Music Retrieval and Adjustment Technique to Support and Motivate Ergotherapy and Daily Exercises

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ABSTRACT

To maintain and uplift the motivation for doing exercise which is tend to be too simple in rehabilitation and ergotherapy, doing exercise with music is one of the good solutions. In this paper, we confirm that doing exercise with music is fun. Next, we design five types of musical features which relate to exercises. These features are evaluated by doing five types of exercises with listening to the tunes. Based on the results obtained from the experiments, we found many new things, for example, tempo has the adjustment limitation based on how well the user knows the tune. In this paper, we report the latest results from the experiments and explain the way to progress of this research.

Categories and Subject Descriptors

H.3.1 [Content Analysis and Indexing]; H.3.3 [Information Search and Retrieval]

General Terms

Design

Keywords

Music, Ergotherapy, Phisical Exercise

1. INTRODUCTION

Less people are killed by a car accident, stroke, and so on, since the medical techniques are highly improving. As a result, people who need rehabilitation are increasing. The elderly people are also increasing in advanced countries. They need to do exercises to keep self-reliant way of lives. In this society, ergotherapy plays an really important role to restore and maintain autonomous daily lives of the patients and the elderly people. The effectiveness of the exercises needed for the rehabilitation and the long-term care depend on the motivation of the patients and the elderly people. However, keeping the motivation high is often difficult, since many of the exercises in the ergotherapy are painful and monotonous.

We are researching music retrieval and adjustment technique for people who need to do the painful and monotonous exercises with fun. More concretely, we are researching music retrieval technique for exercise planner[1] to find tunes which fit to the exercises and match the users' preferences, and as well as a technique to adjust music according to the exercise loads. The point is that we are not going to make a music recommendation technique, but a music retrieval and adjustment technique that can find tunes that can make users easy to do exercises and also feel fun. For example, suppose a lesson pianist of a ballet class. In a ballet class, when students move the body according to the indication from the teacher, the lesson pianist improvises a tune which enables the students to move the body easily. We are going to develop a system that can play a role of such lesson pianist, however, in this research, the system will not improvise, but retrieve the user's favorite and exercise-supportive tune.

Figure 1 represents the outline of the processing. An instructor makes an exercise plan for each user every day. The system retrieves tunes which is suitable for the exercises and suggests some ways to adjust the tunes according to the exercise plan. Next, the system selects some tunes based on the user's preference and provides a tune list to the user. The user selects some tunes from the list according to mood. Finally, a package of exercises and tunes is generated. As a result, the user can do the exercises by listening to his/her favorite tunes.

In this paper, we explain the investigation result of the relationship between exercises and music, which is the first step of the research, and describe the future work based on the results.

2. RELATED WORK

In music therapy, clients do simple exercises with music. They sometimes move the body based on the tune's lyrics in stead of physical exercises. In many Japanese nursery songs and popular songs, many words that are easy to match to movements are used in their lyrics. Thus, movements based

[1]The planner may also be the person who will do the exercise.

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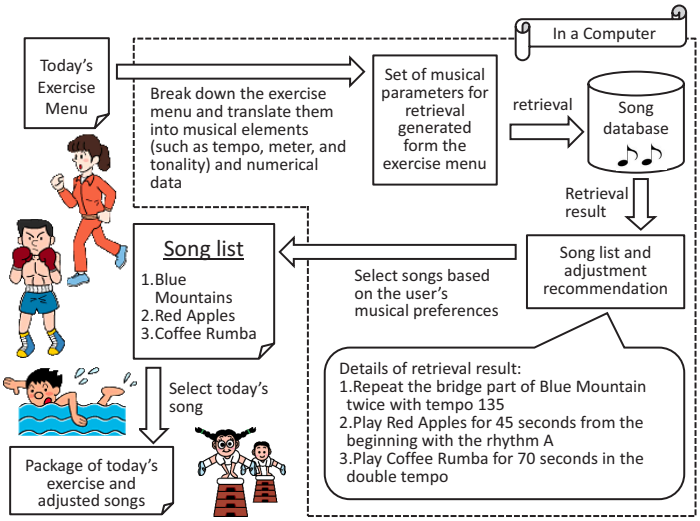

Figure 1: From exercise plan to the today's package of the exercises and tuens

on the lyrics are frequently used as activities in many nursing homes for children and the elderly people. However, making movements based on lyrics for each song is so hard and some movements are not suitable as exercises. Thus, requirements for good exercises are getting stronger and for tunes, requirements for selecting based on the mood by themselves are also getting stronger.

Neurologic music therapy was proposed by Dr. Thaut in Colorado State University [3]. It uses music based on the functional and scientific foundations for exercises and rehabilitation. It has multiple methods such as therapeutic instrumental music performance, rhythmic auditory stimulation, patterned sensory enhancement. In the therapeutic instrumental music performance, instrument's play that is similar to the training movement is used. For example, training of the movement of a spoon up and down is replaced to beating an tambourine on the table with a mallet. Thus, simple movement for the training can be done with fun, by replacing the movement into instrument's play. The patient feels comfortable, since he/she can know the end of the exercise based on the length of the tune.

It is clear that using music for exercises and rehabilitation has a lot of good potentials. However, if the tune is not his/her favorite one or the variation of tunes is not enough, his/her motivation will reduce. We are trying to make a retrieval system of music which is suitable for exercise and the user's preference to support he/she can continue the training aspiringly.

3. PILOT STUDY

In this research, experts of exercise, music therapist, and researchers of music information processing are doing research together. The first author is a researcher of music information processing. In research discussion, exercise experts sometimes say " I won't use this tune for this exercise." or a music therapist says "I'd like to do such movement, when I hear such a tune." and so on. At present, we are not sure why we think so nor what kinds of musical elements cause such judgements. Moreover, it is so hard for us to express what we think and how to feel with words. However, there surely is a certain relationship between exercises and music.

The main challenge of this research is to find music elements that cause their judgments described above, to systemize the elements, and to represent them numerically. And then, we are going to make a music database using the numerical data, and use them for retrieval and adjustment.

Thus, we did a pilot study. In the pilot study, we asked for around 10 university students to do exercise hearing their favorite songs. They could select any kinds of exercises and change music tempo according to the exercises. Each student selected two kinds of exercises and two tunes.

After all, we had many important opinions about exercise and music as follows.

1. Most of the students said that doing exercise with favorite music is fun. Compared to doing exercise by counting, it is much more fun. $\cdots$ This sustains our hypothesis.

2. Some students said that they could concentrate on the exercise by listening to music.

3. Some people felt uncomfortable, when they drastically changed tempo of their favorite music.

4. If the exercise contains multiple steps of movements, tunes whose meter is the same as the number of steps should be retrieved. However, if such tunes are not selected, users will not be tired of the exercise.

Many students said positive opinions, such as thanks to the music "I enjoyed the exercise.", "I could keep high motivation", "I could do exercise long time.". A student said he felt mental freedom and a student said he improved the mind for exercise. Such impression can be clearly observed by the three steps as follows: 1) doing exercise with listening to a tune, 2) continuing the exercise without listening to the tune, 3) doing the exercise with listening to the tune, again. Some students said they could concentrate on the exercise by listening to music. They also said that they couldn't concentrate on the exercises without listening to the music, since they thought about assignments, preparation for the experiments on tomorrow, and so on. Music sometimes irritates patients in the acute stage, since they are concentrating on doing things in front of them. On the other hand, some patients in recovery phase think various things, such as family, money, and work. This may lead another injury while they are in ergotherapy. Thus, giving concentration on the exercise is one of the very important advantages of using music in the ergotherapy.

A student selected an exercise which looks like writing a ∞ in the air. He said: I felt it is easy for me to move the arms when a beat comes when the arms in the lower position. This means in a exercise, there will be some movements which allow music to be a trigger for the exercise. Actually, some students had difficulty to match a certain beat to a movement in an exercise. For this case, students proposed to play guide sounds with music to indicate the timeing for movements.

We obtained some very important points about tempo. It is easy for us to think that there is a strong relationship between exercise and tempo of music. If the tempo is too fast, some exercises cannot be done, and if the tempo is too slow, some exercises cannot be done, either. However, we realized that we cannot adjust tempo as much as we

want. Many students said that if the tempo was greatly adjusted and differed too much from the original, they felt uncomfortable and difficult to do exercise with the adjusted music. The more they are familiar to the tune, the more they feel uncomfortable when the tune's tempo is adjusted too much. They said they felt that they are listening to an unknown tune when its tempo is changed too much. They also said that if the tempo is not too fast nor too slow, they felt that music was supporting the movement of the body. In this research, if users feel uncomfortable about the music, it is like putting the cart before the horse, since we are researching techniques to support doing exercises with fun by listening to music. Too much adjustment of tempo lose the beauty of music. Thus, we also have to investigate how much the tempo can be adjusted. As one of the concrete solutions, if the tempo of the retrieved tune is too fast to do the exercise, users can use the tune for the exercise by moving the body in every two beats.

Meter is also closely related to exercise. Many tunes' meter is two or four. We sometimes find a tune of meter three. We sometimes find tunes of other meters, too. For example, suppose that we need to do exercise which contains three steps such as 1) jump to the front with both feet, and then return the right leg to the original position, and 3) finally return the left leg to the original position. We can do this exercise easily with tunes in the meter 3, however, if we use tunes of the meter 2 or 4, we have to have a rest in every four beats. In this pilot study, students selected tunes by themselves. Thus, some students tried to use tunes of various meters. For example, a students selected a tune of the meter 7/8. He said that it was so difficult for him to do exercise with a tune of the meter 7/8. However, he also said that he felt fun and concentration, since he was not tired of doing the exercise with such a complicated tune. This is a new advantage of doing exercise with music.

4. EXERCISES

Though there are various categorizations for exercises, we use the following categorization in this research [2].

1. Isotonic exercise $\cdots$ General exercise by moving joints. The length of muscles are chaging rapidly.
2. Isometric exercise $\cdots$ Exercise without moving joints. The length of muscles are not changing.
3. Stretching $\cdots$ Exercise with changing the length of muscles. Keep the posture for a while.

Isotonic is an exercise to move the body in constant tempo. Its main objective is to make the joints easy to move and also make the range of the joint's movements broader. In isometrics, parts do not move during the exercise, Its main contribution is increasing muscle power by putting pressure to the parts. Stretch is a little close to isometric. It does not move the parts as frequently as the isotonic does. In stretch, muscles are extended. Sometimes the muscles are extended longer to make the body softer and suppler gradually.

Categorization of exercises varies depending on the way to do them, for example, stopping the movement or moving at the constant rate. For example, twisting upper body is categorized to isotonic if doing it at the constant date, however it is categorized to isometric if doing it with maintaining a posture for a certain time. Thus, exercises cannot be categorized without defining how to do it.

As parts to move, we can think the upper body, the lower body, and the whole body. Isotonic of the upper body is the most frequently used exercise, since it is flash, easy to feel accomplishment, and especially in a nursing home for the elderly, many people use wheelchairs. However, because of the health boom in these days, isometric and stretch become more and more popular, since improving muscle strength is considered as important as broadening the range of joints. Especially there are more muscles in the lower body than in the upper body, so the exercises to increase muscle strength for the lower body is very important for the elderly people. However, the compatibility between music and exercises of isometric and stretch, since their movements are unglamorous. Thus, we'd like to focus on the topic in the research.

5. MUSIC FEATURES

We define five types of music features that seem to be related to physical exercises.

1. Number of Notes (N) $\cdots$ This feature shows the number of notes in a constant time of a tune. If the value is big, there are many notes in the constant time in the tune.
2. Average Tone (T) $\cdots$ This feature shows the average pitch in a constant time of a tune. It is calculated with eq. (1) where t_i means the MIDI tone number (from 0 to 127) of the ith note.

$$T = \sum_{i=0}^{N-1} \frac{t_i}{N} \tag{1}$$

   If the value is big, the tune has a lot of high tones.
3. Average Interval (I) $\cdots$ This feature shows the average of intervales in a constant time of a tune. It is calculated with eq. (2).

$$I = \sum_{i=0}^{N-2} \frac{|t_{i+1} - t_i|}{N} \tag{2}$$

   If the value is big, pitches in the time of the tune vary greatly.
4. Sign Continuity (S) $\cdots$ This feature shows the change frequency of pitch direction. Pitch direction is categorized into up and down. When $t_{i+1} - t_i \geq 0$, the pitch direction is up. When $t_{i+1} - t_i \leq 0$, the pitch direction is down. It is calculated as B/C, where C is the number of times when the pitch direction is changed from up to down and from down to up, and B is the total number of beats in the constant time of the tune. For example, if there is a tune in 4/4 meter whose length is four bars and in which the pitch direction changes twice, the sign continuity is $4 \times 4/2 = 8$. If the value of a tune is big, its pitch direction changes rarely.
5. Rhythm Complexity (R) $\cdots$ This means a ratio where notes exist in the beginning of the beat. If there are many short notes and dotted notes, this value becomes small. In other words, if the rhythm becomes complex, quarter notes and eighth notes decrease and short notes and dotted notes increase. Then, the value of R becomes small, since fewer notes exist at the beginnings of the beats. Thus, this feature is considered to

Figure 2: Score example to calculate all the kinds of Rhythm Complexity (R)

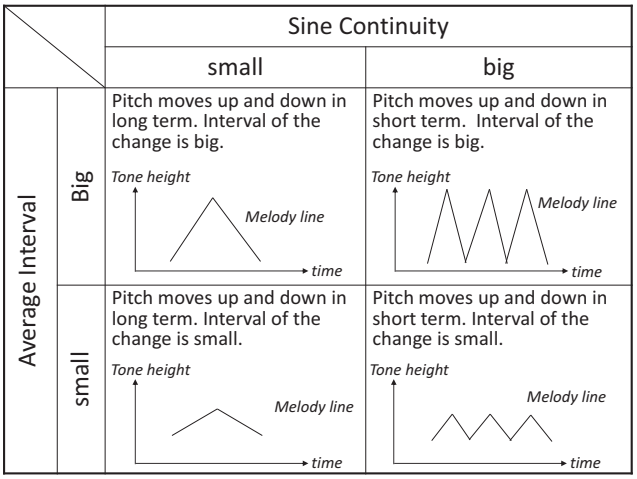

Figure 3: Melody lines and the two features: sine contiuity and average interval

show the rhythm complexity. This feature is designed based on the result of the pilot study. In this research, we define the beat grain and the unit as follows for the calculation. As the beat grain, whole beat and half beat are used. Thus, for the case where the beat grain is the half beat, the ratio of the existence of notes at the beginning of each half beat is calculated. As the unit, beat and note are used. For example in Figure 2, one bar has four beats since the tune's meter is 4/4, and the number of notes is three. Based on the above discussion, this feature is devided to four sub-features as follows.

(a) $R_b^w \cdots$ resolution is the whole beat and the unit is beat.

(b) $R_b^h \cdots$ resolution is the half beat and the unit is beat.

(c) $R_n^w \cdots$ resolution is the whole beat and the unit is note.

(d) $R_n^h \cdots$ resolution is the half beat and the unit is note.

In the tune in Figure 2, the tune has four beats, and eight half beats, and three notes. In this case, $R_b^w = 3/4$ since there are four whole beats and only three notes are at the beginning of the beat, $R_b^h = 4/8$ since there are eight half beats and all notes are at the beginning of the beat, $R_n^w = 3/4$ since there are four notes but only three notes are at the beginning of the beat, and $R_n^h = 4/4$ since there are four notes and all notes are at the beginning of the half beat.

Figure 3 shows an image of melody line based on the two new features: sign contuinity and average interval. For example a tune has big sine contuinity and big average interval, the pitch of the tune may change greatly and the changes in the pitch may be gradually.

Table 1: Evaluation indices

code	indices	score	meaning
F	easiness	1	difficult to match
		2	difficult to match a little
		3	neither
		4	easy to match a little
		5	easy to match
E	fun	1	not fun
		2	not so fun
		3	neither
		4	a little fun
		5	fun
C	concentration	1	cannot concentrate
		2	cannot concentrate a little
		3	neither
		4	can concentrate a littel
		5	can concentrate
A	accomplishment	1	cannot feel accomplishment
		2	cannot feel accomplishment a little
		3	neither
		4	feel accomplishment a little
		5	feel accomplishment

6. EVALUATION

In the experiment, 14 young people more than 20 years old did exercises described in Section 6.1 by listening to the tunes which has features described in Section 6.2. Tunes were segmented for 30 seconds from the first note in the melody sounds. Features presented in Section 6.2 are values in the 30 seconds' segments. Melodies were accented when they were played.

At first, we heard the tune and clapped to recognize beats and grasp timing to move. Then, they did exercises for the amount described in Table 2 by listening to the tune for about 20 seconds. Finally, they put scores from 1 to 5 based about the indices presented in Table 1 in the next 40 seconds.

To keep off order biases, the order of the exercise is decided using random number. Also for tunes, to keep off the biases, a tune of the same pattern of the feature is not used continuously.

6.1 Exercises

Table 2 shows five kinds of excercises used for the experiments. We selected exercises in good balance about the category and the parts Figure 4 shows the snapshots of each exercise.

6.2 Tunes

In the experiment, tunes are selected from a music database that holds 1400 tunes in MIDI format. Most of the tunes are Japanese pops. Figures from 5 to 10 show distribution of the features presented in Section 5 of all tunes in the be-

Table 2: Description of exercises

ID	exercise	Fig. #	method	category	body part	the number of times
1	moving shoulders in circles	4-(a)	Put both hands on the shoulders. Turn the shoulders forward and backward in turn.	isotonic	upper body	Turn forward 8 times, turn backward 8 times.
2	twisting upper body	4-(b),(c)	Twist the upper body in turn to where you can see the back wall.	isometrics	upper body	Count eight seconds in both sides
3	raising a toe	4-(d)	Put hands on hip. Raise the leg with pointing the toe to the ceiling to where the degree becomes 45.	power stretch	lower body	Count eight seconds in both sides.
4	doing squat	4-(e)	bend the knee to where eyes drop from 10 to 15 centimeters	isotonic	lower body	Do eight times.
5	stepping	4-(f)	Bend the knees at a right angle and raise them in turn. Wave the arms, too.	isotonic	whole body	Stepping in eight times.

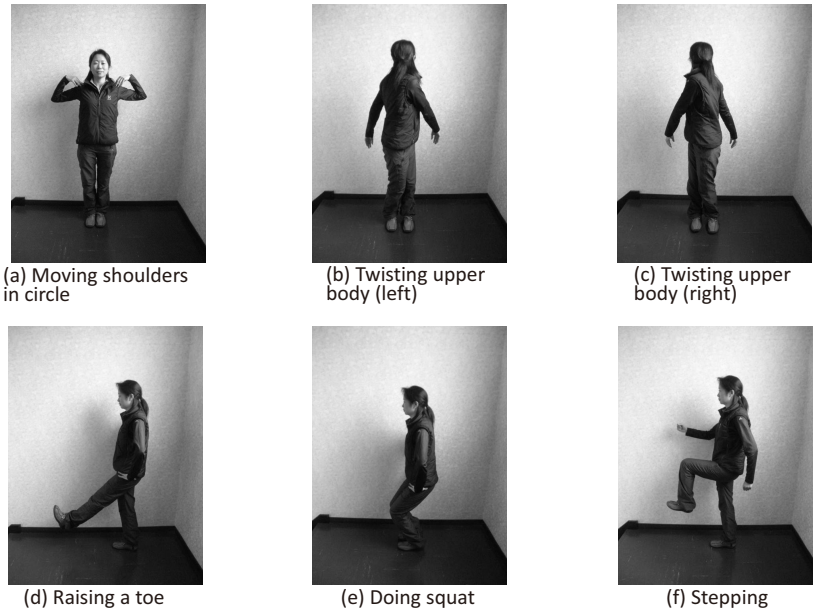

Figure 4: How to do the exercises

Table 3: Tunes used in the experiment and their features

ID	N	T	I	S	R_b^w	R_b^h	R_n^w	R_n^h
1	101	52.3	2.29	3.15	0.87	0.66	0.46	0.70
2	29	52.6	2.34	8.0	0.6	0.36	0.62	0.76
3	56	83.1	1.77	4.42	0.5	0.55	0.39	0.88
4	66	81.1	1.56	3.55	0.57	0.41	0.58	0.85
6	75	74.0	1.37	1.95	0.53	0.54	0.28	0.57
7	99	80.6	2.34	1.96	0.45	0.51	0.34	0.79
9	59	77.3	1.15	13.89	0.30	0.43	0.34	0.98
10	49	63.7	0.81	12.25	0.40	0.45	0.43	0.98
11	67	72.6	0.53	8.22	0.47	0.46	0.27	0.52
12	96	68.1	0.60	7.06	0.63	0.49	0.41	0.64
14	70	67.4	3.53	2.68	0.75	0.37	0.71	0.71
15	80	77.6	3.43	2.69	0.49	0.53	0.36	0.79

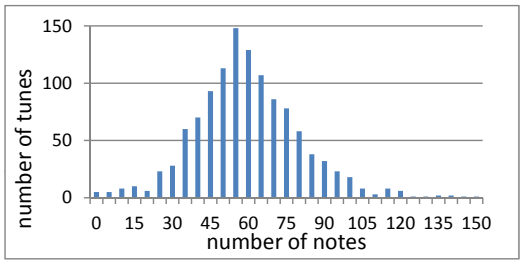

Figure 5: Distribution of number of notes

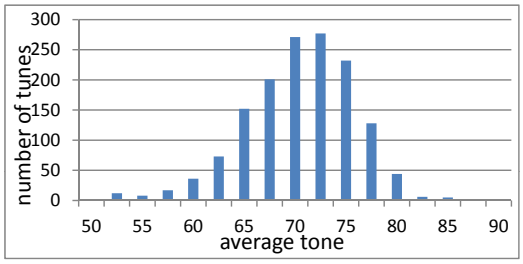

Figure 6: Distribution of average tone

ginning 30 seconds. (Figures for R_b^w and R_b^h are not shown, since their distibutions are almost the same as Figure R_n^w).

Because all tunes in the database are tunes for singing, no tunes have big intervals (Fig. 8). Many tunes have about 60 notes (Fig. 5). This implies two Japanese letters are sung in a second in most cases. The most characteristic figure is the one which represents the distribution of the rhythm complexity R_n^h (Fig. 10). The range of this feature is from 0 to 1. Thus, the most frequently appearing value about R_n^h is around 0.95. This shows the same result as described in [1] that most frequently appears notes in Japanese songs are the eighth notes. It also shows that most of the notes are put at the beginnings of the half beats. Table 3 shows the feature values of all the tunes used in the experiment.

6.3 Experimental results and discussion

6.3.1 *Easiness and Hardness of Exercises*

Figure 11 shows the results of easiness and hardness of each exercise. The x-axis represents the exercises and the y-axis represents the evaluation scores. In the evaluation, users put score from 1 to 5, as 1 means hard and 5 means easy. Thus, in the Figure 11, the bigger the score is, the easier the exercise is. Load of exercises can be represented by the parts, the range, the frequency, the time, and so on. In this experiments, time is fixed to 20 seconds, so we discuss

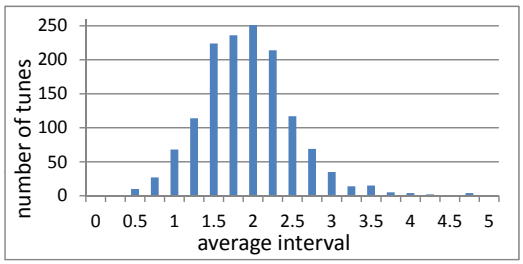

Figure 7: Distribution of average interval

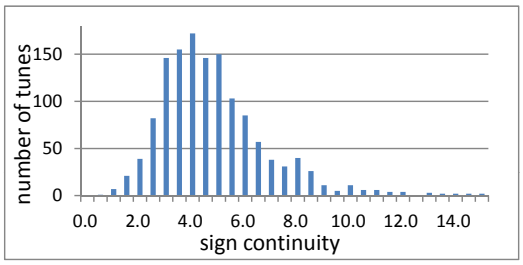

Figure 8: Distribution of sign continuity (S)

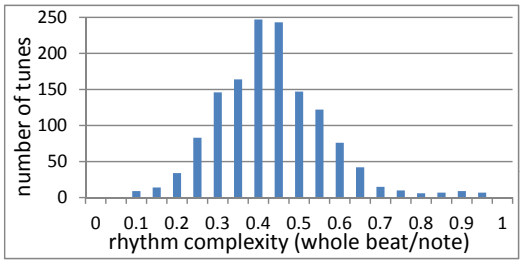

Figure 9: Distribution of rhythm complexity (R_n^w)

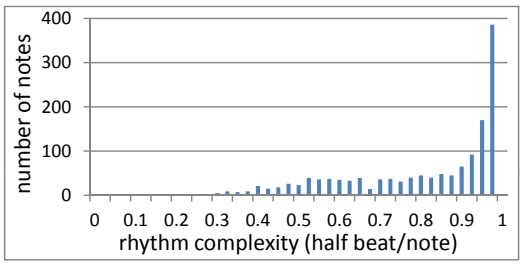

Figure 10: Distribution of rhythm complexity (R_n^h)

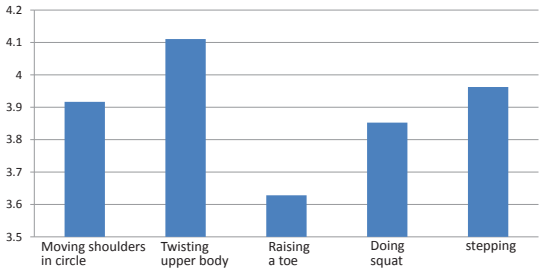

Figure 11: Easiness and hardness of exercises

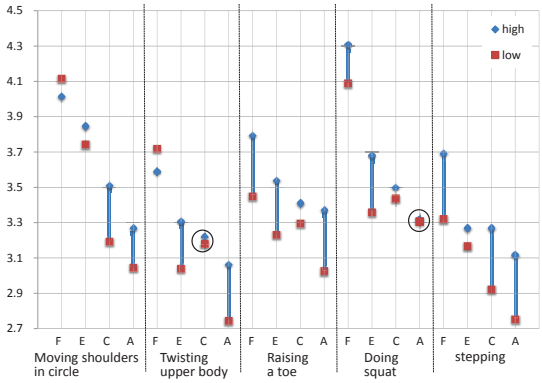

Figure 12: Evaluation based on like/dislikes the tunes

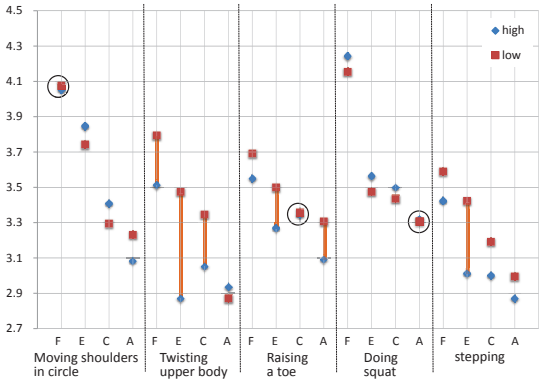

Figure 13: Evaluation based on known/unknown the tunes

about other elements. In regard to the parts, many people felt easy for exercises of the upper body. This is one of the reasons that exercises of the upper body are frequently used in music therapy sessions and our daily exercises. In exercises for the lower body, the lower the part to move drops, the harder the users feel for the exercise.

6.3.2 *Evaluation based on like/dislike the tunes and known/unknown the tunes*

In this section, how users feel for doing exercises with tunes they like and how users feel for doing exercises with tunes they don't like, and how users feel for doing exercises with tunes they know and how users feel for doing exercises with tunes they don't know. The distribution of the evaluation based on like and dislike is shown in Figure 12. The distribution of the evaluation based on knowing and unknowing is shown in Figure 13. In these figures, to roughly grasp the tendency, average score in the upper six tunes and that in the lower six tunes are used. The upper six tunes has bigger number than the lower six tunes about the number of people who know or who like the tune. The x-axis represents evaluation indices of each exercise, and the y-axis represents the scores. For example in the stepping of Figure 12, in regards to the easiness (F), the easiness score when doing exercise with using tunes which many people like the tune is about 3.7, on the other hand, the easiness score when doing exercise with using tunes which many people dislike the tune is about 3.3. Thus, we can understand that users feel the much easiness when doing exercise with their favorite tunes about stepping.

According to Figure 12, users answered that using their favorite tunes is better for them for the exercises for almost all indices of all exercises. Thus, the result of the pilot study was proved. Users felt higher accomplishment when using favorite tunes for four exercises.

On the other hand, we obtained the opposite results to our expectation about the results of the evaluation based on the known and unknown the tunes. At first, we expected that doing exercise with known tunes can obtain higher accomplishment. However, it is not always true based on the results of Figure 13. About moving shoulders in circle and doing squat, most of the scores of the known tunes are a little bigger than those of the unknown tunes. However, about twisting upper body, doing squat, and stepping, most of the scores of the unknown tunes are bigger than those of the known tunes. What does this mean? Two exercises which obtained bigger scores for known tunes are isotonic. Users might be easy to estimate the timing to move body when they are listening to the known tunes, since isotonic is an exercise to move body parts in constant tempo as described in Section 4. On the other hand, exercises which obtained bigger score for unknown tunes are twisting upper body and raising a toe which are not isotonic. This means these two exercises have duration without movement. Thus, users have to estimate the next timing to move body parts carefully. In this situation, if the users don't know the tune, they concentrate to listen to the tune more carefully and as a result, this might make them feel fun.

In the future, when we retrieve music for a exercise plan which contains multiple categories of exercises such as isotonic, isometric, and stretch, the system can select tunes from a database of old tunes for the isotonic exercises and the system can select tunes from a database of recent hits for the isometric and stretch. This makes the user enjoy two aspects: both exercise and music, since the user can listen to the latest pop hits with doing exercises.

6.3.3 *Evaluation of each musical feature*

In this section, evaluation results of each musical feature are explained. Figures from 14 to 18 shows the results. The x axis represents evaluation indices (Table 1) of each musical feature. The y axis represents the evaluation scores. To analyze the influences between each exercise and each musical feature, average value of the upper 6 tunes (legend symbol is lozenge) and the lower 6 tunes (legend symbol is square) are used to make the figures. For example in Figure 14, in regards to the number of notes, the score about easiness of tunes with less notes is about 4.15 and the score about easiness of tunes with more notes is about 4.0. For more convenient for the readers, points of the scores whose difference exceeds 0.2 are connected the points with a line, and a circle is put on the points of the scores whose difference is less than 0.05. First of all, the evaluation values of each exercise differ widely. In regards to easiness (F), moving shoulders in circle and doing squat (isotonic) obtained score more than 4.0, on the other hand, other exercises did not obtained such a big score. Isotonic exercise is frequently used in music therapy, aerobics, and so on. The reasons are not only it is easy but also it matches to music. It is proved that isotonic exercise is highly affinity to music with

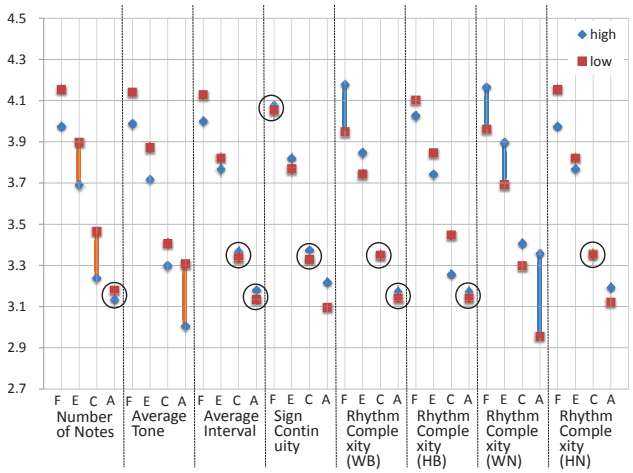

Figure 14: Evaluation results of moving shoulders in circles

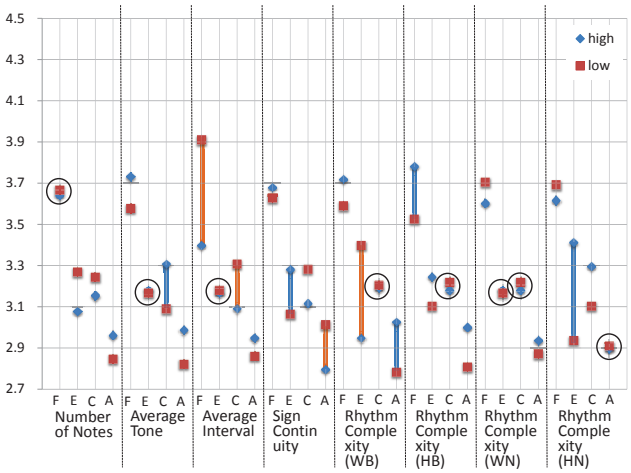

Figure 15: Evaluation results of twisting upper body

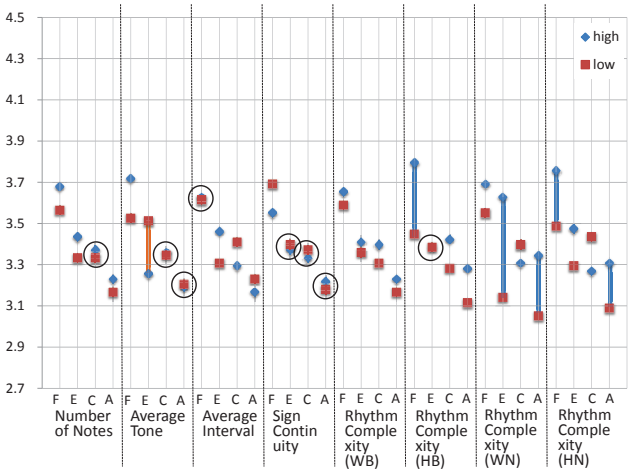

Figure 16: Evaluation results of raising a toe

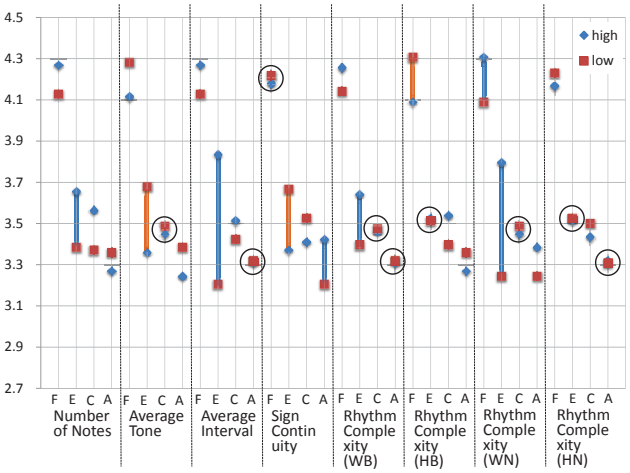

Figure 17: Evaluation results of doing squat

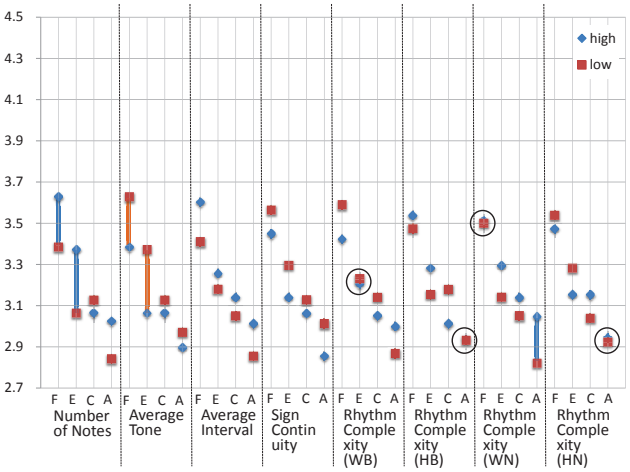

Figure 18: Evaluation results of stepping

the results in this paper. On the other hand, isometric and stretch are getting more and more popular, since they can contribute to improve muscle power, however, their affinity of music has not been investigated, since their movements are unglamorous and a few. However, isometric and stretch have time without movements. This implies users can listen to music carefully, too. Thus, they might have high affinity to music with totally different reason of isotonic.

Users felt higher accomplishment for moving shoulders, raising a toe, and doing squat. These exercises are those that users felt harder (Figure 11). According to the results in Figures from 14 to 18, scores about accomplishment do not vary in regards to the kinds and values of musical features. Accomplishment is one of the most important elements which relates to motivation maintenance and improvements for exercises. Does this result mean music has nothing to do with the maintenance and improvements of the motivation? Based on the results in the pilot study and in Section 6.3.2, it is definitely true that users feel fun to do exercises with listening to music. Thus, the results might imply that it is difficult for users to feel accomplishment when they do exercise with short musical segments, even though the segments are well-matched to exercises. Accomplishment might be felt by listening to tunes in a certain length. There are many phrases in a tune. To make users feel accomplishment with listening to music when they do exercises, a technique to allocate multiple types of exercises in a tune is necessary.

From here, each musical feature is evaluated.

1. Number of Notes $\cdots$ We expected that the number of notes has some impact for isotonic exercise. Based on the results, three isotonic exercises are given some impact from this feature, on the other hand, exercises which are not isotonic are not given impact from this feature, thus the hypothesis is proved.

2. Average Tone $\cdots$ We expected that the average tone has some impact to the heights of the parts for the movements. For moving shoulders which is an exercise of the upper body shows lower average tone is better and raising a toe which is an exercise of the lower body shows either is OK. However, doing squat and stepping which are exercises of the lower body show the lower average tone is better, and twisting upper body which is an exercise of the upper body shows that the higher average tone is better. We obtained both good and bad results about this feature. Thus, we have to investigate this musical feature more in the future.

3. Average Interval and Sign Continuity $\cdots$ As shown in Figure 3, we thought the transition pattern of a melody line can be expressed by combining these two features. Thus, we made hypothesis as follows. Small average interval is supposed to be good for exercises with small movements such as moving shoulders and rasing a toe. And small sign continuity is supposed to be good for isotonic exercises. By combining the two hypothesis, small average interval and small sign continuity are supposed to be good for moving shoulders in circle. Only doing squat and stepping are proved the hypothesis. Especially for stepping, very good results are obtained. On the other hands, we did not obtain the completely opposite results to the hypothesis. However, there are few difference in the evaluation score for the two musical features for moving shoulders in circle and raising a toe. This may imply another hypothesis is needed for these musical features.

4. Rhythm Complexity $\cdots$ The music feature which shows the biggest difference in the scores is R_n^w. The tunes whose R_n^w values are big mean less complex about rhythm, since many quarter notes in the tunes are allocated at the beginnings of the beats. Especially, big difference in the scores can be seen in moving shoulders in circle, rasing a toe, and doing squat. The common points of these three exercises are those in the top three about the hardness, which can be seen in Figure 11. We'd like to focus on raising a toe and doing squat. Both are the exercises for the lower body. Lower body is harder to move than the upper body. Thus, in these exercises, when a tone sounds at the timing to move it will be the good support for users' exercise, since users need a trigger to move the parts.

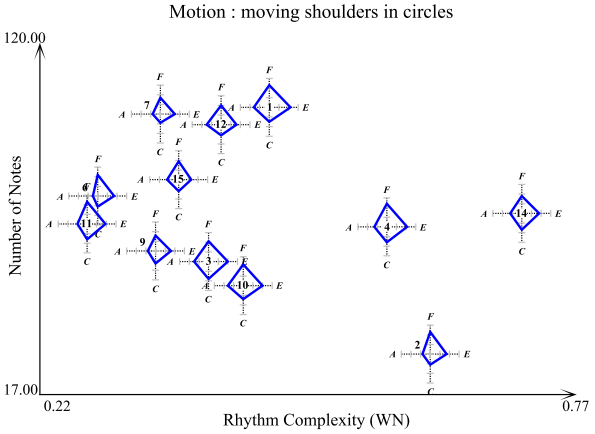

Figure 19: Radar chart about rhythm complexity and number of notes of moving shoulders in circle

Finally, we investigate the relationship between musical features and evaluation scores by displaying distributions of all tunes about two features in one figure. Figure 19 shows the distribution of all the tunes about the rhythm complexity and the number of notes of moving shoulders in circle. The x-axis represents the rhythm complexity and the y-axis represents the number of notes. The number in the center of each diamond shape represents the tune id. Figure 20 shows the distribution of all the tunes about the rhythm complexity and the average tone of doing squat. The x-axis represents the rhythm complexity and the y-axis represents the average intervals. In the figure, a radar chart represents a tune. The center of the chart is in the coordinate of the two features. The up axis represents the easiness (F), the right the fun (E), the down the concentration (C), and the left the accomplishment (A). Thus, the size of the charts represents each evaluation results. We can grasp the relationship between exercise and music feature by checking the place where the chart is and the size of the chart.

In regards to moving shoulders in circle of Figure 19, we can see bigger charts in less number of notes. However, if the number of notes is too small, the size of the chart is not so big. On the other hand, about the rhythm complexity, we can see the bigger the values become, the bigger the sizes of the charts are.

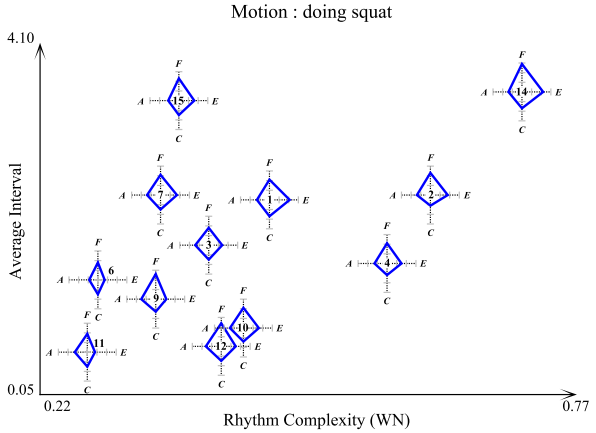

Figure 20: Radar chart about rhythm complexity and average interval of doing squat

In regards to doing squat of Figure 20, the more the rhythm complexity becomes, the right side of the chart becomes bigger and bigger. About the average interval, it seems to have the biggest charts in the middle of the feature value.

7. FUTURE WORK

A technique to decompose tunes automatically based on the musical features that relate to exercises is necessary. As described in Section 6, we only used 30 seconds musical segment in the beginning of each tune in the experiment. However, there are many phrases in a tune. Thus, it is rare for the case that whole tune is good for a certain exercise. In general, some phrases are good for isotonic exercises, but other phrases are good for isometric exercises, and so on. To efficiently use the whole tune, tunes have to be decomposed into segments based on the musical features that relate to exercises and the segments have to be registered in a database according to the features. As a result, we can retrieve musical segments based on the exercises.

Next, we have to consider about accomplishment feeling of the exerciser. According to the result in Section 6.3.3, music might not contribute for the improvement of accomplishment feeling of the users at present. We think the reason might be that the users only heard short parts of tunes for doing exercises. As described in Section 2, in music therapy session for the elderly people, sometimes movements that match to the lyrics are used instead of the exercises. One of the objective to use the whole tune is that let the elderly people feel accomplishment feeling. Thus, in our research, we also have to research and develop functions to integrate retrieved segments into some whole tunes. In other words, we also have to make a technique to gather musical segments based on the tunes to support some kinds of exercises by a few tunes.

In addition, we have to consider the case where some segments in a tune can not be used for the exercises given from the instructor. In this case, some generally good exercises such as finger exercises or simple posture of Yoga can be allocated to the segments. Thus, the system needs the technique to allocate proper exercises to the musical segments that are not useful in a certain exercise plan.

Finally, tempo should be adjusted based on the exercises. According to the results in the pilot study, the range of the tempo adjustment can be determined based on how well the user knows the tune. Based on the results in Section 6.3.2, users can feel fun with music even though they don't know the music. Thus, if the tempo of some retrieved songs are difficult to adjust, the system can retrieve songs in the bigger music database which contains many tunes that the user does not know.

Moreover, guidance sounds are good to tell users the timing (beat) to move when tunes are played for the exercises. This is caused by the result of the pilot study and the observation of the experiment. In the experiments for this paper, people did the same exercises using the same tunes. Sometimes some people was confused about the timing to start the movements. Thus, a technique to automatically find a trigger movement in a exercise is necessary, to play guidance sounds at the proper timing.

8. CONCLUSION

We are researching technique to retrieve music for exercises. Music should be good to support doing exercises and also should be preferred ones to the user. As the first step to make the retrieval system and the database, we did two experiments to analyze the relationship between exercise and music. We did a pilot study to roughly grasp the relationship and reasonability of the research. From the pilot study, we confirmed that doing exercise with music is fun, and tempo has the limitation for the adjustament based on how well the user knows the tune, and so on. We designed five types of musical features that seems to relate to exercises and investigated the relationship by doing an experiment using five kinds of exercises, such as isotonic, isometric, and stretch. As a results, the rhythm complexity seemed to be a good musical feature for the exercises. In this paper, we reported the latest results from the experiments and explained the way to progress of this research.

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