On the Effect of Performance Evaluation in Acquiring Samba Rhythm

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ABSTRACT

It is difficult for anyone to acquire a new rhythm if it is unfamiliar to him. It is difficult, for example, for Japanese to acquire a Samba rhythm as its rhythmic structure is so different from the ones they have been familiar with. To study how one learns to play a new rhythm, we investigated the process in which Japanese subjects are trained to play Samba rhythms. We employed 18 subjects to separate them into three groups. An instructor showed all of them how to play Samba rhythm with a shaker. Two groups were provided with additional information, which was calculated based on the data obtained from acceleration sensors put on their wrists. We calculated for each subject’s acceleration data its auto correlation function to compare it with the instructor’s by calculating the cross correlation function between them. The cross correlation function represents how his arm movement is close to the one of the instructor, which we regard as an index to evaluate his or her performance. Of the two groups given additional information, one group was only informed whether or not his performance was correct. The other group was furthermore shown his auto correlation along with the instructor’s, expressed as wave form on computer display. We compared these three groups to investigate how the different instructions affected the learners. It turned out the group who were shown auto correlation as wave forms learnt better than the group who were not given any information of their wrist movement. The group who were only told whether his performance was correct did however not outperform the group without any feedback. The result suggests that the learner needs a direction, not just a judgment, to acquire a new rhythm when they imitate the instructor.

I. INTRODUCTION

Acquiring a new rhythm is often difficult for a performer if it is unfamiliar to him. Samba, Brazilian dance music, is relatively popular among Japanese and quite a few of people enjoy playing and dancing Samba. The authors belong to a Samba team and play percussions on regular basis. We found it difficult for ourselves to play Samba as beginner and observed many people required long term of practice, often more than half a year, until they get accustomed to playing the music. We are interested to know why we Japanese, if you allow us to expand our personal experience to general theory, have difficulties in acquiring Samba rhythms and how we learn to play the music effectively (Yamamoto, Ishikawa, & Fujinami, 2006).

As for the reason why it is difficult for us to acquire the Samba rhythm, we came up with several findings. To summarize our findings, you have to be able to dance on the rhythm in order to play the music. It is still a matter of discussion whether you dance before acquiring the rhythm or you acquire the rhythm through dancing, but the ability of dancing on the Samba rhythm is prior to the ability of playing the Samba music (Matsumura, Yamamoto, & Fujinami, 2007). In other words, you have to learn to express the rhythm on your feet before you learn to express it with your arm (Yamamoto, Ishikawa, & Fujinami, 2006). Based on the observation, we have devised a method to evaluate the degree of acquisition by calculating auto-correlation functions of data obtained from acceleration sensors put on dancer’s back. We also applied the method to evaluating arm movements.

Although the question, why it is difficult for us to acquire the Samba rhythm, remains to be solved, we thought it might help learners to acquire the rhythm to show the result of analysis of their arm movements. Most learners showed some interests when he was presented the auto-correlation function of his arm movement because it gave him the exact information of how he moved his arm, which goes beyond his perception.

Initially, our instruction was quite simple. The teacher demonstrated how to play Samba using an instrument, e.g., shaker, to produce a wave form on computer display, which shows the acceleration data obtained from the sensor. The learner then plays the instrument himself to monitor the wave form produced by his arm movement. He compares the wave form with that of instructor’s to see the difference between his performance and instructor’s. Some students were benefitted from the method, but others were not. We were interested to know which factors worked effective in teaching students how to play Samba.

We explain in this paper our experiment to examine the effects of feedbacks to learners and present our ideas of teaching students unfamiliar rhythms.

II. EXPERIMENT

We employed eighteen subjects to prepare for three groups, each of which consists of six persons. All the subjects were post-graduate student at our institute and they were all male. The experiment lasted for three days and each subject was asked to participate in a session every day for half an hour. Each session was carried out as follows:

1. Introduction: The subject was taught how to play the shaker.
2. Data collection: The subject was asked to play the Samba rhythm for a minute. We collected data as is explained shortly.
3. Practice: The subject was allowed to play the shaker for ten minutes. Some subjects were given a feedback of their arm movements. (Detailed explanation follows.)
4. Second Cycle: The subject repeated the Data collection and Practice steps above.
5. Data collection: The session was concluded with Data collection.
III. DATA COLLECTION

A. Task
Each subject is asked to play the Samba rhythm as follows:

The accents are posed on the first and fourth notes within a beat. Figure 1 shows how to play the shaker. To produce the rhythmic pattern, the player has to accelerate his arm movement at the steps 1 and 4. The difficulty lies in the different acceleration between 4-1 and 2-3 pairs. While the directions in which the arm moves are the same, the speeds in performing the movements are different, i.e., 4-1 movement is fast, but 2-3 movement slow. The faster the tempo is, the harder to alternate accelerations is. It usually takes half a year for a person to learn to play the Samba rhythm with shaker.

B. Acceleration Sensor
We employed a wireless acceleration sensor, WAA-001, developed by ATR-Promotion, which measures the acceleration in three axes to transmit the data to a portable computer via Bluetooth connection. We put the sensor on subjects’ wrists as shown in Figure 2.

C. Acceleration Data
Of three axes, we focus on the Z axis to analyze the forward and backward movement of the arm as the movement affects most the resulting sound. Typical data are shown in Figure 3.

IV. ANALYSIS

A. Auto-Correlation Function
We calculate the auto-correlation coefficient of acceleration data to see the rhythmic character of his performance. The auto-correlation coefficient is calculated with the formula below, where $X_i$ is the value of acceleration, $N$ the number of data, $a$ lag, and $m$ the average of acceleration. It is also depicted as is shown in Figure 4.

$$R = \frac{\sum_{i=1}^{N-1} (X_i - m)(X_{i+a} - m)}{\sqrt{\sum_{i=1}^{N} (X_i - m)^2} \cdot \sqrt{\sum_{i=1}^{N} (X_i - m)^2}}$$

The reader may notice that there are two different levels of peak, each alternates the other. The alternation indicates the different acceleration of arm movements between 4-1 and 2-3 movements as explained above (Section III-B. Task). The high peak corresponds to 4-1 (quick) and the lower peak to 2-3 (slow).
B. Cross-Correlation Coefficient

We can capture the characteristics of performance by referring to auto-correlation functions, but it does not tell us how well he is playing the shaker. To see the degree of acquisition, we compare his auto-correlation function with that of the instructor. The degree is thus judged relative to the performance of the instructor.

Figure 5 shows two auto-correlation functions, one of which is that of the instructor and the other of which that of the learner. The reader may notice that the learner’s peak comes always behind of the instructor’s, which means that the learner’s timing of acceleration is not right for playing Samba.

We use the cross-correlation coefficient to calculate how close the learner’s arm movement is to that of the instructor. The formula is as shown below, where $X$ is the auto-correlation coefficient of the learner’s at $i$-th datum, $Y$ that of the instructor’s, $m$ the average of the learner’s auto-correlation coefficients, $n$ that of the instructor’s, and $N$ the number of data.

$$R = \frac{\sum_{i=0}^{N} (X_i - m)(Y_i - n)}{\sqrt{\sum_{i=0}^{N} (X_i - m)^2} \cdot \sqrt{\sum_{i=0}^{N} (Y_i - n)^2}}$$

V. FEEDBACKS TO LEARNER

A. Presenting Auto-Correlation Function

The feedback to the learner can be done in several ways. The simplest way is to show him the acceleration data as obtained from the acceleration sensor. Most learner are amazed to see how his arm movement is depicted in wave forms, but the presentation does not help much the learner to improve his performance because it only distinguishes quick movements from slow ones. He understands that he has to produce two distinctive tones to express the rhythm, but the timing information for alternating strong and weak tones is missing.

Auto-correlation function can convey the information of timing for alternation. The quick periodic movements to produce accented notes result in the peaks appearing at the timings of the beat. The weak periodic movements to produce sounds without accent on the other hand result in the lower peaks appearing in between the peaks.

B. Overwrapping Auto-Correlation Functions

Auto-correlation function tells the learner how periodic his arm movements are, but he needs another help to learn to alternate quick and slow movements. It is often easy for a learner to produce accent-free periodic movements, resulting in periodic peaks in auto-correlation function, but it is difficult to alternate quick and slow movements, resulting in two levels of periodic peaks alternating each other for the half of the beat.

Overwrapping the learner’s auto correlation function onto that of the instructor greatly helps him to improve his arm movements. As is inferred from the Figure 5, the overwrapped auto-correlation functions show him whether the timings of peaks are correct. The learner whose movements are depicted in Figure 5 may realize, for example, that his arm movements are slightly behind than is expected.

He may realize that the first lower peak is too low, which means he needs more control in producing the weak tone in between the beat. He may also realize that peaks are getting lower as the time period for checking periodicity gets longer, which means his performance is not stable.

C. Presenting Cross-Correlation Coefficient

Overwrapping auto-correlation functions helps the learner to see what is wrong with his performance, but the information has to be extracted by the learner himself. We are fond of a clearer index to indicate how close his performance to that of the instructor. To represent the similarity between two performers, we employ the cross-correlation coefficient.

Figure 6 shows two trends of cross-correlation coefficients as is explained above (Section IV-B). The cross-correlation coefficient between the model and given data is plotted in time series. The trend of the instructor’s remains high and stable, where the average is 0.94. That of the learner’s however stays low and decreases towards 30 second. The average is also low, i.e., 0.36.
Informing the learner of the trend enables him to check if he is doing better or worse. It should also be noted that the cross-correlation coefficients do not change drastically, thus updating the value can be a matter of a few seconds.

VI. TEACHING METHODS

A. Cross-Correlation Coefficient with Overwrapped ACFs

The first group A consisted of six subjects, who were shown the cross-correlation coefficient with a pair of auto-correlation functions, one of which depicts the learner’s ACF and the other of which the ideal ACF as model (Figure 7). The panel is divided into three planes. The upper square shows the learner’s ACF and the lower square the target ACF. The score bar to the right indicates the cross-correlation coefficient between the learner’s ACF and the model ACF. The information is updated every 1.5 second.

![Figure 7. Learner’s interface for Group A](image)

B. Indication of Similarity to Instructor Only

The second group B consisted of six subjects, who were only informed whether their performances were correct. They were shown the circle when the cross-correlation coefficient gets over 0.83 and the cross when it gets lower than the value. Figure 8 shows the signs as is presented to the subject.

![Figure 8. Indication of Cross-Correlation Coefficient](image)

C. Demonstration by the Instructor

The third and last group C were given no feedback. Most learners could however not acquire the skill without instruction. The first author thus ended up with playing the shaker together with the subject to demonstrate how to play the Samba rhythm. The demonstration was however limited to the practice time and lasted only for a few seconds approximately every two minutes during ten minutes of practice.

All the groups A, B, and C, were shown his demonstration in the same manner. Minimum efforts are applied to demonstration so as not to affect the skill acquisition process of the subjects.

VII. RESULTS

A. Evaluation of Skill Level

We asked each subject to play the Samba rhythm for one minute every time we collected data. We used the data for 50 seconds by cutting off the first and last five seconds for evaluation. We calculated the cross-correlation coefficients of his performance relative to the model for 50 seconds and regarded the average as the index of skill level. Figure 6 (Section V-C) shows two examples. The average of cross-correlation coefficients for 50 seconds is 0.94 for the instructor and 0.36 for the learner.

B. Tracing Progress of Each Subject

We collected data nine times for each subject as we had three chances per person for each day and the experiment was carried out for three days. We could thus trace the progress of each subject with nine values. Figure 9 shows for each subject belonging to group A how his performance was improved throughout the experiment. The subjects belonging to group A were presented the cross-correlation coefficient with his and the instructor’s ACFs (see Section VI-A). The figure shows most subjects had improved their skills during the experiment.

![Figure 9. The progress of six subjects belonging to Group A](image)
The figure shows most subjects had improved their skills throughout the experiment although the progress was not monotonic.

**Figure 10. The progress of six subjects belonging to Group B**

Figure 11 shows for each subject belonging to group C how his performance was improved throughout the experiment. The subjects belonging to group C were not presented any feedback. Note that the six alphabets A to F denote different persons from the ones they denote for group A or B although the same alphabets are adopted.

As for the last group, some people had improved their skills, but others were not. It is unclear whether there are general tendency of improvement for this group.

**Figure 11. The progress of six subjects belonging to Group C**

**C. Tracing Progress of Each Group**

We roughly estimate the progress of each group, abstracting from individuals, by calculating the average of all member’s coefficient. Figure 12 shows the progress of each group.

**D. Evaluating Progress of Each Subject with Learning Curve**

To evaluate the progress made near the top end appropriately, we introduce a learning curve into our analysis and evaluate the progress relative to it. The skill level (SL) may be captured with the following formula, \( SL = 1 - \frac{1}{(\alpha \times N)} \), where \( \alpha \) is a learning coefficient and \( N \) the number of practices. The effect of a practice varies depending on the learning coefficient, \( \alpha \), as is defined by the formula.

The learning curve as is defined by the formula is depicted as shown in Figure 13. The \( x \) axis indicates the number of practices and the \( y \) axis the degree of skill. The curve indicates that the skill is very quickly acquired in the beginning, but it is getting harder to make a progress as the acquisition process approaches to completion.

As is expressed above, we regard the cross-correlation coefficient to represent the skill level (SL). We assume then the degree of progress (DoP) to be measured by \( \alpha > N \), where \( \alpha \) is a learning coefficient and \( N \) the number of practices. The formula is transformed to the following: \( SL = 1 - (1/DoP) \). The DoP is calculated then by the formula, \( DoP = 1/(1-SL) \).
We calculate the degree of progress (DoP) for each group with the formula. Figure 14 shows the progress of six subjects belonging to Group A when we calculate it with the formula, DoP = 1/(1-SL), where SL is the average of cross-correlation coefficients for 50 seconds. Y axis indicates the degree of progress and X axis the number of practices.

The progress of Group B is shown in Figure 15 and that of Group C in Figure 16. The progress in acquiring skills can be seen more clearly when it is calculated with the formula, 1/(1-SL). Figure 14 shows more clearly the increase in the degree of progress than Figure 9. The difference between Figures 15 and 10 is subtle, but the difference between Group A and B becomes clearer by referring to Figures 14 and 15. It becomes easier to compare the progress of Group C with other groups when it is calculated with the formula. The progress of subjects belonging to Group C seems certainly to be slow when we refer to Figure 16.

E. Tracing Progress of Each Group with Learning Curve

Now that we have observed how the proposed method depicts the progress of learners, let us redraw Figures 12, showing the progress of each group, in terms of the degree of progress. Figure 17 shows how each group preceded in acquiring the skill.

The trends of each group as is depicted in Figure 17 may be approximated as linear phenomena. The result indicates that our assumption on the learning curve is verified by the data.

We focus on the learning coefficient, $\alpha$, then. The coefficient is represented as the ratio between the degrees of progress in the figure. The learning coefficient of the second trial relative to the first one is calculated by dividing the DoP of the second trial with that of the first one. As each subject went through nine data collections, we obtain eight values of learning coefficient for a subject. Each group consisting of six subjects provides for 48 values in total. The average of the values may be regarded as an index of efficiency of learning.
Figure 17. The progress of each group when it is calculated based on the learning curve

Figure 18 shows the average of learning coefficients for each group. Y axis represents the average of learning coefficients. The student’s t-test is applied to the values at the significant level=0.1 to check if the differences are statistically meaningful. It turned out that the difference between Group A and C is significant while no significant difference exists between Group A and B, also between Group B and C.

Figure 18. The average of learning coefficients for each group

VIII. DISCUSSION

We believe that Group A outperformed other groups although only the difference between Group A and C was statistically verified. The number of subjects was not enough to distinguish Group A from Group B, but the clear difference in terms of the average of learning coefficients is convincing enough for us to believe that the difference will be verified once we have gathered more subjects for our experiment.

What made the difference between Group A and B? Both groups were informed whether their performances were correct, but only Group A were informed of their arm movements. The auto-correlation function of arm movements presented to the learner somehow helped him to acquire the Samba rhythm. The visual presentation of the rhythm significantly improved his skill. The fact suggests that auditory information, that is, a demonstration by the instructor, is not enough to teach students how to play the rhythm.

Reflecting on our own experiences, the result is reasonable. We had difficulties in mastering Samba rhythms in the beginning. The instructor demonstrated how to play Samba, but it was difficult to memorize the rhythm. We produced a rhythmic pattern to mimic it, but we were unsure if our rhythm was the same as the instructor played. Auditory memory is unreliable when you learn to play unfamiliar rhythms. You have to understand its rhythmic structure to memorize it. If you cannot understand the structure of the rhythm, it is impossible for you to memorize the rhythm.

One may argue that learners received visual information by observing the instructor’s demonstration. Observation is however not helpful because the performance is carried out very quickly. The number of notes produced within a second is eight when the music is played on the tempo of 120 beat per minute. To produce each note, the player is assigned only 0.125 second. The time period is too short for us to perceive the things involved to be meaningful because our brain requires at least 0.2 second to process the information.

The auto-correlation function we presented to learners was meaningful. They could perceive the rhythmic structure in the unit of beat, i.e., about 0.5 second, and could observe the internal structure of the beat in wave form, which otherwise went beyond their cognitive capabilities. We believe that the visual presentation of the arm movements greatly helped the learners to understand the Samba rhythm.

IX. Conclusion

It is difficult for anyone to master unfamiliar rhythms. We have developed a method to help learners to master the Samba rhythm. We collected the data of arm movements using a wireless acceleration sensor to calculate their auto-correlation functions. By comparing the learner’s auto-correlation function with that of the instructor, we taught him how his arm movement was different from that of the model with the degree of similarity. We have shown through our experiment the proposed method was effective in teaching learners how to play Samba.

Future tasks include carrying out another experiment with more subjects to verify our hypothesis statistically. The number of subjects, eighteen, was not sufficient for supporting our claim.

We also need to investigate the effect of the score bar. We only presented to Group B a sign which tells if the arm movement is close to that of the model. Group B might have shown different result if they had been presented the degree of similarity using the score bar although we doubt it helps learners.

Another issue concerns the understanding the meaning of ACF. We have not particularly controlled their knowledge of ACF. If the subject knows what ACF tells concerning his arm movement, he might outperform others without knowledge of ACF. We believe that knowledge may help the learner to master the skill. Practice must be most effective when the learner knows what he is doing.
ACKNOWLEDGMENT

We are grateful to people who participated in our project as subject. To name all of them, they are: Yoshito Matsudaira, Wakayuki, Hishida, Hideki Katagiri, Yosuke Kami, Syotaro Araki, Taku Ookawa, Masahiro Shimamori, Zhou Liang, Ryuji Yamazaki, Kazumasa Mizusawa Hiromichi Tohmatsu, Tadahiro Narita, Taiji Osafune, Hiroyuki Oouchi, Kazuyoshi Sugiyama, Akihiro Masuda, Sunao Funamoto, Kiyohisa Kadono, and Kensaku Aoyama. This work is partially supported by Grant-in-Aids by Ministry of Education, Culture, Sports, Science and Technology of Japan (no. 17500090).

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