Toward Music Communication with Supplemental Visual Information

Rumi Hiraga
Tsukuba Univ. of Technology

Keitaro Takahashi
Music Academy of Basel

Nobuko Kato
Tsukuba Univ. of Technology

Abstract

We recognized that college students who are deaf and hard of hearing are also interested in music and have been working toward creating an environment in which both people with and without hearing impairments can enjoy music together. Visual assistance raises one possibility of enhancing information that music implies. We have developed a system music with motion pictures (MPM), which generates motion pictures from drawings. MPM animates a drawing with sound data, thus providing a motion picture that is synchronized with the sound data. We generated a set of motion pictures using a musical performance and a drawing that were intended to convey the same specific emotion. Then, we conducted an experiment to investigate whether a musical performer's emotional intention was better conveyed to listeners when motion pictures were provided with the music. While the results matched our expectations in that the motion pictures improved the recognition of the emotion in the music, we observed conflict of recognition when combining information from several media and generating motion pictures that yielded a better recognition of emotion.

Keywords: music, deaf and hard of hearing

1 Introduction

Our experiences with college students who are deaf and hard of hearing made us realized that these students are keenly interested in music. It encouraged us to develop a system that can be used to accompany musical performances [6]. We also knew that visual information, even though it does not necessarily involve physical movement, was effective in music communication mediated by a musician's emotional intention [4]. We proceeded to the next step in providing a better music communication environment where one possible medium was motion pictures that synchronized with the music performance.

We assumed that motion pictures which convey the same emotion as the musical performance would improve listeners' recognition of the emotion in the music compared to circumstances where people can only recognize the emotion by listening to the musical performance. Therefore, we developed a system music with motion pictures (MPM), which could generate a motion picture from a drawing as a seed with sound data to activate the drawing. In this paper, we describe an experiment on music communication using the motion pictures generated using MPM. The purpose of the experiment was to investigate whether our assumption was valid, and if valid, to determine the extent of improvement in recognition and the relationship between the sound and visual information.

The results of the experiment indicated that the recognition of emotion improved when motion pictures were synchronized with the music performance. Some of the results were consistent with those of our past experiment, e.g., there was no difference in the ability of subjects of deaf and hard of hearing and subjects with hearing in recognizing emotions. However, further studies are required for investigating certain issues, such as generating motion pictures to appropriately represent an emotion and the relationship between the sound and visual information since there was disparity between the sound and visual information in our experiments. Furthermore, we have not yet been able to make optimum use of the system in devising methods to generate good motion pictures which would convey emotions effectively.

Music, as non-verbal communication method, should be beneficial to deaf and hard of hearing students in gaining a positive experience of cooperation when they play music together. By confronting new issues, we should be able to propose a music performing environment for deaf and hard of hearing people.

2 Related Work

This research can be considered as an interdisciplinary approach involving musical activities by hearing-impaired people, aesthetics, multimedia, cognition, and computer systems.

There are many active music classes and music therapies for people with deafness and hearing impairments. Furthermore, there are several instances of professional musicians with deafness, e.g., Dame Glennie, a percussion soloist; Dr. Paul Whittaker OBE, an accomplished pianist; and the participants at Deaf Rave in London. Music classes and music therapies for deaf and hard of hearing people have mainly been established by people who have specialized in music. Darrow has performed an important study on musical therapy for deaf and hard of hearing people [3]. She provided music therapy to young deaf and hard of hearing students and statistically analyzed their responses during successive therapy sessions. Ota investigated the musical abilities of young deaf and hard of hearing students from the view point of special education [11].

The relationship between sound and visual information is an interesting research area and researchers from several fields have worked on this, e.g., Yamasaki as a psychologist [16] and Parke et al. as computer scientists [12]. They analyzed how visual information enhances the understanding of music (Yamasaki) and how music complements movies (Parke et al.). Levin and Lieberman [9] as media artists, attempted to create sounds according to the content depicted in pictures.

In musical research, emotion is a significant area of interest for both performers and listeners. Juslin introduced research methods to analyze emotions in music [8]. Senju, a professional violinist, played solo pieces to convey specific emotions and investigated the possibility of conveying emotions through music [14]. Schubert and Fabian analyzed piano performances using a Chernoff face [13]. Bresin and Friberg's system automatically generated music performances that convey emotions [2].

Our work has evolved from the idea of developing a system to assist performing activities by deaf and hard of hearing when playing music together. For this purpose, we needed to understand how the deaf and hard of hearing listened to music, especially how they recognize emotion in improvised drumming, since we intended to use ensemble percussion music with our system. In the past, we have focused on determining whether there is a difference between the deaf and hard of hearing and people without hearing disabilities in recognizing emotion in several types of media (e.g., [4][5]). The results consistently showed that there were no significant differences at the 5% level between deaf and hard of hearing and people with hearing abilities in recognizing emotion, when the emotion was conveyed either through music performances or drawings. We observed that fear, when conveyed through either of the media, was the most difficult emotion to recognize.

3 MPM

MPM is a software system that provides a set of effects for modifying the shapes of drawings to create motion pictures. MPM uses a drawing given as a seed that is then dynamically modified on the basis of sound information. Users can select an effect for suitable movement; MPM presets parameter values for the shades of OpenGL Shading Language (GLSL) and those supported by Apple Core Image. The most important parameters for modifying image shapes are the strength, depth, and speed which correspond to and affect how much, how smoothly, and how fast a shape varies. The effects provided by MPM are listed in Table 1. MPM users can intuitively try out and choose the effect that they intend to convey.

Sound information can either be obtained audio files or a microphone input. It is then analyzed to obtain the amplitude, brightness, and attack. All of these are dynamically used to control the parameter values of an effect.

Effect Names	Traits
Soft	Gentle movement; shallow depth
Wave	Wave-like movement; fine movement with more depth and less strength
Notch	More strength; sharper notch with greater speed and depth values
Collapsing	More strength and large speed values;
Jell-o	Tremulous movement; less strength, more speed, and greater depth values
Bump	Bold shivering movement; use bump distortion
Torus	Sight through lens; use torus distortion
Blur	Smoothing movement; creating afterimages, and some other blurring
Disappearance	Presents or deletes objects with amplitude
Vortex	Modifying shape by calculating coordinates of vertices

Table 1: Effects in MPM

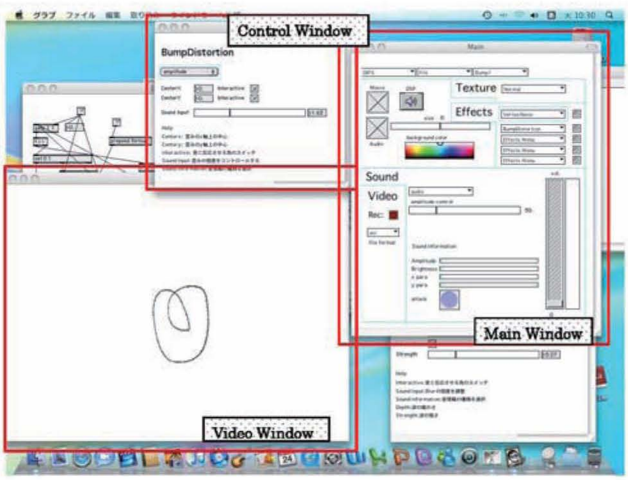


Figure 1: Screen shot of MPM

Figure 1 is a screen shot of MPM. In the main window to the right of the figure, users specify an audio file and a drawing file and then try a preset effect. The default values for each preset effect appear in the corresponding control window (in the center at the top of the figure). By pushing the start button in the main window, a motion picture is generated from the files and appears in the video window (bottom left in the figure). Users can replace either the audio or drawing files and change the parameter values at any time. The motion picture thus generated can be saved as a video file.

MPM, which runs on Mac OS X, is as an application of MaxMSP (Cycling '74) [1], which uses digital image processing with sound (DIPS) [10]. MaxMSP is a programming environment that prepares a rich set of functions called objects, which are provided as icons for digital signal processing. Typically, MaxMSP is used in interactive media art. DIPS provides a set of Max objects that handle OpenGL functions, GLSL, and Apple Core Images, along with real-time visual-image-processing events. Other sets of objects have also been developed for MPM for effects and to generate video files.

4 Experiments

We found in our previous experiment that emotion in music was recognized better when music was combined with a drawing that conveyed the same emotional intent. When music was presented with a motion picture without emotional intention, the recognition rate was lower than that for music conveyed with a drawing containing the same emotional intention [4]. However, as people who were deaf and hard of hearing demonstrated a greater preference and interest in music with motion pictures, we performed an experiment to provide music with motion pictures containing the same emotional intention as the music. We used the same four emotions as those used in our past experiments: joy, fear, anger, and sadness, because these are basic emotions and are often used in research on music cognition.

On the basis of our past experiment, we made three assumptions in this experiment.

1. There is no significant intergroup difference with respect to the subjects (two types, with and without hearing impairment) in recognizing emotions in music with motion pictures generated from a drawing, which conveys the same emotional intention as the music.

2. There are significant intergroup differences with respect to the stimuli (two types, only music and music with motion pictures) for recognizing emotions in terms of providing subjects with the ability to recognize better.

3. There are significant intergroup differences in the recognition of emotions, with fear recognized the least.

Although it is statistically not apparent, we wanted to know whether conflict was likely to occur in this experiment. Conflict occurs in recognizing emotions on using two types of media (music and motion pictures). In addition, we wanted to determine the effect of auditory capacity on recognition.

4.1 Material

We used four drum improvisations and eight motion pictures in the experiment. Each stimulus was used to convey one of the four emotions (joy, fear, anger, and sadness). We reduced the variety of control variables when generating materials in this experiment. Thus, the drum improvisations were only played with a snare drum with specific type of drum sticks and the drawings used as the basis for generating moving pictures were closed shapes with the same bold lines.

Closed shapes are often used in psycho-cognitive experiments [15]. We simplified the shape metric, because we planned to quantitatively analyze the shapes of the drawings.

4.1.1 Drum performance

We used a set of drum improvisations played by a professional percussionist. This set consisted of four improvisations, each of which represented one of the four emotions. They lasted from 30 to 70 seconds.

The performance set is one of the four sets in our past experiment [5]. All of the other sets were played with several types of percussion instruments: a bass drum, a snare drum, a set of five different-sized concert toms, Chinese gong, suspended cymbal with drum sticks, mallets, brushes, and other items, such as a small ball. The recognition rate for the four performance sets was determined by one-way analysis of variance (ANOVA) and was found to be significant ($p = 0.05$). The performance set we used in this experiment had the lowest recognition rate of the four sets.

4.1.2 Motion pictures

Motion pictures were generated from drawings using MPM. First, we asked ten undergraduate students (aged 20-21; females with impaired hearing) who were studying design to make a closed shape that represented one of the four emotions with a white, 24-cm long piece of braid. These shapes were then glued to black Kent sheets. Then, they were scanned and converted into drawing files, which were black-lined shapes on a white background.

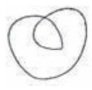
Emotions	Joy		Fear		Anger		Sadness	
Name	J1	J2	F1	F2	A1	A2	S1	S2
Drawings								
Effects	Jell-o	Bump	Wave	Jell-o	Collapse	Bump	Wave	Jell-o
Sample Snapshots								

Table 2: Seed drawings and effects used to generate motion pictures. Names were given to all of the motion pictures.

Two hard of hearing students used MPM to create what they thought was a suitable combination of MPM effects and drawings to represent an emotion. We asked them to use the same emotions in the drum performance and in drawings. They reported the combinations of the drawings, effects, and control values.

We also asked 18 people (15 deaf and hard of hearing, 3 without hearing impairment; aged 20-48; 5 males and 13 females) to try to recognize the emotion in each drawing. After considering the two hard of hearing students' reports and the results of the emotion recognition for the drawings, we generated eight motion pictures by combining the musical performances that were used in this experiment with a seed drawing and an effect. Table 2 shows the eight drawings used as the seeds of the moving pictures (two for each emotion), the types of effects used to generate the motion pictures, and a frame from each of the motion pictures.

We can see three of the motion pictures, J1, F2, and S2, used the Jell-o effect. The motion picture for joy that used the Jell-o effect (J1) had a higher strength value than the other two motion pictures. As a result, the drawing appeared in different positions with greater variations than the effects with smaller strength values (F2 and S2). Even though the snapshots for the motion pictures with the Wave effect (F1 and S1) and Jell-o effect (J1, F2, and S2) in Table 2 resemble the seed drawing, the actual motion pictures yielded different impressions.

A motion picture was presented to the subjects with a musical performance with the same emotional intention that was used to generate the motion picture.

4.2 Subjects

Sixteen deaf and hard of hearing students (aged 20-21: 5 males, 11 females) and 12 hearing individuals (aged 22-48: 3 males, 9 females) participated in the experiment. All of the deaf and hard of hearing subjects were students at Tsukuba University of Technology, where all of the students have hearing impairments.

The auditory capacity of the subjects who were deaf and hard of hearing varied from 65 dB to beyond the scale (over 110 dB). Table 3 lists the number of subjects in each of four ranges of auditory capacity. All of the deaf and hard of hearing subjects, except one, used their hearing aids for the experiment. The auditory capacity of the student who did not use a hearing aid was over 110 dB.

Of the 15 subjects that used their hearing aids, nine did not know their auditory capacity with a hearing aid. Of the other six, one had a capacity of 20 dB (this capacity was classified as hearing ability); one, 30 dB; two, 40 dB; one, 60 dB; and one, 90 dB.

All of their hearing impairments were present before they entered elementary school: five

auditory capacity (dB)	number of subjects
60-69	1
70-79	3
90-99	2
100 ≤	10

Table 3: Auditory capacities of deaf and hard of hearing subjects.

subjects developed hearing impairment at the age of 0-11 months; six, one year old; two, two years old; two, three years old; and one, five years old.

The deaf and hard of hearing subjects learned to play the recorder (*Blockflöte*) and a drum set in their early education at either a special or an integrated school. Some learned playing the guitar and the piano at school. One played the piano from elementary to high school. Two had experience conducting a chorus. At college, one belonged to a Japanese taiko drum club (the one whose auditory capacity was beyond the measurable range) and three played instruments in a band at a college festival.

The experiment took place three times for both the deaf and hard of hearing subjects and the subjects that could hear. Each subject joined an experimental session whenever they wanted.

4.3 Methods

The experiment took place in separate classrooms for each group of subjects. The drumming was conveyed through a speaker set, and the motion pictures were projected onto a screen. The subjects listened to four drum improvisations and viewed eight motion pictures.

We explained the purpose of the experiments, adjusted the volume of the speaker set, and started presenting the stimuli. After each stimulus was presented, the subjects indicated the emotion that they felt from it. The deaf and hard of hearing subjects subjectively evaluated the degree to which they felt they had listened to music by providing a score between 0 and 100 for each stimulus. The subjects were asked to list the order of the cues (music, still images, and movement) used in determining an emotion when presented with motion pictures. First, four performances were presented to the subjects consecutively, which they scored on a questionnaire. They then took about 10-minute break and were presented with music accompanied by eight motion pictures, which they scored on another questionnaire. The motion pictures were presented in the order of S1, A1, F1, J1, S2, F2, A2, and J2, along with the performances that were used to generate them (the same as the four performances used in this experiment).

We asked the subjects with hearing abilities to put on a headset, through which they listened to white noise on a Mini Disk to mimic listening to music under pseudo hard of hearing conditions. The hearing subjects were further exposed to the same four performances and eight motion pictures, which were presented in a different order than that in the first half of the experiment. In this session, the subjects put down the subjective evaluations of their listening experiences, answering the same questions as the deaf and hard of hearing subjects. Even though white noise is often used to allow subjects to experience pseudo hard of hearing conditions, we asked them to adjust the sound level of the noise so that they did not feel uncomfortable.

5 Results

A statistical analysis was performed using the Matlab Statistics toolbox. The differences were considered significant at $p < 0.05$.

First, we compared the recognition rates for the music stimuli in this experiment and the experiment we did last year. The mean recognition rates for the four emotions were compared by using both the ANOVA and the paired t statistic. These revealed that a null hypothesis was not necessarily rejected. The results suggested that the recognition of the music stimuli by the subject groups this year did not differ considerably from last years' results.

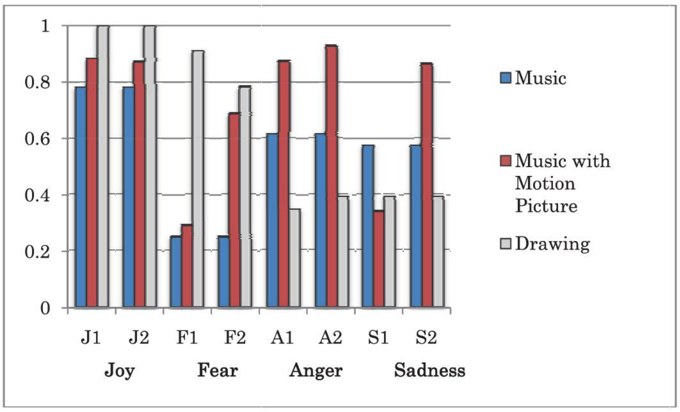


Figure 2: Recognition rates for different media. The recognition rates for the drawings are presented here for reference (the subjects were not the same as this experiment).

	p-value	Music mean	Music with motion picture mean
DHH	0.177	0.547	0.680
HA	0.008	0.500	0.771
All Subjects	0.006	0.527	0.719

DHH: deaf and hard of hearing subjects
HA: subjects with hearing abilities under noiseless circumstances

Table 4: Recognition by stimulus type.

5.1 Subject groups

There were no significant differences between the groups.

A one-way ANOVA was used for comparison between the group of deaf and hard of hearing subjects, subjects with hearing abilities without noise, and subjects with hearing abilities with noise. The p-value from the analysis was 0.450, indicating that there were no significant differences between the three groups. The mean recognition rates for the three groups corresponded to 0.654, 0.701, and 0.764.

We then investigated what effect the white noise had on the subjects with hearing abilities. Using the mean recognition rate for the four emotions, the t statistic revealed that there were no differences between the two listening environments (with and without white noise for subjects with hearing abilities). Moreover, we did not expect that the mean recognition rate would be higher with white noise. The mean recognition rate without white noise was 0.500 and that with white noise was 0.688 for the stimulus music only, while with motion pictures they were 0.771 and 0.802.

The results indicated that the best recognition rate was achieved when white noise was applied to subjects with hearing abilities. This implies that acclimation by listening to a music set overcomes the noise. Thus, we used the data without white noise for subjects with hearing abilities in the analysis that followed.

5.2 Music only and music with motion picture

There were significant differences between the types of stimuli.

We compared two types of stimuli by using a hypothesis test. There were no significant differences between the two types of stimuli for the deaf and hard of hearing subjects, while there were for the hearing subjects. Table 4 lists the P-values and means.

5.3 Recognition according to emotion

The recognition differences between emotions decreased with the use of motion pictures.

The emotions were compared using a one-way ANOVA. The resulting p-values for recognizing the emotions in the music and motion pictures corresponded to 0.001 and 0.043. This means that the motion pictures affected the subjects' abilities to recognize emotion.

The results of a multiple comparison test revealed that there were recognition differences when listening to the music alone between fear and the other three emotions, and between sadness and joy. When motion pictures were synchronously presented with the music, there were no differences between the emotions. Table 5 lists the p-value results of the one-way ANOVA.

5.4 Motion pictures

The recognition was affected by the type of motion pictures.

We presented two groups of motion pictures in the experiment with the same set of drum improvisations. We calculated the recognition means for all of the the music with motion picture stimuli (Table 6). Motion picture 1 for joy corresponds to J1 in Table 2.

Figure 2 shows a bar chart of the recognition rate by music only, music accompanied by motion pictures, and drawings only. The drawings were used as the seeds for generating the motion pictures[1].

Comparing the recognition by music only and music accompanied by motion pictures, only S1 decreased the rate, while all of the other motion pictures increased the recognition rate. The recognition rates with the motion pictures for joy and anger did not differ greatly between the two generated motion pictures; however, those for fear and sadness differed considerably.

5.5 Results from questionnaire

5.5.1 Conflict and mutual reinforcement between media

From the subjects' spontaneous descriptions, we found both conflict and mutual reinforcement in recognizing an emotion between media (music and motion pictures). The descriptions were all written by subjects with hearing abilities. Five subjects mentioned conflict and six used both types of information. Since these subjects are not exclusive, some felt both ways based on the stimuli.

5.5.2 Effect of noise on hearing abilities

Five subjects with hearing abilities reported that the experience of listening to the drumming twice surpassed the white noise. Other descriptions of white noise were: "The visual information compensated for uncertain parts in the music because of the white noise," "I attempted to listen to the sound more under the white noise," and "The white noise freed me from having to listen to the music in detail."

5.5.3 Auditory capacity and music experience

Of the 16 subjects of deaf and hard of hearing subjects, the four with the lowest and the highest recognition rates were both fluent and had fewer difficulties with verbal communication with hearing people. The recognition rate for the subject whose auditory capacity was beyond the scale was higher than the average recognition rate for the deaf and hard of hearing.

Five of the deaf and hard of hearing subjects played music with either a band or drum club, at a dance club or a college festival in November 2008. Four of these had a better than average recognition rate.

Two of the deaf and hard of hearing subjects recognized all of the emotions. Their auditory capacities were 100 dB and 110 dB. They were not actively involved in music related circles, even though both had graduated from academic high schools (not schools for special education).

Four of twelve subjects with hearing abilities stated that they participated in no special musical activities such as personally practicing musical instruments or belonging to music-related clubs.

[1]The recognition rate for the drawings have been presented here for reference. The subjects were not the same as those in this experiment. They were eighteen deaf and hard of hearing subjects and five subjects without hearing impairments.

		Joy	Fear	Anger	Sadness
	p-value	mean	mean	mean	mean
Music only	0.001	0.781	0.250	0.615	0.573
Music with motion picture	0.043	0.880	0.490	0.901	0.603

Table 5: Recognition of emotion. Data obtained from deaf and hard of hearing subjects and subjects with hearing abilities under noiseless circumstance.

	Subject group	motion pictures 1	2
Joy	DHH	0.769	0.750
	HA	1	1
Fear	DHH	0.250	0.625
	HA	0.333	0.750
Anger	DHH	1	0.9383
	HA	0.75	0.917
Sad	DHH	0.308	0.813
	HA	0.375	0.917

DHH: deaf and hard of hearing subjects.
HA: subjects with hearing abilities under noiseless circumstances.

Table 6: Comparison of recognition rates for two motion pictures for four emotions.

6 Discussion

The three assumptions we made prior to the experiment were all valid as described in Sections 5.1, 5.2, and 5.3. However, a closer analysis revealed some unexpected results and these raised new issues.

6.1 Learning experiment

Even though no significant differences were found by ANOVA between the subjects who were deaf and hard of hearing, those with hearing abilities, and those with hearing abilities under white noise, this analysis revealed the effect that learning and repetitive experience had on listening to music. How deaf and hard of hearing people, especially, gain learning experience with music and recognize it will be issues even if we provide visual information that is synchronized to the music.

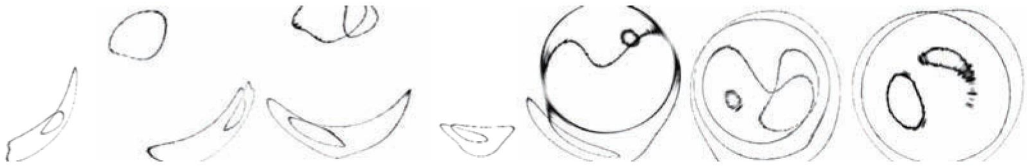
6.2 Effect of visual information on deaf and hard of hearing

Even though we could observe improvements in the subjects abilities to recognize emotion when the music and synchronized motion pictures were presented together, these results were mainly for subjects with hearing abilities. Table 4 lists results that were contrary to our expectations, i.e., (1) the recognition rate for music was higher by the deaf and hard of hearing. (2) the motion pictures affected the deaf and hard of hearing less in relation to recognizing emotions.

The fact that only the subjects with hearing abilities described the stimuli with combined media might explain the limited effect that the motion pictures had on the deaf and hard of hearing subjects. That is, once the visual information was provided, the deaf and hard of hearing might have obtained information mostly from the visual images even though the auditory information was presented simultaneously. We should conduct another experiment using a third type of stimulus with motion pictures only.

6.3 Emotion

The lowest recognition for fear was consistent with our previous experiments, i.e., whether the stimulus was music accompanied by a drawing or only a drawing. Although recognition differences



Frame samples of J2 (Bumping effect)

Frame samples of F1 (Wave effect)

Frame samples of A1 (Collapse effect)

Frame samples of S2 (Jell-o effect)

Figure 3: Frame samples. Every three consecutive frames are shown.

still remained even with motion pictures, we can expect motion pictures to reduce the differences in the recognition rates.

6.4 Motion pictures

By looking at Table 2, Figure 2, and Table 6, we can see large differences in the recognition rates between the two motion pictures for fear and sadness. The Wave and Jell-o effects were accidentally used for these two emotions. As we can see in Figure 3, the movements with the Wave and Jell-o effects are very small. Each row of Figure 3 shows every three contiguous frames. Since the video conforms to the National Television System Committee (NTSC) standards, one second consists of 30 frames. Thus Figure 3 shows about two-thirds of a second for each video.

We only used two motion pictures for each emotion in this experiment, although there were many possible motion pictures that could have been used to present emotions. Thus, we should try other effects with MPM to generate other motion pictures.

6.5 McGurk effect

The conflict between the emotions felt by the subjects in the sound and motion pictures is similar to McGurk effect. This is consistent with that of the previous experiment: subjects with hearing ability felt a conflict when the music and drawings were presented synchronously. This implies the possibility of basic differences in representing objects, especially if they are abstract, with different types of media.

6.6 Auditory capacity and music recognition

Currently, we cannot draw any conclusions about the relationship between music recognition and auditory capacity. However, hearing loss does not necessarily affect music recognition. Moreover, if auditory capacity affected recognition, the subjects which could hear should have recognized the music better than those with deafness and hearing impairment; however, this did not happen.

In addition, people with deafness just sensed sound; therefore, it was difficult for them to participate in this experiment using only the speaker set. We could not draw any conclusions even in this case regarding whether they could recognize music from acoustic instruments.

6.7 Future work

Even though there are numerous issues in proceeding with work based on the discussion above, we intend to make more extensive use of drawings and motion pictures in the future.

The drawings that were used as the seeds of motion pictures were created with various restrictions in this experiment, i.e., length of the lines, their width, color, and closed shapes. The motion pictures can be made more interesting by expanding the types of seeds that are used to make them, bearing in mind that such motion pictures are being used to facilitate the understanding of music. We intend to generate many more motion pictures by combining music, drawings, and effects. Then, we intend to investigate the movements in these motion pictures that are most effective for conveying emotion to enhance musical communication. We plan to analyze both drawings and the effect of objectively related shapes and movements with emotions.

We feel the necessity to use acoustic instruments for those who are profoundly deaf and have little experience with music to enable better musical communication with the deaf and hard of hearing, even in experiments.

7 Conclusion

We created a software system called MPM to generate motion pictures from drawings by dynamically using sound information. With MPM, we made motion pictures from drawings that were intended to depict emotions. Then, we conducted an experiment to investigate whether the emotions expressed in musical performances were recognized better by synchronously providing motion pictures with the same emotion as that conveyed by the music. The results demonstrated improved recognition with motion pictures, while they revealed that subjects with hearing abilities benefited more from motion pictures than the deaf and hard of hearing. Using these results and trying to solve new issues, we intend to pursue musical communication for those who are deaf and hard of hearing to enable them to interact with people without hearing impairments.

8 Acknowledgments

This research was supported by Kayamori Foundation of Information Science Advancement and grant-in-aid by the dean of faculty of Tsukuba University of Technology.

This article is an extension of a paper presented at the second International Conference on Music Communication and Science (ICoMCS2) [7].

References

[1] F. Blum. *Digital Interactive Installations: Programming interactive installations using the software package Max/MSP/Jitter*. VDM Verlag, 2007.

[2] R. Bresin and A. Friberg. Emotional coloring of computer-controlled music performances. *Computer Music Journal*, 24(4):44–63, July 2000.

[3] A.-A. Darrow. The role of music in deaf culture: Deaf students' perception of emotion in music. *Journal of Music Therapy*, XLIII(1):2–15, March 2006.

[4] R. Hiraga and N. Kato. Understanding emotion through multimedia–comparison between hearing-impaired people and people with hearing abilities. In *Proc. of ASSETS*, pages 141–148. ACM, October 2006.

[5] R. Hiraga, N. Kato, and N. Matsuda. Effect of visual representation in recognizing emotion expressed in a musical performance. In *Proc. of ICSMC*, pages 131–136. IEEE, October 2008.

[6] R. Hiraga and M. Kawashima. Performance visualization for hearing-impaired students. *Journal of Systemics, Cybernetics and Informatics*, 3(5):24–32, 2006.

[7] R. Hiraga, K. Takahashi, and N. Kato. Toward music communication with supplemental visual information. In *Proc. of ICoMCS*, pages 34–37, December 2009.

[8] P. N. Juslin. Communicating emotion in music performance: a review and a theoretical framework. In P. N. Juslin and J. A. Sloboda, editors, *Music and Emotion, theory and research*, pages 309–340. Oxford University Press, 2004.

[9] G. Levin and Z. Lieberman. Sounds from shapes: Audiovisual performance with hand silhouette contours in the manual input sessions. In *Proc. of NIME*, pages 115–120, 2005.

[10] C. Miyama, T. Rai, S. Matsuda, and D. Ando. Introduction of dips programming technique. In *Proc. of ICMC*, pages 459–462. ICMA, October 2003.

[11] Y. Ota and Y. Kato. Musical education at elementary school department for the deaf. *Education for the Deaf in Japan*, 43(2), July 2001.

[12] R. Parke, E. Chew, and C. Kyriakakis. Quantitative and visual analysis of the impact of music on perceived emotion of film. *ACM Computers in Entertainment*, 5(3), July 2007.

[13] E. Schubert and D. Fabian. An experimental investigation of emotional character portrayed by piano versus harpsichord performances of a j.s. bach excerpt. In E. Mackinlay, editor, *Aesthetics and Experience in Music Performance*, pages 77–94. Cambridge Scholars Press, 2005.

[14] M. Senju and K. Ogushi. How are the player's ideas conveyed to the audience? *Music Perception*, 4(4):311–323, 1987.

[15] Y. Wada, K. N. D. Tsuzuki, H. Yamada, and T. Oyama. Perceptual attributes determining affective meanings of abstract form drawings. In *Proc. 17th congress of International Association of Empirical Aesthetic*, pages 131–134. IAEA, August 2002.

[16] T. Yamasaki. Emotional communication mediated by two different expression forms: Drawings and music performances. In *Proc. of ICMPC*, pages 153–154. ICMPC, August 2006.