Analysis of a Chunk-Based Learning Process in a Piano Learning Support System

Yoshinari Takegawa, Keiji Hirata, Emiko Tayanagi, and Mio Tsubakimoto
Future University Hakodate
Japan
{yoshi, hirata, tayanagi, mtsubaki}@fun.ac.jp

Abstract: Beginners often give up practicing the piano because of the difficulty of acquiring piano techniques such as reading a score, correct keying, and proper fingering. We developed a piano learning system to support correct keying and fingering for beginners. We observed that beginners looked at the keying position many times, and they did not comprehend the relationship between musical notations. However, they constructed musical `chunks', by grouping together successive notes, as they practiced the trial piece. If we use this chunking model, we may be able to propose a more effective piano learning system. Therefore, the goal of our study is to analyze a chunk-based learning process in our piano learning system in order to construct a more effective learning system. We conducted an experiment to assess the process of the formation of a chunk. We found that there was a trend in the transformation of chunks among the subjects.

Introduction

Piano players need to master various techniques and skills, such as reading a score, correct keying, proper fingering, correct rhythm (the timing of pressing and releasing a key), keeping tempo, and dynamics. Players generally need long-term training. Unfortunately, beginners often give up because of the difficulty of acquiring these techniques. We developed a piano learning system (Takegawa et al. 2011, Takegawa et al. 2012, and Takegawa et al. 2013) to support correct keying and fingering for beginners. It uses a projector which is set above the keyboard and can display information along the entire MIDI keyboard. The proposed system has a fingering check function that uses the real-time fingering recognition technique that we developed (Takegawa et al. 2006). Additionally, we devised presentation methods to indicate useful information for piano performances effectively. We place emphasis on teaching how to read a musical staff in order to enable learners to be independent from our proposed system after training.

In our research about piano learning support systems for adult piano beginners, we observed that beginners looked at the keying position many times, and they did not comprehend the relationship between musical notations. However, they constructed musical `chunks', by grouping together successive notes, as they practiced the trial piece. In general, pianists use their chunking ability to memorize multiple notes as a chord (Weaver 1943). The `chunks' referred to in this paper are related to not only short-term memory, which is used in cognitive psychology and artificial intelligence, but also long-term memory (Ericsson et al. 1995). If we account for the role of chunking in the piano learning process, such as ``the relationship between chunk construction and piano skill level,'' ``what factors cause variations in chunk construction,'' and ``the meaning of the position of the borderlines between chunks,'' we are able to propose a more effective piano learning system, by incorporating features such as a new method for measuring beginners' degree of piano learning skill based on chunking results, an inference of learning strategy, and intuitive guide information given chunk by chunk.

Therefore, the goal of our study is to analyze a chunk-based learning process in our piano learning system.

We conducted an experiment to observe the process of the formation of a chunk with six adult subjects. The subjects practiced a trial piece for 30 minutes per day with the proposed learning system, took a test at the

end of each day to assess their current keying accuracy of the trial piece, outlined the chunks they had formed on the musical staff, and explained the reason for each chunk in the test. We recorded keying data throughout the experiment as well. We investigated and analyzed the relationship between skill level and construction of chunks based on quantity data and quality data.

The remainder of this paper is organized as follows: Section 2 describes related work, Section 3 explains about the evaluative environment focusing on the learning support system used in the experiment, Section 4 describes the evaluation, and finally Section 5 describes our conclusions and future work.

Related Work

There are many studies of methods to support piano learners. There are systems that automatically detect the weak points of learners, including mis-keying and fluctuation of tempo or dynamics, on the basis of a conventional practice log (Akinaga et al. 2006, Akinaga et al. 2007, Kitamura et al. 2006, and Mukai et al. 2007). Piano Tutor (Dannenberg et al. 1990) is an interactive expert system that uses multimedia technology and has functions such as automatic page-turning based on score-following technology, and creating and presenting performance support information with video, music notation, and graphics, in response to learners' performance. There are also piano lesson support systems (Smoliar et al. 1995) that show current articulation, agogik, and dynamics. There are keyboards and software (Takegawa et al. 2011, Takegawa et al. 2012, and Keyboardmania) that display keying position, fingering, and sample videos as support information during performance. While these systems show useful information for a piano learning objective based on keying information, we investigate the transition of the musical cognition of a learner based on chunks.

Takegawa et al. (Takegawa et al. 2013) investigate the transition of eye-movement considering learning process, but do not focus on chunk data. Weaver (Weaver 1943) investigates chunking ability according to the music-reading of expert pianists. However, the target learners in our research are piano beginners, and our research focuses on not only music-reading but also piano playing and the transition of chunks. Sakai et al. (Sakai et al. 2003) proves the existence of chunks in the case where a learner presses and releases keys on a keypad while looking at visual information. Piano playing requires higher-level analysis, since chunk construction in piano playing comprises not only the factor of sight but also the factors of hearing and musical knowledge.

System Structure

Fig. 1 and Fig. 2 show the system appearance and system structure as used in the evaluation. The system has a projector and a display to present learning support information. The display is put in front of the learner. The projector is set above the keyboard and can show information along the entire MIDI keyboard. The system uses MIDI data including pitch data and keying intensity data from the MIDI keyboard to generate information. Moreover, we used a video camera to record the entire evaluation. We used a SONY VGN-SR94VS to provide images. Additionally, we used a CASIO PriviA PX-110 as the MIDI keyboard, and BenQ MP776 ST as a projector. The projected area was 6 octaves (72 keys) and we painted all the black keys of the MIDI keyboard white. We implemented the system using Microsoft Visual C++.NET 2010.

Information presented to learners

We explain the presented information with Fig. 3. This information is updated in sync with the performance. The Arabic numerals in Fig. 3 correspond to the following list:

1) The system presents a musical score. The role of the score information is the same as that of the conventional score.
2) The bar indicating the current execution position in the score is shown. This support helps learners understand the keying timing of both hands easily from the score. When a learner makes a keying mistake while using a score with chunk information the bar moves back to the beginning of the current chunk. On

Figure 1: System appearance

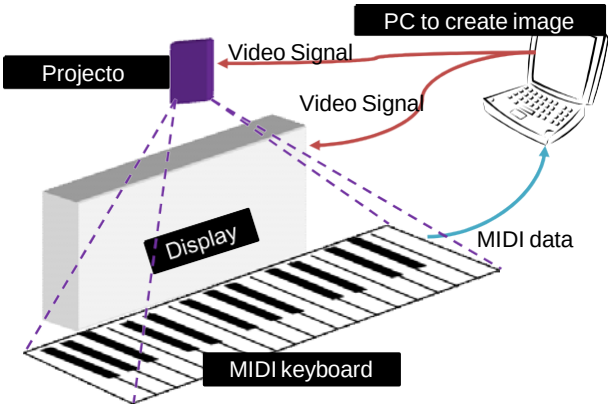

Figure 2: System structure

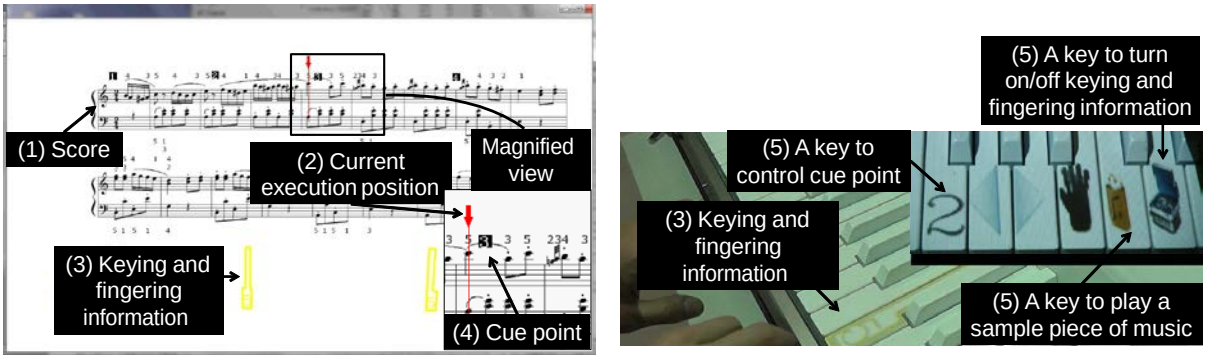

Figure 3: Presented Information

the other hand, when a learner makes keying mistakes while using a score without chunk information the bar does not move from the position until the learner presses the correct keys.

3) When a key is outlined in color this indicates that it is the next key that should be pressed. A number on the key denotes fingering. This function is useful for beginners, who cannot read keying and fingering information from a piece of music. Moreover, keying position and fingering information are shown on the display as well. Learners who are used to pressing correct keys while they look at the keying and fingering information on the keyboard use this information on the display as the next step, since they practice pressing correct keys without looking at the keyboard or their hands.
4) Learners can select cue points which are indicated on the score by numbers in black squares. The cue points enable learners to change the point from which they want to start practicing. The number of cue points is four. This function is useful when learners want to practice part of the score again and again without having to start from the very beginning each time.
5) Learners are able to control the playback of a sample piece of music, and turn keying and fingering information on or off. These functions are controlled using the keyboard. Commands can be assigned to keys for operating the system, and an icon which represents the command assigned to a key is displayed on the key.

Experiment

We conducted an experiment to investigate the relationship between skill level and construction of chunks based on keying information, chunks which were created by the subjects in the experiment, and the results of an interview, when the subjects were practicing the keying of a new score with the proposed system.

Method	Subject	Duration of piano playing (years)	Length of trial piece (bars)	Length of practice/listening duration (minutes/day)	Condition at end of experiment
Proposed method	A	10	18	30	No keying errors
	B				
	C to G (5 subjects)	over 20			
Proposed method	H to N (7 subjects)	none	18	30	Fewer than 10 keying errors
Traditional method	O to Q (3 subjects)	none	8	20	No keying errors
Listening method	R to T (3 subjects)	none	8	20 (5minutes * 4)	Chunk results unchanged

Table 1: Profile for each subject

Experimental procedure

Tab. 1 shows summary of the experimental procedure. The detailed experimental procedure was as follows:

Comparative method: In this evaluation, we compared the proposed method to two conventional methods: the traditional method and the listening method. In the traditional method, the subjects practice the trial piece without using the proposed system, reading the music from a score printed on paper. In the listening method, subjects listen to the trial piece from beginning to end again and again, and look at the score of the trial piece. The score has a bar indicating current playing position, as shown in Fig.3 - (2).

Subject: 20 subjects took part in this experiment. All subjects were adults in their twenties. Seven subjects (Subjects A to G) had had over ten years of formal piano training and were experts. The other 13 subjects had had no formal piano training and were beginners. The target user of the proposed system is a piano beginner, but we included experienced piano players in the experiment to ensure consistency by comparing their chunk construction results with those of the beginners. Subjects A to N were assigned to the proposed method, Subjects O, P, and Q were assigned to the traditional method, and Subjects R, S, and T were assigned to the listening method. Moreover, we explained to Subjects A to N how to use the proposed functions, and taught the beginners how to read a musical staff.

Trial piece: The subjects using the proposed method practiced “Turkischer Marsch (Piano Sonata No. 11 in A major, K. 331: III (W. A. Mozart)),” from the beginning to bar 18, as the trial piece for two-handed playing. Other subjects practiced Turkischer Marsch from the beginning to bar eight, as the trial piece for two-handed playing. All subjects had listened to the trial piece but had never played the trial piece.

Flow of the evaluation of Subjects A to Q: This examination for the subjects from Subjects A to Q consisted of three phases: practice, testing and chunking. Subjects A to N practiced the trial piece for 30 minutes during the practice phase. Subjects O to Q practiced the trial piece for 20 minutes during the practice phase, since their trial piece was shorter than that of Subjects A to N. They learned the trial piece by practicing over and over using the assigned method. Afterwards, they played the trial piece from beginning to end in the test phase. In this phase, we presented only a score that was the same as the score used in the practice phase. In the experiment, the

system logged the keying data from the MIDI keyboard and the video camera recorded the evaluation. Finally, after the test phase, the subjects outlined the groups of notes that they recognized as chunks on the musical staff with a pencil, and we asked them the reason why they had chunked the piece in this way. We counted the number of keying errors based on the following three types of keying error: incorrect keying, when the subject presses an incorrect key, non-keying, when the subject does not press a key that the musical score indicates should be pressed, and extra keying, when the subject presses not only correct keys but also other keys. We continued this evaluation until the number of keying errors was zero (Subjects A to G, and O to Q)/fewer 10 (Subjects H to N) in the test phase. The subjects completed each of these phases once a day, and then retried them the next day. They rested for over 12 hours between one day's session and the next.

Flow of the evaluation of Subjects R to T: The examination for Subjects R to T consisted of two phases: listening and chunking. The subjects listened to the sample piece of music while looking at the score and watching the bar indicating the current execution position for 5 minutes. Then, after the test phase, they outlined the groups of notes that they recognized as chunks on the musical staff with a pencil, and we asked them the reason why they had chunked the piece in this way. The subjects repeated these phases 4 times without breaks on each day. We continued this evaluation until the subjects' chunks ceased to change, so that their current chunks were the same as those they had created in the previous session. They rested for over 12 hours between one day's session and the next.

Instruction: In the practice phase, we instructed the subjects to practice freely, and aim to become able to play the training piece without keying errors in natural tempo. Also, we told them to remember that they had to take a test after the practice phase, in which they would play the trial piece from beginning to end without system support, and finally that they should feel free to ask any questions. Additionally, in the test phase, we instructed the subjects to play the trial piece in five minutes without keying errors, in natural tempo like the sample music. We permitted them to skip forward to the next note when they did not understand correct keying positions, but we prohibited them from replaying notes. When the subjects outlined the chunks on the musical staff, we instructed them to enclose the notes, which they felt could be grouped as a chunk, with a rectangle. We permitted them to leave out notes which did not belong to any chunk, to create a chunk composed of a single note, and to create a large chunk which includes smaller chunks. In the listening phase, we instructed the subjects to listen to the sample piece of music carefully.

Results and discussion

Fig. 4 shows the number of keying errors on the test of the trial piece. The experts (Subjects A to G) played the trial piece with few keying errors on the first day of the experiment, and they controlled rhythm, tempo, and dynamics in the test on the final day of the experiment. On the other hand, piano beginners (Subjects H to Q) practiced only the right-hand part of the trial piece repeatedly until the end of the second day of the experiment. They did not play the trial piece with both hands smoothly until the penultimate day of evaluation in the practice phase, but the number of keying errors decreased as they repeatedly practiced.

There were two types of learning strategy in the group of piano beginners using the proposed method: adaption to the system and dependency on the keying information. The subjects who used the former strategy used not only keying information but also other functions of the proposed system, for example, they used the function which allowed them to turn off the keying and fingering information displayed on the keyboard, since they got used to the learning environment in the test phase, and used the cue point function to practice the difficult phrases in the trial piece. The subjects who used the latter strategy used only keying information. It was difficult for beginners to add musical expression, such as controlling tempo, dynamics and rhythm, even on the final day of the experiment.

Note that these strategies, as well as the behaviors of the subjects described below, were observed by the experimenter, and subjective aspects, such as the psychological states of the subjects, were confirmed by interviewing them.

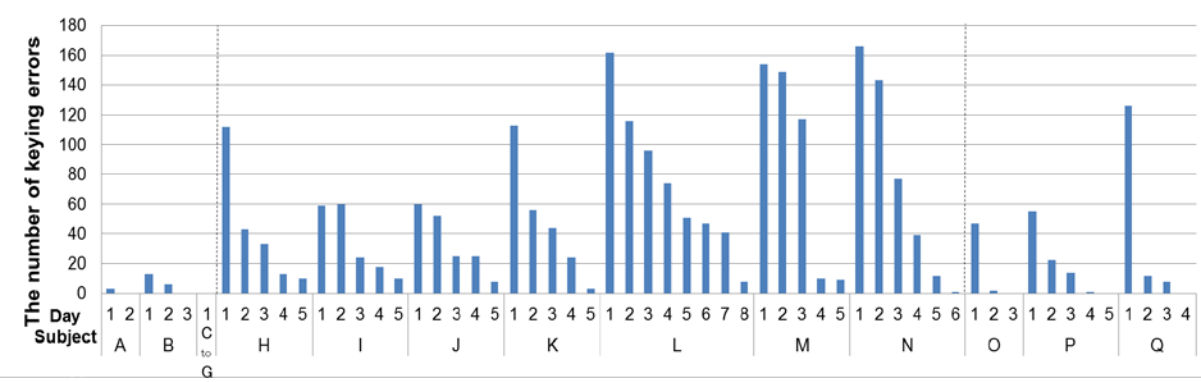

Figure 4: Number of keying errors on the test

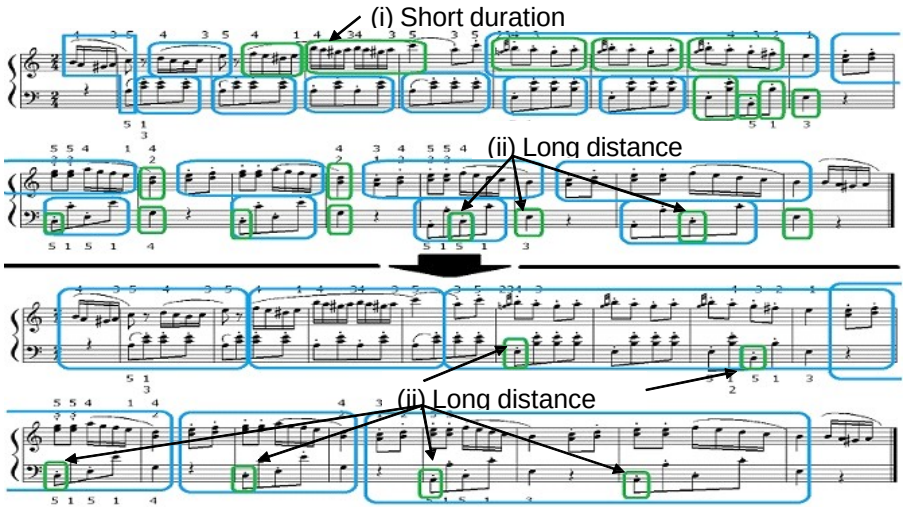

Figure 5: Chunk results of Subject I (Beginner using the proposed method)

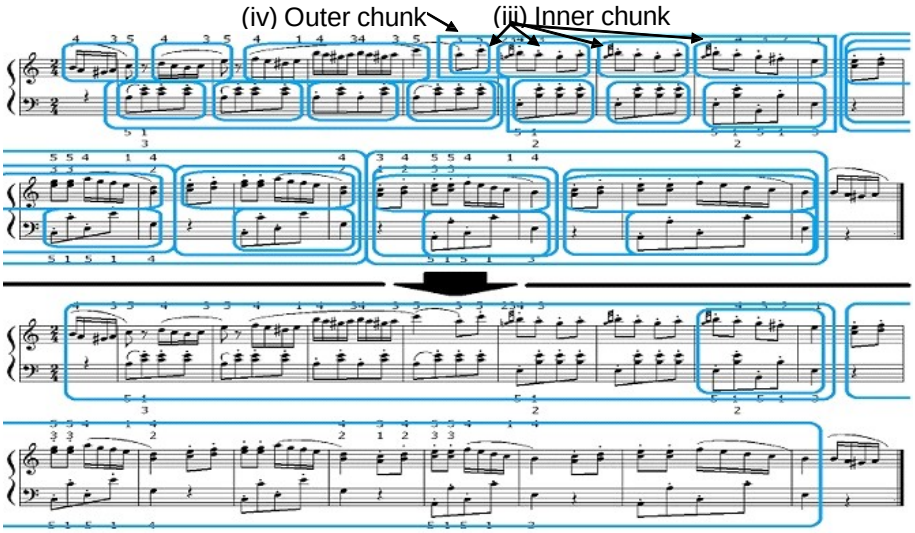

Figure 6: Chunk results of Subject B (Expert using the proposed method)

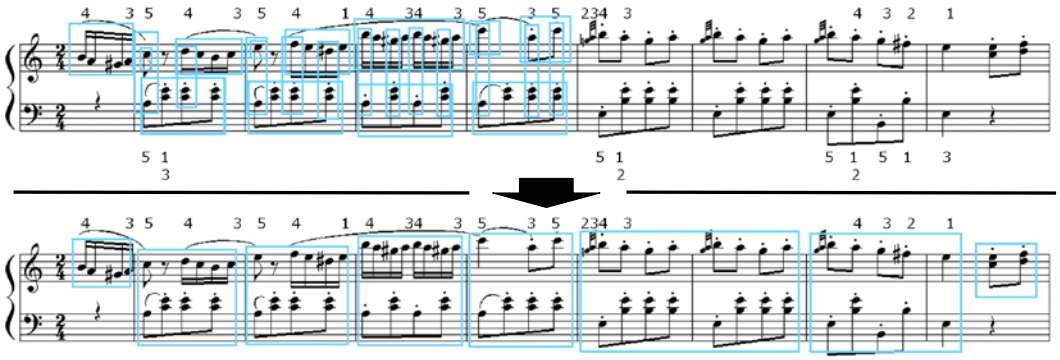

Figure 7: Chunk results of Subject O (Traditional method)

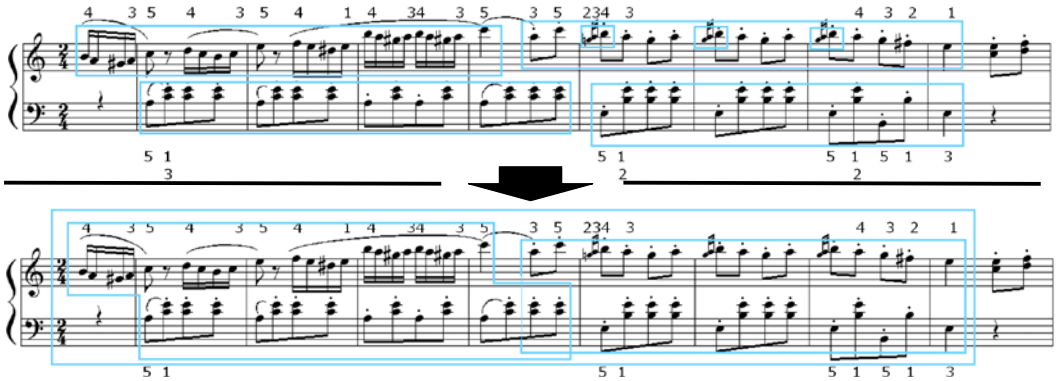

Figure 8: Chunk results of Subject S (Listening method)

Figures 5 to 8 show chunking results for each method. The upper and lower parts in Figures 5 to 7 show the results of the first and final day of the experiment respectively. The upper and lower parts in Fig. 8 show the results from five minutes into the first day, and 20 minutes into the final day of the experiment.

Based on the interview results concerning the reason for the construction of each chunk, and characteristic features of each chunk, the chunks can be classified into two types: skill-required chunks and phrase-pattern chunks, which are indicated by green rectangles and blue rectangles respectively in Figures 5 to 8.

Skill-required chunk: A skill-required chunk is constructed in the case where there is a high concentration of musical notes with short duration, such as successive sixteenth notes as shown in Fig. 5-(i), or in the case of long distance between current keying position and next keying position, as shown in Fig. 5-(ii). Subjects need a high level of concentration to play the notes in a skill-required chunk. The size of a skill-required chunk is usually smaller than one bar. Beginners using the proposed method constructed skill-required chunks even on the final day of the experiment. In particular, the skill-required chunks where there was a long distance between current keying position and next keying position remained until the final day of the experiment. On the other hand, it was observed that the expert players mostly ceased to construct this kind of skill-required chunk on the final day.

Phrase-pattern chunk: A phrase-pattern chunk is constructed in the case where subjects find a pattern, such as same rhythm and same keying position, or a musical phrase, which is related to musical grouping and not to physical movement such as fingering. From the beginning stage of the evaluation, experts and beginners constructed phrase-pattern chunks. A phrase-pattern chunk has a hierarchical structure, such as an inner chunk which is enclosed in a larger chunk and an outer chunk which is not enclosed, as shown in Fig. 6-(iii) and (iv). In general, the size of the outer phrase-pattern chunks of experts is bigger than that of beginners in the beginning stage of the evaluation.

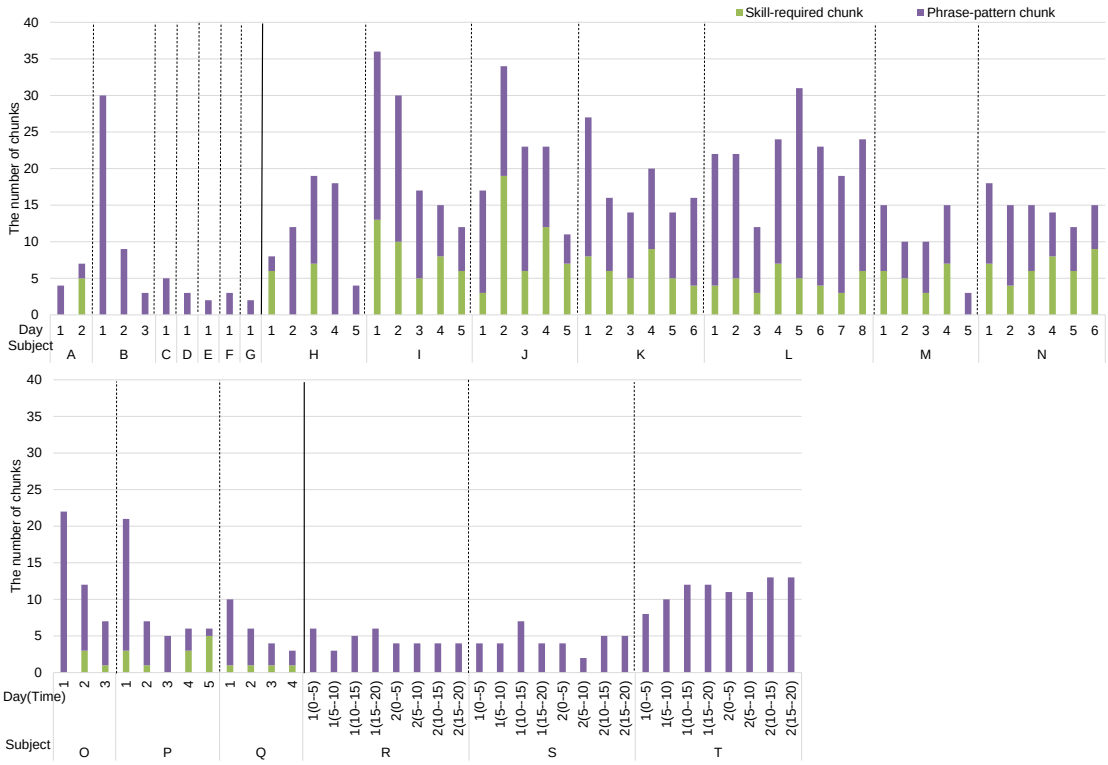

Figure 9: The number of chunks

The analysis of chunk construction based on the chunk results of the proposed method

Experts and the beginners in the ending stage of the evaluation construct phrase-pattern chunks based on their music knowledge, and their auditory cognition, meaning that they find patterns or phrases through playing the trial piece and listening to it again and again. However, beginners in the beginning stage of the evaluation construct phrase-pattern chunks based on just the physical movement of the fingers, noting patterns such as "same keying position" and "successive similar rhythm."

Chunk construction and piano skill: Focusing on the chunking results of the proposed method, it can be seen that skill-required chunks and phrase-pattern chunks with one bar were constructed in the beginning stage of the evaluation. However, subjects constructed bigger phrase-pattern chunks when they got used to playing the trial piece. The number of skill-required chunks of beginners is higher than that of experts, since it is mainly difficulty with fingering that leads to the creation of skill-required chunks. Once the subjects are able to play the notes in a skill-required chunk smoothly, they cease to be conscious of the chunk. Fig 9 shows the number of skill-required chunks (green bars), and the number of phrase-pattern chunks (purple bars), per subject per day. The average number of skill-required chunks of beginners in the evaluation is 5.9, and that of experts is 0.5, according to the results of Fig. 9. We confirmed that the average number of skill-required chunks of the experts was significantly less than that of the beginners ($t(12) = 4.3$, $p<.01$). These results show that the development of chunk construction would be an effective index of piano proficiency.

Similar chunking results on the final day: The chunking results of each subject using the proposed method in the beginning and middle stages of the evaluation were different, however, the chunking results of each subject on the final day of the evaluation were similar. In particular, all the experts divided the piece into the following two

Theme X			Theme Y			Theme X'		
A	B	A	C	D	E	A	B'	A

Figure 10: Rondo form

large-sized phrase-pattern chunks: the first half of the trial piece (from the first bar to the first beat in the ninth bar) and the second half of the trial piece (from the second beat in the ninth bar to the first beat in the seventeenth bar). This trend arises from the musical form of the trial piece. The musical form of the trial piece is rondo, and the first/second half of the trial piece corresponds to the episode A/B as shown in Fig. 10. That is, the chunking structure on the final day was affected by the musical structure of the trial piece. Therefore, we argue that chunking structure can be used as a common measure for the variety of piano learners.

Comparing the proposed method to other methods

The size of each chunk created by the subjects (Subjects O to Q) using the traditional method on the final day of the experiment was smaller than that of the beginning subjects (Subjects H to N) using the proposed method, as shown in Fig. 7. Subjects H to N constructed phrase-pattern chunks of over 4 bars, but Subjects O to Q did not. The subjects using the proposed method became able to play the trial piece smoothly in the practice phase on the final day, by using the presented keying information on the keyboard. However, the subjects using the traditional method were not able to play the trial piece smoothly, and they looked at the musical notation of the score and the keys again and again to confirm keying position in the practice phase on the final day in the evaluation. The subjects using the traditional method developed good score-reading ability and skills for mapping between musical notations and keys with this training, and they were able to play the trial piece with no mistakes in the test. It was difficult for them to sense musical phrase in the practice, since they were concentrating on pressing correct keys.

The subjects using the listening method were able to make phrase chunks from 5 minutes into the practice phase on the first day of the experiment, as shown in Fig. 8. They were able to concentrate on listening to the sample track of the trial piece, and did not need to consider finger movement and keying position. Basically, being used to listening to western-style music, they were able to feel and recognize musical phrase easily. Thus, they could construct phrase chunks in a short time while simply listening to the sample track.

These results suggest that Subjects R to T would recognize phrase chunks in the beginning stage of the evaluation. However, phrase chunks would not be expressed in their chunking results since they tend to sense skill-required chunks and pattern chunks more strongly.

Conclusions

We analyzed a chunk-based learning process in our piano learning system. The results of the evaluation show that the construction of chunks is related to audio and visual cognition, physical movement, and musical knowledge. The chunks are classified into two types: skill-required chunks and phrase-pattern chunks. The number and timing of each kind of chunk depends on the skill level of the person playing the trial piece. In general, skill-required chunks and small phrase-pattern chunks are constructed in the beginning stage of the evaluation, to be replaced by large chunks in the final stage of the evaluation. The final construction of chunks of each subject is similar. There is a strong possibility that chunk construction can become a new method to measure the skill-level of performance of a trial piece.

Future work will involve investigation into the process of the construction of chunks in other trial pieces, with different evaluative environments, such as using a musical piece in which the notes do not have beams. We will analyze the process of the construction of chunk based on accuracy of not only keying but also fingering, rhythm, and tempo, and propose a new piano learning system that makes use of the knowledge regarding chunk construction.

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