Evaluation of a Piano Learning Support System Focusing on the Learning Process

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. Our research group developed a piano learning system 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. We have developed a prototype system, and evaluated its effectiveness through actual use of the system. We found that it had significant advantages over conventional methods. However, we cannot examine the learning process for keying technique, using this system. Therefore, the goal of our study is to evaluate the proposed learning system, focusing on the learning process. We conducted an evaluative experiment with eight participants over five successive days (30 minutes per day), using the proposed learning system. We analyzed the learning process considering not only accuracy of keying but also gaze.

Introduction

Piano players need to master various techniques and skills, such as reading a score, correct keying, proper fingering, correct rhythm, keeping tempo, and dynamics. Players generally need long-term training. Unfortunately, beginners often give up because of the difficulty of acquiring these techniques.

Our research group developed a piano learning system to support correct keying and fingering for beginners (Takegawa et al., 2011). We found that it had significant advantages over a lighted keyboard method (CASIO: Lighted Keys Keyboards), which was the most commonly used interactive learning method for piano beginners. The lighted keyboard method indicates the next key to be pressed by filling it in red. However, we have not examined the learning process related to keying techniques such as “acquirement of generic keying technique” and “transition between important presented information and level of keying technique” yet.

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 (Mukai et al., 2007; Kitamura et al., 2006; Akinaga et al., 2006). 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, creating performance support information and presenting it with video, music notation, and graphics in response to learners' performance. There are keyboards and software (Takegawa et al., 2011; Takegawa et al., 2012; CASIO: Lighted Keys Keyboards; KONAMI: Keyboardmania) that display keying position, fingering, and sample videos as support information during performance. There are also piano lesson support systems (Smoliar et al., 1995) that show current articulation, agogik, and dynamics. There are several researches which observe the movement of the gaze during musical performance, focusing on the gaze on a score or other musical players (Wikipedia: Eye movement in music reading; Kobori et al., 2008; Kawase, 2009; Nguyen et al., 2006). Our research combines both approaches of presenting the keying information and gaze data on a musical keyboard as well as a score during performance. Therefore, the goal of our study is to evaluate the proposed learning system, focusing on the learning process.

Plan of an evaluative experiment

Our research group developed a piano learning system for beginners to teach correct keying and fingering, as well as how to read a musical score, to enable learners to play music, which is not stored in the system, without the support of the system. The proposed learning system presents next keying information, fingering, and an interactive score, where musical notations are connected to the corresponding keys with a line, to make the score easier to read, as shown in Figure 1. As described in the “Introduction” section, we evaluate the proposed learning system with eight participants over five successive days (30 minutes per day), focusing on the learning process.

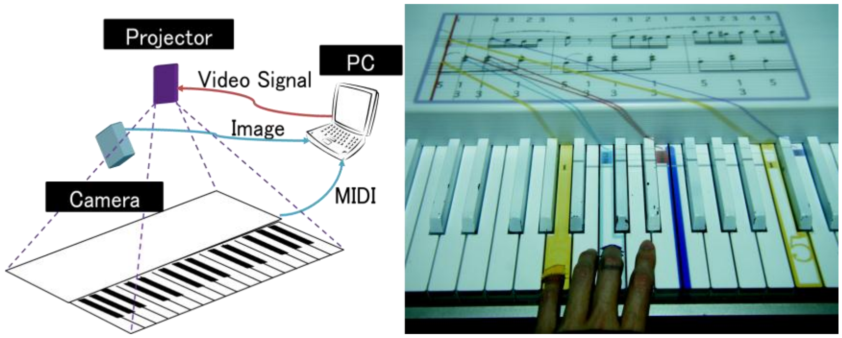

Figure 1 : System structure and presented contents of the previous system

Policy of the evaluative experiment

There are two policies for constructing our evaluative experiment:

Acquirement of generic keying technique:

We developed the piano learning system and evaluated its effectiveness from the point of view of keying accuracy. We found that it had significant advantages over a lighted keyboard method. The participants practiced a trial piece for 30 minutes. The number of keying errors of the participants who used the proposed learning system was few and they finally became able to play the trial piece without the proposed system support. From this evaluation, we found that the proposed system enabled the participants to learn the keying position of the trial piece. However, we did not find that the participants acquired a generic keying technique, meaning that there is no need to use the proposed system if they practice playing a new musical piece. Therefore, in order to examine this, the participants took not only a test to check the piece-specific keying technique of a trial piece at the end of each experimental day, but also a test to check their generic keying technique at the beginning of the evaluative experiment and at the end with a trial piece which is different from the trial piece used for checking piece-specific keying technique.

Transition between important presented information and level of keying technique:

The proposed learning system presents various kinds of information to support piano performance. The important information might change based on the level of keying technique; for example, a beginner pays attention to the keying information on the keyboard, but an expert pays attention to the musical score. Therefore, we examine the transition between important presented information and level of keying technique to propose a more effective leaning system. We analyze it based on not only keying accuracy but also gaze on the keyboard and the musical score.

An evaluation system

Figure 2 shows the system structure as used in the evaluation. The system has a projector and a display to present learning support information. The display has an eye-tracking function as well, and is put in front of a user. 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 set an eye-tracking device, which traces the gaze on the MIDI keyboard, and used a video camera to record the entire evaluation. We used a SONY VGN-SR94VS to provide images and record gaze data on the display, a SONY VPCSA to record gaze data on the MIDI keyboard. Additionally, we used a CASIO PriviA PX-110 as the MIDI keyboard, and a Tobii X1 Light for eye-tracking on the MIDI keyboard, a Tobii T60 for eye-tracking on the display, 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.

Presented information

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

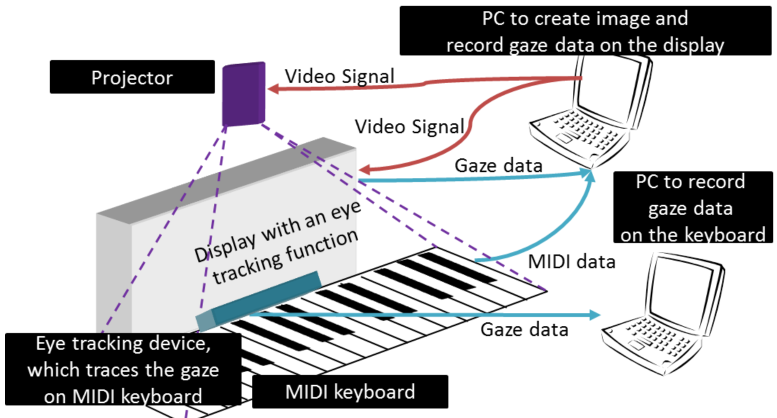

Figure 3 : System structure of the proposed evaluation system

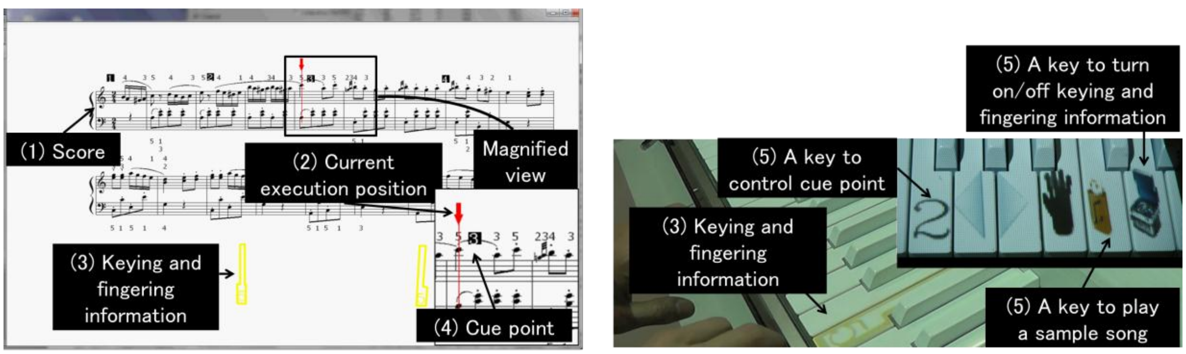

Figure 2 : Presented information

1) The system presents a musical score. The roles of the score information are the same as those 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 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 show 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 while not looking at the keyboard and their hands.
4) Users 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) Users control the play of a sample song, and turn keying and fingering information on or off. These functions are controlled using the keyboard. Keys can be assigned to commands for operating the system, and an icon which represents the command assigned to a key is displayed on the key.

Evaluative experiment

We conducted an evaluative experiment to investigate the learning process of the proposed system in the beginning stage of piano performance based on the keying data and gaze data, when a piano beginner is practicing the keying of a new score.

Experimental procedure

Eight subjects took part in this experiment, all of whom had no formal piano training, and were not able to read a score. All participants were aged between 20 and 40. We explained how to read pitch from notes on the musical score, and how to use the proposed functions.

There were two trial pieces: Turkish March (Piano Sonata No. 11 in A major, K. 331: III (W. A. Mozart)) as a training piece and Minuet (BWV Anh. 114 (J. S. Bach)) as a test piece. To check the piece-specific keying technique, the subjects practiced the Turkish March from the beginning to bar 18, playing with both hands, and to check the generic keying technique they played the Minuet from the beginning to bar 9, playing with both hands.

This examination consisted of two evaluation items: the piece-specific keying technique and the generic keying technique. Checking of the piece-specific keying technique consisted of two phases: practice and testing. The participants practiced the training piece for 30 minutes during the practice phase. They learned the training piece by practicing over and over using the functions of the proposed system. Then they played the training piece from beginning to end in the test phase. In the test phase, we presented only a score that was the same as the score used in the practice phase. The system logged the keying data from the MIDI keyboard and gaze data from the eye-tracking devices during both phases. This evaluation was conducted over five successive days.

To check the generic keying technique, the participants took a test before the practice phase of the training piece on the 1st day and after the test phase of the training piece on the 5th day. The system logged the keying data and gaze data as well. 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.

In the practice phase, we instructed the participants 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 training 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 participants to play the training/test piece without keying errors, in natural tempo like the sample music, in five minutes. We permitted them to skip forward to the next musical notation when they did not understand correct keying positions, but we prohibited them from replaying musical notations.

Results

Figure 4 shows the number of keying errors and execution time of the test of the training piece, and Figure 5 shows the number of keying errors and execution time of the test of the test piece. Note that when we analyze the results of the trial pieces we do not consider the difference between a score with chunk information and a score without chunk information as chunk information does not affect the results. Additionally, since Participant G and Participant H have good piano performance technique compared to that of other participants, we do not use their results. The more the participants practice the training piece, the fewer the number of keying errors of the piece and the shorter the execution time of the training piece. However, some participants reduced the number of keying errors and the execution time of the test piece, while others did not.

Figure 6 shows the distribution of gaze of Participant B for each evaluation day. Figure 7 shows the areas of gaze, which are used in Figure 6. Participant B had difficulty looking at the score of the display on the second day, and looked at the keyboard and the right-hand side of the display as shown in Figure 6. On the other hand, the frequency of looking at the score increased on the fourth day. Thus, the more the level of keying increases, the more important the musical score becomes and the less important the keying information becomes. Moreover, she looked at the right-hand side of the display to check the keying position of the right hand. On the other hand, she looked on the left-hand side of the keyboard to check the keying position of the left hand.

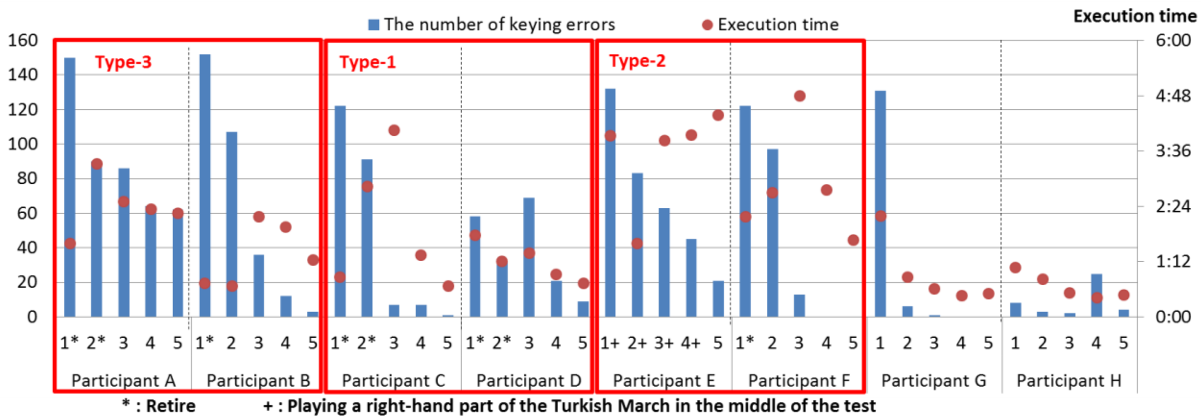

Figure 4: Results of the number of keying errors and execution time on the test of the training piece

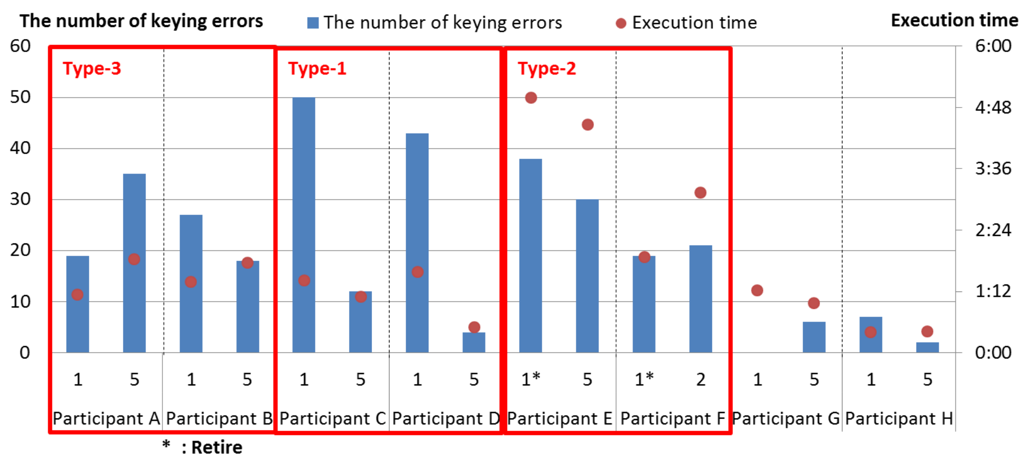

Figure 5: Results of the number of keying errors and execution time on the test of the test piece

Discussion

Considering the observed learning process under our system, we extract and interpret a few crucial points from the results of our experiment as below:

- Influence of each learner's individual learning strategy
- Difficult points of making progress especially in piano learning
- Distinction between piece-specific technique and generic technique

1) Influence of each learner's individual learning strategy:

The eight learners show quite different attitudes toward the learning method of our system. We aim not for precisely controlled experiments but rather flexibly changeable environments, depending on each learner's preference, in order to observe a more spontaneous learning process. Learners can select a few modes of the system, including avoidance of using the system, by themselves, as mentioned earlier. They exhibited varied behaviors, from relying strongly on the assistance of the system to learning completely in their own way.

The learning strategies can be classified into three types; type-1: adaption to the system, type-2: non-adaption to the system and type-3: dependency on keying information. Type-1 does not mean passive dependence on the system assistance. While this type of learner initially seems to display passive attitudes, after a while they start to unconsciously combine their own learning strategy with the system strategy, because they must at least decide when and how they should move their gaze between the score and the keyboard. They can control their learning behavior with the progress of learning.

We analyzed the learning process of a typical novice learner of type-1: Participant C. At first

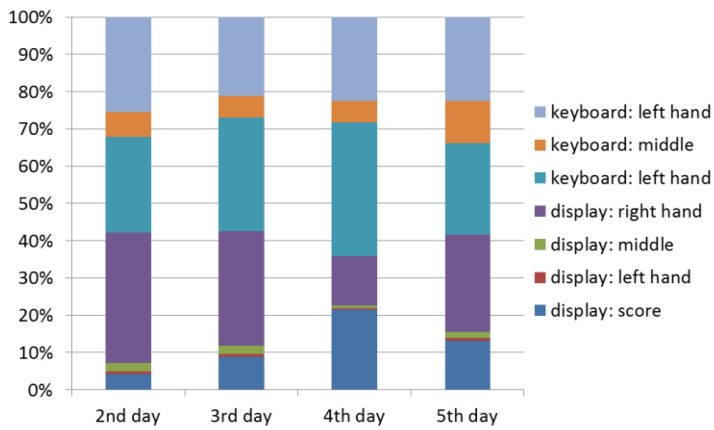

Figure 6: Distribution of gaze for each evaluation day

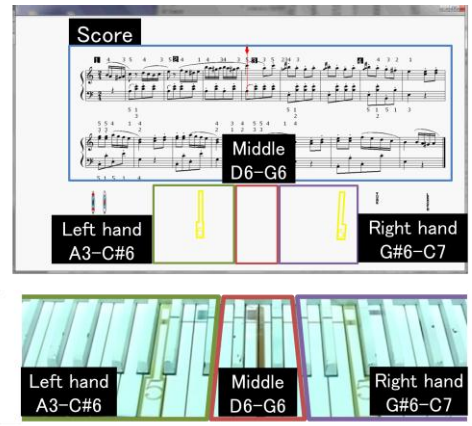

Figure 7: The areas of gaze

Participant C accepted the system strategy, mainly watching the optical guidance for keying and fingering on the keyboard. However, the learner's eyes started to move between the score and the keyboard while learning the basic keying and fingering of the trial piece, to seek pattern matching between the notes of the score and the position of the keyboard's scale because the learner knew that the goal of lesson was to play the piano without system assistance. Comparing the number of keying errors for each day's test performance of the trial piece over five days clearly shows that the number of keying errors decreases drastically (Figure 4).

Type-2 learners of the non-adaption to the system strategy, showed non-adaptive and deviated attitudes but also seemed to show similar transition of the number of keying errors to type-1 learners (Figure 4). However, there is a clear distinction between the two types of learner when it comes to the number of keying errors in the test piece (different from trial piece). We will discuss this point later in relation to the third point of distinction between the piece -specific technique and the generic technique.

Type-3 learners (Participant A, B), adjusted themselves to the system assistance for keying information, however they progressed slightly differently from each other. Participant A's test results show a slow decrease in the number of keying errors, except between the first day and the second day (Figure 4). Participant A seems to fail to adequately learn how to play the trial piece because of too much dependence on the system assistance. In contrast, Participant B shows similar progress to the other types of learners even though the learner did not make a strategic choice to become independent from the system assistance like type-1 learners. We need to further investigate the reason for this.

While the research has not yet succeeded to clearly define relations between learning progress and individual characteristics, the results suggest the importance of recognizing each learner's particular learning strategy. Although existing literary works of cognitive science, learning psychology and differential psychology state such differences and the necessity of adapting the approach of assistance to each learner (Jonassen and Grabowski, 1993), former ideas of research and development on such learning assistance systems, mainly in the engineering field, have ignored such differences among individuals.

Obviously, the results also indicate problem with our system. In the present circumstances piano learners must make exercise self-control in order to eventually stop using our system. Our system also needs to add some smarter assistance functions to help learners leave the system smoothly.

2) Difficult points of making progress especially in piano learning

Needless to say, piano learners need to learn how to play the piano in its particular way. Existing works state that the process of becoming an accomplished/expert musician is quite different in every field, and also very complex in every field. Therefore we should focus on the distinct characteristics of piano learning as well as the generic characteristic of playing instruments. One of the crucial characteristics of piano learning is building musical mapping between notes on a score and scales on a keyboard. In the case of piano learning it is difficult to play with blind touch even for experts. If a learner wants to play the piano concentrating only on the keyboard, they must completely memorize the score of a tune. However, this is not practical for novices and even for intermediate and expert pianists in everyday practice. Therefore when beginners start a piano lesson, they must attempt to understand musical mapping by rising and lowering their eyes between the score and the keyboard.

Our system is designed to support such a complicated process, generating a virtual learning environment where a learner can concentrate on looking at only the keyboard, upon which alternative notation of tunes as fingering and keying information is presented directly. While we must continuously evaluate how this assistance can support/increase the progress of piano learning by conducting more experiments, the system has successfully to create a virtual environment and enabled the learning process of two learners who are categorized as type-1 to progress smoothly, both in the trial piece (mentioned above) and the test piece (mentioned below).

One more complicated problem particular to piano learning is left-hand fingering and the F-clef. Not only is the left hand physically weaker than the right hand for the majority of right-handed people , but also the F-clef, which differs from the G-clef requires much more cognitive effort to build an understanding of musical mapping. Although our system does not take this point into account, learners seem to find that indication of keying and fingering information is helpful in solving this problem. Gaze data of a type-1 learner (Participant B) shows the leaner mostly did not look at the score, concentrating instead on the keyboard throughout the last four days (Figure 5). This data indicates s the seriousness of the left hand and F-clef problems when learning the piano. We must continuously evaluate the effectiveness of the system assistance by comparing it to the results of experiments conducted without the system assistance.

3) Distinction between piece-specific technique and generic technique

This point is most crucial for our research as stated at the beginning of the paper. Although we have not yet found a clear method to distinguish between the two techniques, the experimental data show an interesting fact. While learners of every type made good progress with the trial piece (Figure 4), type-1 learners were seen to make clear progress with the test piece (Figure 5).

This suggests that our system succeeded in assisting the progress of the generic technique of type-1 learners who adapted to the system strategy. The test piece was different from the trial piece and learners did not have any chances to practice it. We cannot clearly explain the reason why only those using the adaptive strategy could learn to play it smoothly, almost sight-reading. As mentioned in the first discussion point, type-1 learners seem to control their learning behavior with the progress of learning, deciding spontaneously how they should move their gaze between the score and the keyboard using the system assistance.

From a theoretical viewpoint, we can form some hypotheses. If the learners learn not only one-to-one mapping between notes and keys in a particular score but also more generic pattern matching between notes and keys, we can say they do meta-learning. According to existing works, musical activities such as playing, listening and learning do work crossing ones' perception and cognition (Snyder, 2001). Musical learning requires the mind to work in a "perceptual cycle" (Neisser, 1976; Gibson, 1977) in which people explore the real world, get information, store it in their short-term memory, and sort selected meaningful information into their long-term memory though the filtering function of "rehearsal" (Atkinson and Shiffrin, 1971). This cycle works in all levels of learning activities, continuously building and reconstructing cognitive schemata.

In this sense, it suggests that type-1 learners succeeded in employing this learning cycle and in building cognitive schemata relating to meta-level musical mapping. The remarkable point is that type-1 learners seem to be able to take advantage of their spontaneity, both with and without awareness. Type-2 learners seem to desire their behaviors under self-regulation with awareness. We suppose this would be crucial distinction.

If the participants of the evaluative experiment were children, they would find it much easier to adapt to given methods in general. In contrast, adult learners have already developed their own social and cognitive learning strategies through their life experiment. Therefore, sometimes they need to unlearn their firmly embedded strategies and adjust themselves to a new strategy to achieve their goal. In the case of type-2 learners, this mechanism may work much more strongly. If so, it is necessary to assist learners to avoid this kind of behavior, using a more social psychological approach, for instance. However, this is just an assumption and we should further investigate it in the future.

Conclusions

We evaluated the proposed learning system, focusing on the learning process. We conducted an evaluative experiment with eight participants over five successive days (30 minutes per day), using the proposed learning system. The participants took a test without the system support. The participants had individual learning strategy, and the learning strategies could be classified three types. The participants whose learning strategy was adaptive to the system acquired not only the piece-specific technique but also the generic technique compared to other participants. Moreover, we analyzed the transition between important presented information and level of keying technique based on gaze data of a participant. The more the level of keying increased, the more important the musical score became and the less important the keying information became. We discussed further implications to make progress especially in piano learning, and the generic technique based on the evaluation results.

Future work will involve investigation of transition between important presented information and level of keying technique, focusing on the musical notation, analysis of the experiment data based on the results of other participants, and of the learning support system considering learning level.

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