Understanding Relationships between Reading Behavior and Difficulty Level of Musical Score based on Cognitive-behavioral Science

Competency Level Evaluation via Musical Score Reading Processes

Katsuko T. Nakahira and Muneo Kitajima

Nagaoka University of Technology, Nagaoka, Japan

katsuko@vos.nagaokaut.ac.jp, mkitajima@kjs.nagaokaut.ac.jp

Keywords: Competency Level Evaluation, Reading Musical Score, User Profiling.

Abstract: This paper proposes a method to understand relationships between reading behavior and the level of difficulty of musical score. The model of reading behavior is constructed by following the cognitive-behavioral science approach, which has three components: external objects, and internal perceptual-cognitive-motor processes and memory. It suggests that the most critical for smooth score reading is that he or she is able to acquire the right number of objects, k, in a single eye-fixation and to retrieve their relevant information from long-term memory within the time allowed. The model predicts that differences in smoothness should appear in the mean, t_{Mean}, and/or median, t_{Med}, duration times of the field of view, which are strongly related with the degree of matching of the musical score with the level of competency of the student. It was estimated in the space of the following five parameters by collecting eye-movement data: the number of notes, rests, accidentals, meter and velocity, and the other musical symbols. This paper concludes that the estimation procedure should be effective to evaluate the level of difficulty of musical scores perceived by an individual person.

1 INTRODUCTION

A domain of playing music, "piano singing and playing", has been studied extensively in Japan because it is one of the critical skills that pre-school teachers should have in Japan and it has been difficult in allocating enough time for education at universities. To overcome this difficulty, a method that implements the concept of blended learning was proposed for educating piano singing and playing skill (for example, see (Nakahira et al., 2009)). The method consisted of two components; *checking model performance* for each musical compositions, and *reflection via video* which recorded students' performance. A field study was conducted to find that learners' skill improved via blended learning if it was accompanied by video reflection. The degrees of improvement, however, were quite diverse; some learners improved remarkably, but others modestly. Looking at the findings from the viewpoint of the two constituent skills, the degrees of improvement in singing skill were more apparent than those in playing piano.

The study, such as (Nakahira et al., 2009), suggested two things: a blended-learning-based approach would be appropriate for skill development education but at the same time its effectiveness for individual learners would become diverse. This fact suggests that integration of "student-centered" approach with the blended-learning approach should be promising to develop a method for skill education in the domain of educating piano singing and playing skill. One direction towards implementing the student-centered approach is to adopt an ethnographic approach such as the CCE methodology (Kitajima et al., 2012). CCE has been successfully applied to understand the behavior of people who intend to accomplish some happiness goal, such as achieving a self-determined goal, devoting to someone else, etc. A CCE study was conducted in the domain of educating piano singing and playing skill to find that self-instruction, which is the basic mode of blended learning, was more effective in learning syntactic elements than semantic elements (Nakahira and Kitajima, 2014).

Among the syntactic elements the most important was "reading musical score." This is a subject that has been studied extensively by means of eye movements while reading. For example, Kinsler (Kinsler and Carpenter, 1995) focused on the patterns that characterize saccadic eye movements while reading musical scores, suggesting that the relationship between the spatial patterns of the notes and the existence of fixations. Major fixations appear at notes and bar-

Nakahira, K. and Kitajima, M.
Understanding Relationships between Reading Behavior and Difficulty Level of Musical Score based on Cognitive-behavioral Science - Competency Level Evaluation via Musical Score Reading Processes.
In *Proceedings of the 12th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications (VISIGRAPP 2017) - Volume 2: HUCAPP*, pages 67-74
ISBN: 978-989-758-229-5

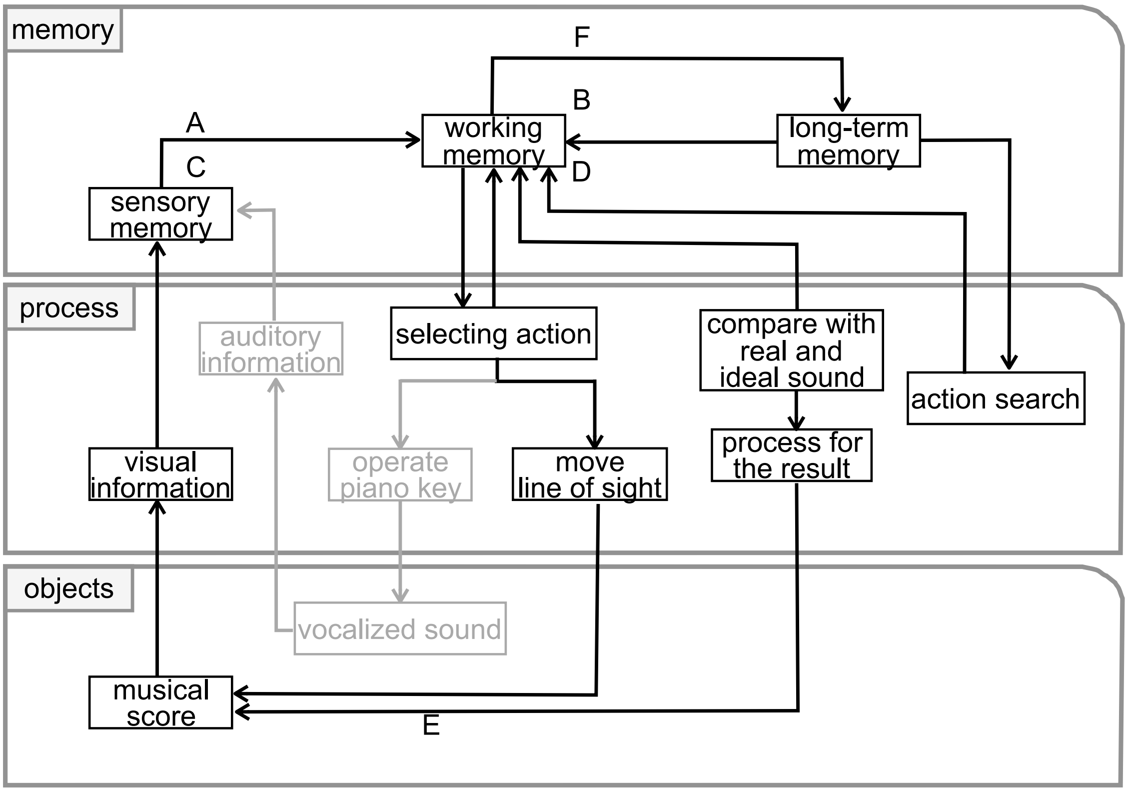

Figure 1: Procedure for reading musical score. Processes A and C are transferring symbols or auditory information. Processes B and D are searching pitch, hand motor to push key, and area what see next. Process E is output of these information processing. In case of reading musical score, output process is moving area of musical score.

lines. Most significantly, the observed fixation duration times tended to be proportional to the length of note values. However, the tempo of performance was inversely related with the average time of saccadic eye movements. On the ground of the aforementioned observations, a number of cognitive model of reading musical score have been proposed. Among them, the model proposed by Emond et al. (Emond and Comeau, 2013) is the one based on the ACT-R cognitive model and is the most sophisticated one. Through simulations with the model, they indicated a possible impact of the different teaching approach on the acquisition of initial reading skills.

This paper aims at gaining more thorough understanding on how people would carry out visual information processing while reading musical scores. It focuses on the relationships between the amount of "reading span" and the perceived difficulty of the musical score to be read. "Reading span" is the term to indicate the degree of proficiency while reading text such as a printed book. It becomes large when the text to read is perceived to be easy. On the other hand, it becomes shorter when it does not match the reading level of the reader, i.e., the text to read is perceived to be hard. This construct might be useful to estimate the degree of matching of the level of the piano player with the level of the musical scores.

2 MODEL FOR READING MUSICAL SCORE

This section describes a model of human behavior while reading musical scores. In the following, the model is described by incorporating three components for reading musical score followed a subsection describing the procedure that constructs reading musical score activity.

2.1 Three Components for Reading Musical Score

Figure 1 shows the basic and general framework of reading musical score. When a learner moves his or hey eye-balls to a specific portion of musical score that exists in the external environment, he or she perceives the objects on the musical score, and then selectively focuses on those where eye-balls are fixated, i.e., pays attention to selected objects, and recognizes them using knowledge retrieved from his or her long-term memory, and then comprehends the meaning the recognized objects considering the context where they appear as they are. The result of comprehension should affect to plan how to move the eye-balls in the future cycles. This basic and general process is summarized as follows:

> move eye-balls → perceive objects → pay attention to objects selectively → recognize objects using long-term memory → comprehend contextually → move eye-balls → ···

In the following, the components, i.e., objects, perceptual–cognitive–motor processes, and memory, that appear in describing the basic and general processes are further elaborated in the context of musical score reading activity.

Objects: In case of reading musical score, there are many symbols for representing musical sounds or melody (syntax) and indicating how to play with expression (semantics). Notes, rests, accidental, meter, velocity, etc., are the symbols for syntax. Dynamics, articulation, relation, etc., are those for semantics. Objects are input to the perceptual process, and output of the motor process, i.e., after completion of an eye movement process, the resultant visual field defines the objects to be processed in the next perceptual process.

Perceptual–Cognitive–Motor Processes: In case of piano playing, processes which a person carry out are visual/auditory information processes including making decision about how to react. For example, when people receive objects via optic nerves, the stimuli are carried to perceptual processes. In this process, objects are the input information and sensory memory is the output. Perceptual process plays a role of maintaining the information.

Memory: In the domain of piano singing and playing, three memory systems are relevant: sensory memory, working memory, and long-term memory systems.

Sensory memory systems include iconic, echoic, and haptic memory systems, each of which is concerned with the process of "reading" musical score, "hearing" the sound he or she makes by playing the piano, and "touching" the keyboard of the piano, respectively. In the case of just reading musical score this paper is concerned with only the iconic memory is considered which which creates memory that represents the type of musical symbols which is regarded as "objects." On reading musical score, a person does not make any real sounds. However, he or she would activate any relevant portions of long-term memory that are associated with what he or she is visually stimulated in any sense: this would include memory of sound and touch, which may or may not be included in working memory depending on the degree of strength of individual memory traces.

Working memory is the place where any cognitive processes should use for their operations, including retrieval of relevant knowledge stored in working-memory to place its result, matching between the information from sensory memory and long-term memory to place the result of comparison. This may include pieces of declarative knowledge to be used to comprehend what the musical score just having been read, or pieces of procedural knowledge concerning how to move his or her fingers in a coordinated way, i,e, the patterns of muscle movements.

Long-term memory is a storage with infinite capacity for declarative, procedural, and the other types of knowledge. Reading musical score is not a process of just reading as reading a printed book but a process for associating what is read with how to move his or her fingers, i.e., motor planning including coordination of five fingers of right and left hands with the degree of strengths of hitting the keyboards. This is a very complex association process of visual information with motor information, and the rules for association must exist in long-term memory, or must be available, and need to be activated via retrieval process, or must be accessible, in order to be smoothly played on the piano as indicated by the visually indicated on the musical score.

2.2 Musical Score Reading Procedure

This subsection describes Fig.1 in more detail by extending the explanation given in the previous subsection.

The first step is to transfer external objects that physically exist on musical score to internal memories to be cognitively processed as information for determining next bodily actions to perform. Normally, a person obtains physical features of symbols on musical score via his or her eyes, which are transmitted to sensory memory, i.e., the visual image store, and then some portion of the contents in the visual image store is transferred to working memory and represented as symbols corresponding to the physical features of the external objects. Symbols are manipulated by the cognitive processes that follow to retrieve relevant knowledge from long-term memory for the purpose of carrying out a series of transformations of information stored in working memory to derive next actions to be realized as a motor movement including "moving eye-balls to the next appropriate location to read the musical score given the results of comprehension reached so far."

In the information transformation process, matchings between symbols in working memory and information in long-term memory are carried out. When these symbols are represented in working memory, cognitive process starts searching information in long-term memory. It is assumed that the degree of richness of information in long-term memory should depend on the amount of training of reading and playing musics that a person has experienced in terms of both quantitatively and qualitatively. The more he or she has the experience of training, the shorter the time required of him or her to get access to relevant information stored in long-term memory and the more elaborated or richer the information he or she can retrieve. In addition, his or her information network in long-term memory would be robust because he or she frequently uses the same paths to activate the relevant information associated with the input symbols which includes not only the meaning of symbols but also how he or she should make reaction when he or she encounters with it. The information stores a number of association pairs of symbols–reaction or optimized symbol chunks.

The purpose of the cognitive process is to comprehend the meaning of the symbols by associating them with the procedure of how to play the symbols by his or her fingers, mental simulation of playing the symbols. If a person gets enough information from symbols having been fixated, he or she does not need to get another information from another fixation. In this case, the comprehension process is successfully completed and the cognitive process initiates a new cycle starting from acquiring symbols using his or her eyes, i.e., move eyes to the next location of musical score to cause the shift of the field of vision. In another case where a person has failed to get enough information from the current fixation, the comprehension process would not be carried out satisfactorily. In this case, there would be two possibilities of the cognitive processes to happen: stay within the same field of vision and get more information through more fixations, or give up reaching sufficient comprehension level but initiate a new cycle.

Through these processes, a person continues to obtain as much information as possible from the musical score. It is assumed that it should take a certain amount of time to comprehend the meaning of the symbols, on which his or her eyes must be fixated during a certain amount of time, by activating relevant knowledge stored in long-term memory, and that there should be interactions between the amount of experience of playing piano and the level of difficulty of the musical score to read, which should affect the observed eye-movement patters while reading musical scores.

3 DESCRIBING MUSICAL SCORE READING PROCESS

This section describes the features of musical score, a framework to represent the behavior of reading musical score, and a method to estimate the behavior of reading musical score.

3.1 Features of Musical Score

The following categories of symbols appear in musical score:

(1) notes consisting of head, stem, flag, and value,
(2) rests,
(3) accidentals,
(4) meter, velocity, and
(5) other musical symbols (dynamics, articulation, relation, etc.).

The first category 1 is the most important symbol category when playing music. This is because it is the necessities for communicating melody. In playing music, no melody is produced without recognizing sound lengths, pitches, and chords. All players are required to be able to recognize every note. It is assumed that the degree of ability to recognize notes should be a good predictor for playing skill, and it might be observed in the patterns of eye movements while reading a musical score. When a skilled player reads a musical score, he or she usually searches for a chunk on the musical score consisting of a number of notes, which is a unit to be manipulated by cognitive processes. In some cases it is a group of three notes that constitutes a single chord, or in other cases it is a melody that extentds, e.g., over two bars.

The symbols in Categories 2, 3, 4 and 5 are necessary for emotional playing. These symbols are, however, only effective after recognizing the symbols of category 1 defining notes and melody . Since these symbols modify the piano play defined by the notes and melody, a person who shows fixations on these symbols is likely to have a higher ability of playing skill.

Table 1: Representation frame of musical score.

bar	num. of				
ID	notes(no chunk)	notes(chunk)	rest	accidental	other
1	6	6	0	1	3
2	8	4	0	0	0
...		....			

3.2 Reading Musical Score Process

This subsection describes musical score reading process by using the five categories introduced in the previous subsection.

Ideal Reading Time "T_{ideal}": There are a number of relationships among the features and the following is the first one that defines the relationships among the meter, M, the velocity, v, and the number of bars, N_b, and the ideal playing time for the score T_{ideal}(sec):

$$T_{ideal} = N_b \times \left(\frac{60}{v} \times M \right) \quad (1)$$

Features of Musical Score: In order to characterize a musical score, the following four quantities are introduced for the i-th bar, b_i:

$$\begin{aligned} N_{notes}(b_i) &: \text{the number of notes,} \\ N_{rest}(b_i) &: \text{the number of rest,} \\ N_{acc}(b_i) &: \text{the number of accidental,} \\ N_{sym}(b_i) &: \text{the number of other symbols} \end{aligned}$$

Reading Musical Score with Chunking: Considering that T_{ideal} can be achieved by reading the musical score through compressing several notes in chunks. This compression process is described by introducing $N_{Tc}(b_i)$, the size of chunks in the i-th bar, as follows:

$$\begin{aligned} N_{Tc}^{\vec{f}}(b_i) = & \quad N_{notes}(b_i) \times f(N_{notes}) \\ & + N_{rest}(b_i) \times f(N_{rest}) \\ & + N_{acc}(b_i) \times f(N_{acc}) \\ & + N_{sym}(b_i) \times f(N_{sym}), \end{aligned} \quad (2)$$

by using $f(x)$:

$$f(x) = \begin{cases} 1 & : \text{can deal with symbol } x \\ 0 & : \text{otherwise} \end{cases}$$

where $f(x)$ takes the value of 1 or 0 depending on whether a person has the skill to deal with musical score in category x as a chunk or not, respectively. For example, a moderate level player can recognize rest symbols and accidental symbols as respective chunks but not for the other symbols; a real beginner cannot recognize a chord but read individual notes that constitute it, in this case there is no chunk for chord but a chunk for a note. To represent this situation, Eq. (2) becomes as follows:

$$\begin{aligned} N_{Tc}^{\vec{f}=\text{beginner}}(b_i) &= N_{notes}(b_i) \times 1 + N_{rest}(b_i) \times 1 \\ & \quad N_{acc}(b_i) \times 0 + N_{sym}(b_i) \times 0 \\ &= N_{notes}(b_i) + N_{rest}(b_i). \end{aligned}$$

Finally, the number of chunks actually processed by a person for the i-th bar, b_i, $N_s(b_i)$ becomes as follows:

$$N_s(b_i) = \frac{N_{Tc}^{\vec{f}=\vec{1}}}{k}, \quad (3)$$

where k represents the average size of chunks.

Creating a Chunk by Compression: The features of musical score is represented in Table 1. "Compress" in the table means that the case of packing several notes when a person reads musical score as a chunk, which is regarded as an action of recognizing a chord. Using the framework and the information for meter and velocity, a more sophisticated chunk will be used by a piano player while reading a musical score.

3.3 Estimate Reading Musical Score Behavior

Normally, true values of the average size of chunks, k, are not known but can be calculated as described below. The values available for this procedure are, $N_{Tc}^{\vec{f}=\vec{1}}(b_i)$, fixation times for a fixation point x, t_x (sec), and moving times by saccadic eye-movements to the next field of vision, t_m. Given these values, the estimated reading time, T_{t_x}, for a given t_x is represented as follows:

$$\begin{aligned} T_{t_x} &= \sum_i^{N_b} (N_s(b_i) \times t_x + t_m) \\ &= \sum_i^{N_b} (\frac{N_{Tc}^{\vec{f}=\vec{1}}(b_i)}{k} \times t_x + t_m) \end{aligned} \quad (4)$$

In the case of an expert musical score reader, Eq. (4) becomes as follows:

$$\begin{aligned} T_{ideal} &= T_{t_x} \\ &\simeq \frac{t_{cog}(k)}{k} \times \sum_i^{N_b} N_{Tc}^{\vec{f}=\vec{1}}(b_i) \end{aligned} \quad (5)$$

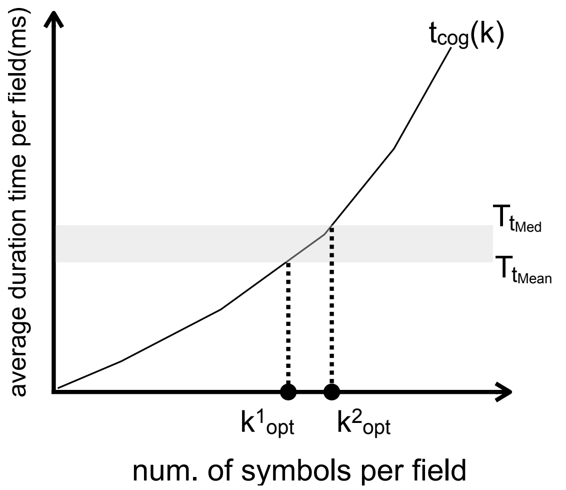

Figure 2: The relationships between $t_{cog}(k)$ and $k_{opt}^{(1,2)}$. $k_{opt}^{(1,2)}$ correspond to the points where $T_{t_{Med/Mean}}$ intersects with $t_{cog}(k)$, respectively.

where $t_{cog}(k)$ is introduced to represent the time necessary for processing a chunk with the size of k. Eq. (5) indicates the relationship that $t_{cog}(k)$ is proportional to k:

$$t_{cog}(k) = \frac{T_{ideal}}{\sum_i^{N_b} N_{Tc}^{\vec{f}=\vec{1}}(b_i)} \times k \tag{6}$$

The quantities characterize eye-movement times, t_x and t_m, are convoluted in $t_{cog}(k)$ in Eq. (6), whose values are to be determined by fitting experimental data in due course.

The optimum value of t_x is obtained by controlling t_x for $k = 1, 2, \cdots$, with the condition of minimizing $|T_{ideal} - T_{t_x}|$, which in turn defines the value $t_{cog}(k)$. Using $t_{cog}(k)$ and $t_{Mean\ or\ Med}$, where t_{Mean} is the average or the median of the length of the observed fixation times, respectively, it is possible to estimate a reasonable range of k values. Figure 2 shows the solution. The coordinate system is defined as follows: the x-axis represents k, the number of symbols per field of vision, and the y-axis represents T, the average duration times per the field of vision. On this plane, $t_{cog}(k)$ looks like the one shown in the figure.

In Figure 2, there are two lines that correspond to $T = t_{Mean}$ and $T = t_{Med}$, respectively. The two k values at which these two lines intersect the curve $T = t_{cog}(k)$, k_{opt}^1 and k_{opt}^2, define a reasonable range of k values.

The degrees of steepness of the slope of the function $T = t_{cog}(k)$ are dependent on the levels of difficulty of musical scores. The more difficult the musical score becomes, the steeper the slope of $T = t_{cog}(k)$ becomes. Or for a given k, the longer it takes to read the content with the fixed chunk size of k, the more difficult the music score become. Figure 3 shows the expectation relationships of the range $k_{opt}^1 - k_{opt}^2$ and the score difficulty level. For example, suppose a case a person feels easy for a given score. In this case he or she can adopt the optimize vale of k to read the score. In this case, the difference between k_{opt}^1 and k_{opt}^2 will be come large. As the result, all $k_{opt}^1 - k_{opt}^2$ will be overlapped each other, and it seems the range of $k_{opt}^1 - k_{opt}^2$ has wide value. Fig. 3 (a) corresponds to this case. There are many $k_{opt}^1 - k_{opt}^2$ bars per musical scores, but as a total they seem to become one area.

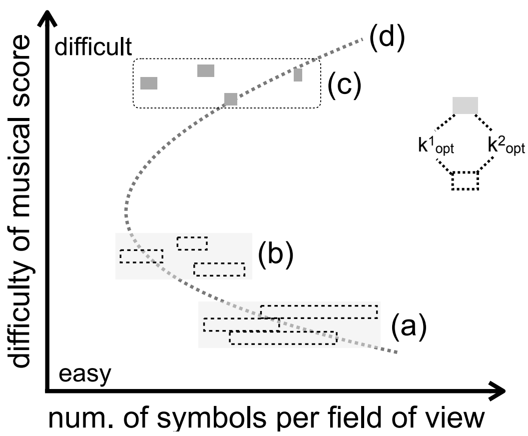

Figure 3: Each bar shows the k values with the range from k_{opt}^1 to k_{opt}^2. Depending on the levels of difficulty of musical score, the bars locate at specific regions in the plane and shows a characteristic distribution pattern on the plane.

There is another case where a person feels difficult for a score. In this case, he or she cannot optimize k per each field of vision. Some fields have optimized k values, but not for the others. For this reason, the differences of $k_{opt}^1 - k_{opt}^2$ will become small and all ranges $k_{opt}^1 - k_{opt}^2$ will not overlap. Fig. 3 (c) shows this case.

There are cases in-between, which correspond to Fig. 3 (b).

4 EXAMINATION OF THE MODEL

It is assumed that the values of reading span, k, relate with the degree of difficulty of the music score to read and an expert piano player should have large values of k compared of those that entry level players would have. This section examines the relationships between the degree of difficulty of musical score and the values of k for expert piano players. To do this, twelve musical scores are used, each of which is associated with the respective difficulty level, or *grade*, defined by the music company. The levels of difficulty

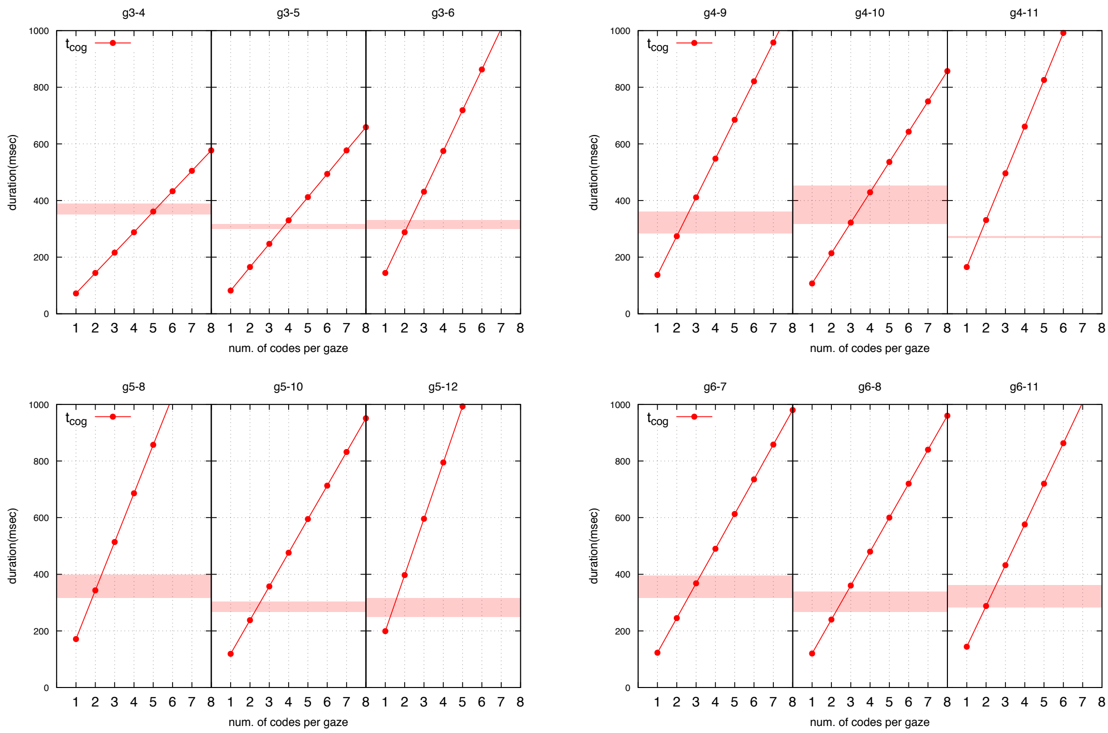

Figure 4: The shaded bands in red color shown in the figures from top-left to bottom-right indicate the solutions for $k_{opt}^{(1,2)}$ for grade 3, 4, 5, and 6, respectively. They were derived by applying the method defined by Fig. 2.

extend from grade-6, the easiest, to grade-3, the most difficult. Eye movement data were obtained from an expert piano player while she read each of twelve musical scores using the Tobii Pro X2-60 and the data were analyzed by the Tobii Studio software.

The detailed specification of the eye-tracking experiment is as follows:

- gazes are measured with the time resolution of 60Hz and 0.4 degree ($\sim$ 20 pix) for precision,
- the expert has 60 seconds for reading each musical score, which is conformed to typical sight playing examination for a grade examination system,
- three musical scores per grade are measured, and the order of presentation is random,
- after measuring gazes, fixation points are identified to derive the field of vision, which is converted to the size of reading chunk by counting the symbols included in the fixated range,
- the mean and median duration times, t_{Mean} and t_{Med}, respectively, are extracted for each of the field of vision.

By applying the the above-mentioned procedure, t_{Mean} and t_{Med} are obtained from the eye-tracking data for each musical score, and the ideal trajectory for $t_{cog}(k)$ is derived. k_{opt}^1 and k_{opt}^2 are obtained as the points that $t_{cog}(k)$ intersects with t_{Mean} and t_{Med}, respectively. In this procedure, it is assumed that the expert level participant of this experiment should be able to read read the musical scores with the time defined by T_{ideal}.

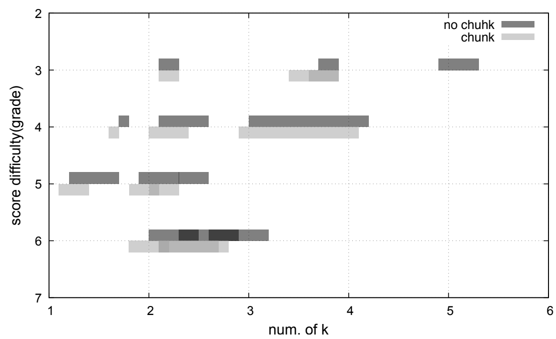

Figure 5: Distribution of $k_{opt}^{(1,2)}$ for each grade. Dark-gray bars represent the result of simulation with no-chunk case, and light-gray bars with chunk-included case.

Figure 4 shows the results, that provide the values for k_{opt}^1 and k_{opt}^2 for each musical score with a different level of difficulty by using the empirically estimated values of t_{Mean} and t_{Med}. By extracting k_{opt}^1 and k_{opt}^2 values for each musical score from the data in Fig. 4 and showing them as a whole, Figure 5 is generated, which plots the level of difficulty of musical score against the empirically estimated ranges of k^1_{opt} and k^2_{opt} values. The dark-gray bars correspond to the cases with the minimal number of chunks, i.e., it is impossible for the expert player to create any chunk due to the layout of the symbols even if he or she is able to create a chunk with the size of k if the symbols are appropriately arranged. On the other hand, the light-gray bars correspond to the cases where there are a number of chunks with the size of k. Here, the number of chunks are estimated by using empirical rules; in case of the same or similar chord patterns, it is assumed that there is one chunk for several objects; in case of there being refrain of a similar melody phrase, one chunk is assumed for each of this phrase.

From Fig. 5, the range of $k^1_{opt} - k^2_{opt}$ for the easiest grade appears in a wide and overlapped fashion, and gradually it narrows its range and becomes less overlapped towards the higher grades. Comparing them with the no-chunk cases (a real beginner who cannot recognize a chord), chunk-included estimation, which is for players who can read a chord, has a different feature. For example, in the grade 3 case, no-chunk estimation predicts that it needs to include up to 5.4 symbols for each field of vision. But chunk-included estimation predicts that it needs to include under 4 symbols. Through these features, it is indicated that if an expert has a method of making effective chunks for musical symbols, he or she can use more time to examine the details of the musical score. For example, if an expert can make 4 chunks from 12 notes, he or she can cut it by watching notes in $2/3$ times comparing with 12 chunks from 12 notes. Using the saved times, the expert makes a time to examine the other symbols, such as dynamics, articulation, relation, and so on. The differences in Fig. 5 suggest that there are possibilities that the lager k values allows a piano player to read smoothly when provided with the musical scores at higher grades.

5 CONCLUSION

This paper proposed a method to understand relationships between reading behavior and the level of difficulty of a musical score. The method has a possibility of training reading musical score – syntactic element for playing music – a supporting tool with ICT.

First, we set three components to construct the model for reading musical score. It was based on a cognitive-behavioral science approach. With the three components, we described the processes. By examining the processes, it was found that the features of eye-movement behaviors such as fixation times and the areas of fixation trace reflected the performance of memory searching in musical objects, which approximated performance of reading musical scores.

On the basis of the above considerations, this paper proposed a method for estimating personal performance of reading musical score using the average and median duration times for each fixation. It was suggested that, along with the observed duration times, the predicted optimum duration times from each musical score were related with the estimated total number of symbols per field of vision, which in turn related with personal performance of reading musical score. It was suggested that the method has a possibility to apply supporting tool for training reading musical score with ICT. In the future, the observation of eye-movement behavior while reading musical scores will be extended to that of beginners to examine the possibility of applying this method to more broad piano players.

ACKNOWLEDGEMENTENTS

The authors are deeply grateful to Miss Takako Nakano for useful comments. This work was supported by JSPS KAKENHI Grant Number 15H02784.

REFERENCES

Emond, B. and Comeau, G. (2013). Cognitive modelling of early music reading skill acquisition for piano: A comparison of the middle-c and intervallic methods. *Cognitive Systems Research*, 24:26 – 34. Cognitive Systems Research:Special Issue on ICCM2012.

Kinsler, V. and Carpenter, R. (1995). Saccadic eye movements while reading music. *Vision Research*, 35(10):1447 – 1458.

Kitajima, M., Tahira, H., Takahashi, S., and Midorikawa, T. (2012). Understanding tourists' in situ behavior: A cognitive chrono-ethnography study of visitors to a hot spring resort. *Journal of Quality Assurance in Hospitality & Tourism*, 13:247–270.

Nakahira, K. T., Akahane, M., and Fukami, Y. (2009). Verification of the effectiveness of blended learning in teaching performance skills for simultaneous singing and piano playing. *Proceedings of the 17th International Conference on Computers in Education*, pages 975–979.

Nakahira, K. T. and Kitajima, M. (2014). Understanding differences of eye movements patterns while reading musical scores between instructors and learners to design learner - centered teaching strategies. *the Proceedings of The 22nd International Conference on Computers in Education*, pages 101–106.