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악곡의 구조와 초견능력에 따른 예비박에서의 시선움직임 비교
- 초등예비교사를 대상으로 -

Analysis of Eye Movements during Perusal Time According to Musical Structure and Sight-Reading Ability of Pre-Service Elementary School Teachers

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Abstract The study aims to analyze the differences in eye movements during perusal time prior to sight-reading according to musical structure and sight-reading ability. To this end, 19 pre-service elementary school teachers read a single-line melody, a melody in parallel motion, and a melody with harmonic accompaniment through a Tobii Pro X2-60 eye tracker installed at the bottom of the computer monitor and played the electronic piano with a 10-second perusal time. Then, their eye movements during the perusal time were analyzed. The results showed that eye movements during the perusal time differed according to musical structure and sight-reading ability. The more complex the music, the more and longer the total fixation number and total fixation duration are in skilled sight-readers, whereas the less and shorter they are in less skilled sight-readers. Second, skilled sight-readers skim all the measures although concentrating on the first measure, whereas less skilled sight-readers mostly read the first and second measures. Third, when reading melodies, skilled sight-readers read the relationship between notes, whereas less skilled sight-readers read focusing on notes. Fourth, when reading music with a two-hand structure, skilled sight-readers gaze more and longer on the right-hand area than on the left-hand area, whereas less skilled sight-readers gaze more on the left-hand area than on the right-hand area.

Key words: eye movement, sight-reading, perusal time, piano education, music education

초록 본 연구의 목적은 악곡의 구조와 초견능력에 따라 피아노 초견 연주 시 예비박에서의 시선움직임 차이를 분석하는 데 있다. 이를 위하여 예비초등교사 19명을 대상으로 컴퓨터 모니터 하단에 설치한 Tobii Pro X2-60 시선추적기를 통해 단선율, 병행진행 선율, 화성반주 선율을 10초간의 예비박과 함께 초견으로 읽고 전자 피아노로 연주한 후 예비박 동안의 시선움직임을

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분석하였다. 연구결과, 예비박에서의 시선움직임은 악곡의 구조와 초견능력에 따라 차이가 있었다. 초견능력이 뛰어난 집단에서는 악곡이 복잡해질수록 총 응시수와 총 응시시간이 더 늘어나고 길어졌으며 평균응시시간은 짧아졌다. 반면, 그렇지 못한 집단에서는 총 응시수와 총 응시시간이 더 줄어들고 짧아졌으며 평균응시시간은 길어졌다. 둘째, 초견능력이 뛰어난 집단은 예비박에서 악곡의 전체 마디를 빠르게 읽는 반면, 그렇지 못한 집단에서는 거의 첫마디와 둘째마디에만 시선이 머물렀다. 셋째, 초견능력이 뛰어난 집단은 선율을 읽을 때 음표와 음표 사이의 관계를 중심으로 읽는 반면, 그렇지 못한 집단에서는 음표에 집중해서 읽었다. 넷째, 양손 연주인 경우 초견능력이 뛰어난 집단은 오른손을 중심으로 읽는 반면, 그렇지 못한 집단에서는 왼손을 중심으로 읽었다.

주제어: 시선움직임, 초견, 예비박, 피아노 교육, 음악교육

Ⅰ. Introduction

Although not a prerequisite, sight-reading is an excellent assistant in performing, composing, and arranging music in many musical genres (Lehmann & Kopiez, 2009; Sloboda, 1978). Therefore, training in sight-reading skills is an important part of music education, and much research has been conducted to determine how expert musicians sight-read. In general, sight-reading refers to the ability to play music after a brief perusal time without practice (Gabrielsson, 1999). However, the interpretation of this varies slightly from person to person. For some, sight-reading is as simple as playing finger-to-note, whereas for others, it is a more complex process that requires playing with the right tempo and expressiveness beyond simply decoding the notes and matching fingers to notes at a tediously slow tempo. According to the latter, music reading is a complex skill that “draws on a variety of cognitive skills that include reading comprehension, audiation, spatial temporal reasoning, and visual perceptions of patterns rather than individual notes” (Gromko, 2004, p. 6). Doing this at sight without prior practice requires very fast processing and a highly developed motor response (Lehmann & Ericsson, 1993). For this reason, most people tend to have perusal time when sight-reading.

Perusal time is the process of preparing for sight-reading, and what information is read during perusal time can affect successful sight-reading. Understanding the differences between musical structures in terms of the tonality, harmony, meter, texture, and melodic and rhythmic structure of the music helps musicians recognize patterns associated with the characteristics of a particular music (Palmer & van de Sande, 1993; 1995). Accomplished sight-readers use perusal time much more efficiently by scanning the score for understanding these musical structures, as opposed to less capable sight-readers, who read less relevant information during their peruse time (Zhukov & McPherson, 2022).

So far, in the study of sight-reading, few studies have explored what information is read during perusal time. Whether any difference exists in the information read during perusal time according to sight-reading ability and musical structure is not known. Therefore, this study aims to determine whether the information read during perusal time differs according to sight-reading ability and what these differences are according to musical structure.

The research problems are as follows:

1. Is there any difference in eye movement according to sight-reading ability during perusal time?

1.1 Is the difference in eye movement according to sight-reading ability affected by the structure of the music during perusal time?

2. Is there any difference in the information read during perusal time according to sight-reading ability?

2.1 Is the difference in information read according to sight-reading ability affected by the structure of the music during perusal time?

Ⅱ. Literature Review

1. Looking and Perceiving in Sight-Reading

Two main approaches are used to understand our perception (auditory and visual): the bottom-up process and the top-down process (Gregory, 1997). The bottom-up is a process that recognizes from a small concept to a large concept. The top-down process connects memories stored in long-term memory to present situations. In music, sight-reading is a combination of a bottom-up process that recognizes physical characteristics, such as pitch and duration, and a top-down process that predicts music patterns and understands the structure. The two processes and their interaction are likely to develop with training (Lehmann & McArthur, 2002).

Research that has tracked eye movements when sight-reading music has begun to reveal the characteristics of the thinking process of performers at different levels. In general, better readers can scan music more efficiently than less skilled readers. One study demonstrated that better readers' fixations are also directed across line and phrase boundaries, whereas less proficient readers tend to focus on individual notes. Also, better readers' eye movements go further ahead in the score but also check on themselves by returning to the current point of performance (Goolsby, 1994).

Talking about memory in sight-reading seems contradictory. However, recall and memory have been shown to affect sight-reading. Better readers showed excellent recall skills despite not being asked to memorize. They remember musical features by identifying and encrypting them when they scan music and can handle more information with less fixation by recalling and playing it (Waters, Townsend, & Underwood, 1998; Waters, Underwood, & Findlay, 1997).

2. Musical Structure and Sight-Reading

Sloboda (1984) strongly argued that music reading is a form of music perception. His reasoning is that if certain characteristics of musical structure affect reading performance in a task from memory, then the cognitive processes underlying this task must come into play to accomplish it.

However, prior studies related to eye movement according to musical structure are relatively a few, making comparisons between studies difficult. The possible reasons are small research participants in previous studies, musical stimulation, eye movement parameters, and various definitions of skill levels. Nevertheless, related studies have reported that musical structure and visual complexity can affect eye movement (Goolsby, 1994; Slobada, 1977).

In the literature related to reading music according to musical structure, a study has examined the difference in reading between contrapuntal and homophonic textures. Weaver (1943) showed performers of counterpoint music tend to follow independent melodies horizontally, whereas chords are scanned and read vertically in homophonic textures.

Subsequently, Furneaux and Land (1999) found that staves in piano music are read separately. Certainly, the eye does not know the difference between the two types of music (contrapuntal and homophonic), but the reader has to invoke different strategies to read the music (Lehmann & McArthur, 2002). In the end, to be a good music reader, pre-reading activities should be involved to establish one's own strategy, whether before or during the performance.

Whether music information is recognized to understand the musical structure has a great influence on reading music. The failure to understand music information, such as chords (Salis, 1980; Waters, Townsend, & Underwood, 1998), tonality (MacKenzie et al., 1986), and phrases (Sloboda, 1977), leads to a decrease in music reading ability.

For instance, Sloboda (1977) identified a clue to sight-reading ability based on whether the performer understands the physical and structural characteristics of music. The physical characteristics are related when looking at the music, particularly the spaces between the phrases. The structural characteristics are related to the harmonic structure of the music phrase; the eye-hand span expanded, especially when harmonic construction was repeated.

3. Eye Tracking and Music Reading

Eye tracking techniques are research methods that track eye movements in real time and analyze what and how the subject sees. Eye tracking techniques can identify not only scientific, objective, and conscious eye movements, but also unconscious eye movements so they can analyze the habitual behavior of the subjects. In the field of music, research using eye-tracking techniques is being conducted, and most of them focus on grasping the cognitive processes that work in sight-reading. According to these studies, people with good sight-reading ability have shorter fixation duration and higher numbers of gaze fixations than those who do not (Madell & Hébert, 2008; Penttinen et al., 2015).

However, these results differ somewhat depending on the structure and form of the music used in each study. For example, Gilman and Underwood (2003) used the score in three voices, and reported that the number of fixations of good sight-readers is lower than that of those who do not; furthermore, no significant difference was found in fixation duration between the two groups.

The difference is that when notes are arranged in a horizontal structure like a single-line melody, quick eye movement is required to group the scattered notes into a certain unit. If the notes are vertically cohesive, such as in a three-voice structure, slower movements are needed. The results of this study suggest the need for further research on the movement of gaze according to the structure of the score, targeting not only those who read well but also non-music majors.

Bae and Kwon (2020) recently conducted a study on non-professional piano learners by analyzing their eye movements according to the music structure. They identified differences according to students' music reading abilities and provided implications for the development of music reading ability. To this end, 21 non-professional piano learners were asked to read a single-line melody in five-measure long and a parallel melody in a grand staff through a computer monitor and play with an electronic piano. Meanwhile, the eye tracker (Tobii Pro X2-60) attached to the bottom of the monitor detects the movement of the gaze and creates a video that reflects the gaze movement on the monitor. The results of the study are as follows. First, a difference was found in the number of gaze fixations, average fixation duration, and total fixation duration in music reading according to the structure of the music. The number of fixations in the parallel melody was 37.16% more on average than in the single-line melody, and the average fixation duration was 20.59% shorter in the parallel melody than in the single-line melody. This means that playing melodies in parallel motion with both hands required shorter and more fixations, rather than looking at and playing one voice only. Second, the ability to reading music was greatly influenced by the way it was read. As a result of comparing the score reading ability of the participants who read forwards and backwards with the participants who read only forwards, the performance accuracy of the two-way participants was higher, on average, in both single-line melody and parallel motion. In this study, Bae and Kwon (2020) suggested that the non-expert group needs a systematic music reading strategy different from that of the expert group. Because the group of professional musicians can integrate and control the ability to decode the score and the ability to respond to motors, it is determined by the speed of information processing and psychomotor speed in reading the score (Kopiez & Lee, 2006). By contrast, given that non-expert group has yet to develop motor response ability when playing musical instruments, the strategy of how to process music information may be more important for successful sight-reading.

III. Methods

1. Participants

The participants in this study were pre-service elementary school teachers enrolled in the first year of undergraduate courses at the K University of Education in Korea. The purpose of the study was explained, and volunteers were recruited to participate. The reason to select pre-service elementary school teachers as the research subject is that they are a non-professional group who are currently learning piano in a general music class, and also have to teach young students to read music in elementary school music classes after graduation. As of the date of the study, those who were 18 years of age or older who read the explanation of this study and agreed to participate in the study comprised the research participants. A total of 25 pre-service elementary school teachers first participated in the study. All of them were asked to sight-read three melodies with 10 seconds of perusal time, and their performances and eye movements were recorded. Then, the researchers evaluated their performances.

Among them, two subjects whose performance accuracy fell below 50% and four subjects whose eye-tracking ratio was less than 60% were excluded from the study. In the eye-tracking process, when the subject looks at a place other than the screen or blinks, or when the eyebrows are particularly long, the gaze point is not well captured. Especially when playing the piano, the high rate of viewing the piano keyboard results in data loss. The eye-tracking ratio refers to the ratio of data acquired by the eye tracker excluding such loss. Among the 19 participants, five whose sight-reading ability was high and five whose sight-reading ability was low were selected as the high-performance group and low-performance group, respectively.

2. Research Procedure

The research procedure of this study is as follows. First, a five-bar single-line melody (hereinafter referred to as single-line melody), a five-bar melody in parallel motion (hereinafter referred to as parallel melody), and an eight-bar single-line melody with block chord accompaniment (hereinafter referred to as harmonic melody) were developed for the study. Next, coordinate calibration was performed before measurement to create a video reflecting eye movement for each study participant, given that each individual's eye position and gaze were different. The eye tracker used in this study (Tobii Pro X2-60 from Tobii, Sweden), which was attached to the bottom of the laptop monitor, was used to detect eye movements, and a video reflecting the eye movement was created on the monitor. Then, each study participant was asked to sight-read every three melodies with 10 seconds of perusal time for each.

3. Research Data

Three pieces of music created by the researchers were used in this study. The single-line melody comprised five bars in 4/4 meter and C major, and the melodic structure consisted of three patterns of ascending, descending, and undulating motion. The rhythmic structure also consisted of three patterns: two half notes, one half and two quarter notes, and four quarter notes.

The parallel melody consisted of the same melody as the single-line melody, but the upper melody was transposed five intervals below, and the lower melody was located ten intervals below the upper melody. The reason for composing a parallel melody with the same melody as a single-line melody was to understand how the subjects perceive the structure and form of melodies. The subjects who recognized the patterns of melody and rhythm in the single-line melody were expected to be able to perform tasks more easily and accurately by identifying that the same patterns of melody and rhythm were used in the parallel melody. Therefore, through eye tracking of the subjects performing these tasks, the process of how they perceive and play the music while reading the score can be understood.

The harmonic melody consisted of a single-line melody on the right hand and block chord accompaniment on the left hand, and the block chords consisted of I, IV, and V major harmonic chords of the G major. Therefore, the subject who understood the basic harmonic progression would be easy to sight-read.

[Figure 1] Music score

4. Data Analysis

The data of this study were analyzed using Tobii Studio, an eye-tracker analysis program. Each melody was divided into areas of interest (AOIs). An AOI is set to determine when and how much a subject has viewed a specific area. The AOI is set in two ways. One is to set the AOIs for the key and time signature area and each measure, and the other is to set the AOIs by dividing each melody into notes, the staves between notes, and blank areas above, in the middle, and below the melody. Through Tobii Studio, quantitative data on eye movements, such as the total number of fixations, mean fixation duration, and total fixation duration in each AOI, were derived. In this study, the standard of fixation was established using the Tobii Fixation Filter. The spatial radius threshold of the Tobii Fixation Filter was set to 35 pixels.

IV. Results

1. Eye movements in all AOIs of each melody

<Table 1> Total fixation number, mean fixation duration, and total fixation duration on all AOIs of each melody

	Group	TFN (count)	MFD (.sec)	TFD (.sec)
Single-line melody	High-performed	109	0.27	29.30
	Low-performed	113	0.26	29.47
Parallel melody	High-performed	144	0.22	31.91
	Low-performed	91	0.27	24.50
Harmonic melody	High-performed	164	0.23	37.84
	Low-performed	93	0.30	28.06

Note. TFN = total fixation number, MFD = mean fixation duration, TFD = total fixation duration.

The total fixation number (TFN), mean fixation duration (MFD), and total fixation duration (TFD) located on all AOIs of each melody for the entire 10 seconds of the perusal prior to sight-reading the music were first analyzed. The difference between the high- and low-performance groups according to musical structure was then analyzed (see Table I). No differences in the TFN, MFD, and TFD in the single-line melody were found between the two groups. However, in the parallel and harmonic melodies, the TFN and TFD were increased in the high-performance group but decreased in the low-performance group, and the MFD was decreased in the high-performance group but increased in the low-performance group. These results indicate that in the high-performance group, the more complex the music, the greater the TFN, the shorter the MFD, and the longer the TFD during the perusal time, indicating that they try to read more information within the same time period. In the low-performance group, the more complex the music, the less the TFN, and the shorter the TFD during the perusal time, indicating that they read less information, which may be because of spending more time reading the score and seeing the position of the hands on the keyboard.

2. Eye movements in each measure of each melody

The results of the TFN, MFD, and TFD for each measure of each melody are presented in Tables 2, 3, and 4. In all melodies, the high-performance group skimmed all the measures although concentrating on the first measure, whereas the low-performance group mostly read the first and second measures. The high-performance group read the last measure of all three melodies, whereas the low-performance group rarely did, which may indicate that the high-performance group tries to figure out tonality during the perusal time.

<Table 2> Eye movements in each measure in single-line melody

Group	Time and Key			Measure 1			Measure 2		
	TFN	MFD	TFD	TFN	MFD	TFD	TFN	MFD	TFD
High	7	0.36	2.51	52	0.3	15.41	12	0.31	3.67
Low	12	0.41	4.96	77	0.24	18.46	14	0.28	3.95
Group	Measure 3			Measure 4			Measure 5		
	TFN	MFD	TFD	TFN	MFD	TFD	TFN	MFD	TFD
High	14	0.19	2.61	15	0.24	3.55	9	0.17	1.55
Low	6	0.21	1.28	2	0.17	0.33	2	0.24	0.48

<Table 3> The eye movements in each measure in parallel melody

Group	Time and Key			Measure 1			Measure 2		
	TFN	MFD	TFD	TFN	MFD	TFD	TFN	MFD	TFD
High	10	0.16	1.6	93	0.22	20	17	0.18	3.12
Low	6	0.17	1.03	80	0.28	22.09	4	0.16	0.65
Group	Measure 3			Measure 4			Measure 5		
	TFN	MFD	TFD	TFN	MFD	TFD	TFN	MFD	TFD
High	11	0.28	3.13	9	0.32	2.86	4	0.3	1.21
Low	2	0.19	0.38	2	0.31	0.62	-	-	-

<Table 4> The eye movements in each measure in harmonic melody

Group	Time and Key			Measure 1			Measure 2		
	TFN	MFD	TFD	TFN	MFD	TFD	TFN	MFD	TFD
High	22	0.25	5.58	87	0.25	22.08	11	0.19	2.12
Low	6	0.4	2.41	73	0.33	23.9	12	0.19	2.22
Group	Measure 3			Measure 4			Measure 5		
	TFN	MFD	TFD	TFN	MFD	TFD	TFN	MFD	TFD
High	8	0.22	1.76	8	0.2	1.59	11	0.15	1.7
Low	-	-	-	-	-	-	1	0.1	0.1
Group	Measure 6			Measure 7			Measure 8		
	TFN	MFD	TFD	TFN	MFD	TFD	TFN	MFD	TFD
High	3	0.16	0.47	-	-	-	15	0.18	2.75
Low	-	-	-	-	-	-	2	0.13	0.26

3. Eye movements on notes, staves and blank areas

To understand where, specifically, the fixation is located during the perusal time in each melody, we set AOIs[1] in notes, staves between the notes, and blank area above, in the middle, and below the staff (only above and below in the single melody). Then, TFN, MFD, and TFD were analyzed.

1) AOIs on notes and staves between notes were grouped into AOI groups.

<Table 5> TFN, MFD, TFD on notes, staves, and blank areas in single-line melody

Group	Blank Above			Blank Below		
	TFN	MFD	TFD	TFN	MFD	TFD
High	22	0.29	6.3	21	0.21	4.34
Low	32	0.27	8.78	16	0.18	2.8
Group	**Notes**			**Staves**		
	TFN	**MFD**	**TFD**	**TFN**	**MFD**	**TFD**
High	28	0.28	7.86	24	0.27	6.39
Low	30	0.26	7.79	15	0.24	3.67

In the single-line melody, in the high-performance group, the ratios of TFN staying on notes (n = 28) and staying on the staves between notes (n = 21) were 4:3, whereas, in the low-performance group, the ratio of TFN staying on notes (n = 30) and staying on the staves between notes (n = 15) were 2:1. This means that the high-performance group focused more on understanding the relationship between notes than the low-performance group, and the low-performance group paid more attention to the notes than the high-performance group.

<Table 6> TFN, MFD, TFD on notes, staves, and blank areas in parallel melody

Group	Blank Above			Blank in Between			Blank Below		
	TFN	MFD	TFD	TFN	MFD	TFD	TFN	MFD	TFD
High	9	0.21	1.93	39	0.18	6.96	8	0.18	1.46
Low	5	0.18	0.88	29	0.23	6.71	-	-	-

Group	Right Notes			Right Staves		
	TFN	MFD	TFD	TFN	MFD	TFD
High	24	0.28	6.64	24	0.26	6.31
Low	4	0.18	0.73	13	0.24	3.11
Group	**Left Notes**			**Left Staves**		
	TFN	**MFD**	**TFD**	**TFN**	**MFD**	**TFD**
High	13	0.25	3.28	17	0.23	3.85
Low	21	0.44	9.14	11	0.25	2.77

In the parallel melody, the eye movements in the right- and left-hand areas were different. The right-hand area included the blank above the right, right notes, and right staves between the notes, and the left-hand area included the blank below the left, left notes, and left staves between the notes. In the high-performance group, the TFN and TFD staying in the right-hand area (n = 57, 14.88 s) were more and longer than those in the left-hand area (n = 38, 8.59 s). In the low-performance group, the TFN and TFD staying in the right-hand area (n = 22, 4.72 s) were less and much shorter than those in the left-hand area (n = 32, 11.91 s). The MFD was also different between the two hands and between the two groups. The MFD in the right-hand area (261 ms) was longer than that in the left-hand area (226 ms) in the high-performance group, whereas, in the low-performance group, the MFD in the left-hand area (374ms) was longer than that in the right-hand area (226 ms). This indicates that when reading the parallel melody during perusal time, the high-performance group focuses more on the right hand, whereas the low-performance group focuses more on the left hand.

Furthermore, when comparing the eye movements in the blank areas, notes, and staves between the notes of the parallel melody, the TFN and TFD on blank areas (especially in between) were the most and the longest, followed by those on staves between the notes in the high-performance group. In the low-performance group, the TFN and TFD on notes (especially on the left) were the most and the longest, followed by those on blank areas, and those on staves between the notes were the least and the shortest. This indicates that the high-performance group tries to read the relationship between notes and the relationship between the right and left hands rather than reading each note one by one, but the low-performance group focuses more on the notes, especially the notes on the left hand.

<Table 7> TFN, MFD, TFD on notes, staves, and blank areas in harmonic melody

Group	Blank Above			Blank in Between			Blank Below		
	TFN	MFD	TFD	TFN	MFD	TFD	TFN	MFD	TFD
High	31	0.21	6.6	18	0.21	3.74	1	0.06	0.06
Low	14	0.22	3.1	15	0.2	3.01	6	0.2	1.22

Group	Right Notes			Right Staves		
	TFN	MFD	TFD	TFN	MFD	TFD
High	14	0.28	3.91	27	0.25	6.62
Low	9	0.24	2.13	6	0.17	1.01

Group	Left Chords			Left Staves		
	TFN	MFD	TFD	TFN	MFD	TFD
High	13	0.36	4.68	6	0.16	0.95
Low	18	0.46	8.19	14	0.45	6.23

In the harmonic melody, the eye movements in the right- and left-hand areas were also different. Given that the low-performance group hardly read the second line of the harmonic melody during perusal time, only the results of the first line were compared. In the high-performance group, the TFN and TFD staying in the right-hand area (n = 72, 17.13 s) were more and longer than those in the left-hand area (n = 20, 5.69 s). In the low-performance group, the TFN and TFD staying in the right-hand area (n = 29, 6.24 s) were less and much shorter than those in the left-hand area (n = 38, 15.64 s). The MFD in the right area was similar between the groups, with 239 ms in the high-performance group and 216 ms in the low-performance group, but the MFD in the left-hand area was much longer in the low-performance group (415 ms) than in the high-performance group (285 ms). As in the parallel melody, these results show that the high-performance group focuses more on right-hand melody than left-hand chords, whereas the low-performance group focuses more on left-hand chords when reading the harmonic melody.

When the eye movements in the notes and staves between the notes of the harmonic melody were compared, the ratios of gazing notes and staves between the notes in the right and left hands in both groups were different. The ratios of TFN and TFD on the notes (n = 14, 3.91 s) and staves between the notes (n = 27, 6.62 s) on the right hand in the high-performance group were 1:1.9 and 1:1.7, whereas the ratio of TFN and TFD on the notes (n = 9, 2.13 s) and staves between the notes (n = 6, 1.01 s) on the right hand in the low-performance group were 1:0.7 and 1:0.5. This indicates that when reading the right melody in the harmonic melody, the high-performance group tries to read the relationship between notes as in the parallel melody, whereas the low-performance group focuses more on the notes. On the other hand, the ratios of TFN and TFD on the notes (n = 13, 4.68 s) and staves between the notes (n = 6, 0.95 s) on the left hand in the high-performance group were 1:0.5 and 1:0.2, whereas the ratios of TFN and TFD on the notes (n = 18, d = 8.19) and staff between the notes (n = 14, d = 6.23) on the left hand in the low-performance group were 1:0.8 and 1:0.8, respectively. This shows that when reading left-hand chords, the high-performance group reads the chord itself, whereas the low-performance group tries to read the chord and the relationship between the chords.

V. Conclusions

The purpose of this study is to investigate the differences in eye movements according to musical structure and sight-reading ability of pre-service elementary school teachers during perusal time prior to sight-reading. To this end, each subject was asked to sight-read a five-bar single-line melody, a five-bar melody in parallel motion, and an eight-bar single-line melody with block chord accompaniment with a 10-second perusal time. The subjects read each melody through a computer monitor and played on the electronic piano while the eye tracker attached to the bottom of the computer monitor detected eye movements. The results are as follows:

First, the eye movements during the perusal time differed according to the musical structure and the participants' sight-reading abilities. The more complicated the music, the higher the TFN and TFD in the high-performance group and the lower the TFN and TFD in the low-performance group. These results show that when more information needs to be read from the music, the high-performance group tries to read more information in advance, whereas the low-performance group pays more attention to the position of the hands on the keyboard to prepare for playing and loses time to read the music score. According to Banton (1995), accomplished music readers are less dependent on looking at their hands and are able to maintain their gaze on the score for longer periods while sight-reading. This was also true during the perusal time, as in this study.

MFD also varied according to the musical structure and the participant's sight-reading ability. When reading the single-line melody, the MFD of both groups was very similar (270 ms in high and 260 ms in low) but differed when reading the parallel and harmonic melodies. The MFD of the high-performance group became significantly shorter when reading the parallel (220 ms) and harmonic (230 ms) melodies, but in the low-performance group, the MFD in the parallel melody (270 ms) was similar to that of the single-line melody, and the MFD in the harmonic melody (300 ms) became much longer. These results are consistent with previous research (see Goolsby, 1994; Truitt et al., 1997; Waters, Townsend, & Underwood, 1998; Waters, Underwood, & Findlay, 1997) showing that the MFD of better music readers is shorter than that of less-proficient readers. However, this was only true for more complicated music in this study.

Second, the scope of music information during the perusal time differed according to sight-reading ability. In all three melodies, the high-performance group skimmed all the measures, although concentrating on the first measure, whereas the low-performance group mostly read the first and second measures. In particular, the high-performance group read the last measure of all three melodies, whereas the low-performance group rarely did, which may indicate that the high-performance group tries to figure out the tonality during the perusal time. This is the same as in Zhukov, Khuu, and McPherson's (2019, as cited in Zhukov & McPherson, 2022) study showing that skilled sight-readers quickly scan the entire music through to the end, whereas less skilled sight-readers only process the first or the second measure at most. This indicates that skilled sight-readers use perusal time much more efficiently than less-skilled sight-readers.

Third, the areas of the music (such as notes, staves, and blanks) fixated during the perusal time, and the eye movements in each area differed according to the musical structure and the participant's sight-reading ability. In the single-line melody, the ratio of TFN on notes and staves between the notes 4:3 in the high-performance group was 2:1 in the low-performance group. This means that the high-performance group focused more on understanding the relationship between notes, as opposed to the low-performance group, which paid more attention to the notes.

In the parallel melody, the high-performance group gazed at blank areas the most and the longest, followed by staves between the notes, whereas the low-performance group gazed at notes (especially on the left) the most and the longest, followed by blank areas. This indicates that the high-performance group tries to read the relationship between notes and the relationship between the right and left hands rather than reading each note one by one, but the low-performance group focuses more on the notes, especially the notes on the left hand.

In the harmonic melody, the ratios of gazing notes and staves on the right and left hands in both groups were different. The ratio of TFN on notes and staves between the notes on the right hand was approximately 1:2 in the high-performance group and 1:0.7 in the low-performance group. This indicates that when reading the right hand of the harmonic melody, the high-performance group tries to read the relationship between notes as in the parallel melody, whereas the low-performance group focuses more on the notes. In contrast, the ratios of the TFN and TFD on the notes and staves between the notes on the left hand were 1:0.5 and 1:0.2 in the high-performance group and 1:0.8 and 1:0.8 in the low-performance group, respectively. This shows that, when reading left-hand chords, the high-performance group reads the chord itself, whereas the low-performance group tries to read the chord and the relationship between the chords.

Finally, when reading music with a two-hand structure, the eye movements on each hand area vary depending on sight-reading ability. In both parallel and harmonic melodies, the high-performance group gazed more and longer on the right-hand area than on the left-hand area, whereas the low-performance group gazed more on the left-hand area than on the right-hand area. Understanding the differences between musical structure in terms of the tonality, harmony, meter, texture, and melodic and rhythmic structure of the music helps musicians recognize patterns associated with the characteristics of a particular compositional style (Palmer & van de Sande, 1993; 1995). For instance, a melody in parallel motion contains imitations between voices, and a melody with harmonic accompaniment contains major chords in a certain key. Skilled sight-readers usually recognize familiar patterns of a compositional style, and recognizing such patterns results in processing the music more rapidly during sight-reading (Waters, Townsend, & Underwood, 1998).

In conclusion, this study showed that training students to understand the characteristics of the musical structure being performed would help develop their sight-reading skills. In particular, it is critical to understand the musical structure during perusal time to effectively sight-read. As a follow-up study, in order to find out the cognitive process in sight-reading more in detail, it is necessary to analyze the differences between reading music during perusal time and actual sight-reading.

References

Bae, S. Y., & Kwon, S. (2020). An analysis of eye movements according to the ability of pre-service elementary teachers to read music. *Brain, Digital, & Learning*, 10(4), 401-417.

Banton, L. J. (1995). The role of visual and auditory feedback during the sight-reading of music. *Psychology of Music*, 23(1), 3-16.

Furneaux, S., & Land, M. F. (1999). The effects of skill on the eye–hand span during musical sight–reading. *Proceedings of the Royal Society of London B*, 266, 2435-2440.

Gabrielsson, A. (1999). The performance of music. In D. Deutch (Ed.), *The psychology* *of music* (2nd ed, pp. 501-602). New York: Academic Press.

Gilman, E., & Underwood, G. (2003). Restricting the field of view to investigate the perceptual span of pianists. *Visual Cognition,* 10(2), 201-232.

Goolsby, T. W. (1994). Eye movement in music reading: Effects of reading ability, notational complexity, and encounters. *Music Perception*, 12(1), 77-96.

Gregory, A. H. (1997). The roles of music in society. In D. J. Hargreaves & A. C. North (Eds.), *The social psychology of music* (pp. 123-140). Oxford: Oxford University Press.

Gromko, J. E. (2004). Predictors on music sight-reading ability in high school wind players. *Journal of Research in Music Education*, 52(1), 6-15.

Jung, Y. J. (2018). A comparative analysis on the textbooks of keyboard harmony for college piano major. *Korean Journal of Research in Music Education*, 47(4), 157-183.

Kopiez, R., & Lee, J. I. (2006). Towards a dynamic model of skills involved in sight reading music. *Music Education Research*, 8(1), 97-120.

Kwon, S. (2016). The correlation between the music learning and the academic achievement through the class piano curriculum. *Korean Journal of Research in Music Education*, 45(4), 1-21.

Lehmann, A. C., & Ericsson, K. A. (1993). Sight-reading ability of accomplished pianists in the context of piano accompanying. *Psychomusicology*, 12, 122-136.

Lehmann, A. C., & Kopiez, R. (2009). Sight-reading. In S. Hallam, I. Cross, & M. Thaut (Eds.), *The Oxford handbook of music psychology* (pp. 334-351). Oxford: Oxford University Press.

Lehmann, A. G., & McArthur, V. (2002). Sight-reading. In R. Parncutt & G. McPherson (Eds.), *The science and psychology of music performance: Creative strategies for teaching and learning.* New York: Oxford University Press.

MacKenzie, C. L., Vaneerd, D. L., Graham, E. D., Huron, D. B., & Wills, B. L. (1986). The effect of tonal structure on rhythm in piano performance. *Music Perception,* 4(2), 215-225.

Madell, M., & Hébert, S. (2008). Eye movements and music reading: Where do we look next? *Music Perception*, 26(2), 157-170.

Palmer, C., & van de Sande, C. (1993). Units of knowledge in music performance. *Journal of Experimental Psychology: Learning, Memory, Cognition*, 19(2), 457-470.

Palmer, C., & van de Sande, C. (1995). Range of planning in skilled music performance. *Journal of Experimental Psychology: Human Perception and Performance*, 21(5), 947-962.

Penttinen, M., Huovinen, E., & Ylitalo, A. K. (2015). Reading ahead: Adult music students' eye movements in temporally controlled performances of a children's song. *International Journal of Music Education: Research,* 33(1), 36-50.

Salis, D. L. (1980). Laterality effects with visual perception of musical chords and dot patterns. *Perception and Psychophysics*, 28, 284-292.

Sloboda, J. A. (1977). Phrase units as determinants of visual processing in music reading. *British Journal of Psychology*, 68(1), 117-124.

Sloboda, J. A. (1978). The psychology of music reading. *Psychology of Music,* 6(2), 3-20.

Sloboda, J. A. (1984). Experimental studies of music reading: A review. *Music Perception*, 2(2), 222-236.

Truitt, F. E., Clifton, C., Pollatsek, A., & Rayner, K. (1997). The perceptual span and the eye-hand span in sight-reading music. *Visual Cognition*, 4(2), 143-161.

Waters, A. J., Townsend, E., & Underwood, G. (1998). Expertise in musical sight-reading: A study of pianists. *British Journal of Psychology*, 89(1), 123-149.

Waters, A. J., Underwood, G., & Findlay, J. M. (1997). Studying expertise in music reading: Use of a pattern-matching paradigm. *Perception and Psychophysics*, 59(4), 477-488.

Weaver, H. E. (1943). A study of visual processes in reading differently constructed musical selections. *Psychol Monographs*, 55, 1-30.

Yoon, Y. W. (2009). An analysis of piano sight-reading textbooks. *Korean Journal of Research in Music Education*, 36, 205-233.

Zhukov, K., Khuu, S., & McPherson, G. E. (2019). Eye movement efficiency and sight-reading expertise in woodwind players. *Journal of Eye Movement Research*, 12(2), 6.

Zhukov, K., & McPherson, G. E. (2022). Sight-reading. In G. E. McPherson (Ed.), *The Oxford handbook of music performance,* (Vol. 1, pp. 192-213). Oxford: Oxford University Press.