate skill level subject for difficult piece, but they declined after the second trial.

IV. DISCUSSION

The preview for the music was observed in all experimental conditions for both instruments, but the preview times were different among subjects, music pieces, and trial numbers. The preview times were longer in the higher skill subjects than in the beginner skill subjects. Also, the preview times were longer for difficult pieces than for easier pieces. Moreover, the preview times in the first trial (i.e. sight reading) were longer than in the later trial for unknown piece and difficult piece.

These results are partially different from the previous study (Miura, 1989). Miura (1989) mentioned that the easier the music was and the higher the level of skill was, the wider the span of preview became. The difference of experimental

conditions is supposed to cause the difference of results. In Miura's study, subjects seemed to be forced to read as many notes as possible, but in our experiment, the eye movement data were measured during natural condition of music performance. In such natural condition, the higher skill subjects seems to be able to read as many notes as possible if it is necessary (e.g. in difficult piece), but if it is not necessary, they might not.

In spite of such difference, the results suggested that skill level of performers, difficulty of music pieces and knowledge for music pieces were crucial factors which influenced the preview time.

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