

Novel Electronic Musical Instrument with Pre-Programmed Score for the Disabled to Enjoy Playing Music

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Abstract We have developed a novel electronic musical instrument with a pre-programmed score, called “Cymis,” to help the disabled enjoy playing musical pieces. In 2008, field experiments commenced at a nursing home (capacity 52 clients; average age 58.6; cerebral palsy 32 clients). The purpose of the present study was to demonstrate that Cymis is useful and effective for helping the severely disabled maintain or improve their quality of life. First, the accessibility of Cymis was revealed by the fact that 34 clients (63%) played Cymis for an average of 5.6 years. Second, each client’s progress in performance, which possibly reflects improvements of upper-limb motor control function, was examined for the longest duration of over 7 years. Among 31 clients, 13 (42%) showed progress, 17 (55%) showed no change (5 of whom showed progress initially but then regressed to their original status), and 1 (3%) revealed deterioration in condition. Third, psychological effects were measured using an original Face Scale before and after playing Cymis, for a total of 395 performances by 38 clients. Clients became happier in 208 performances (53%), showed no changes in 139 (35%), and became sadder in 48 (12%). Finally, with respect to their care plans, 19 of 52 clients (37%) selected Cymis in 2015, and this number itself implies the importance of Cymis. Basic reasons for selection were investigated by care workers’ assessments from mental and psychological perspectives. In conclusion, Cymis was useful, effective, and attractive to the disabled; it permitted them to enjoy playing music that might not otherwise be possible, and some evidence of therapeutic effect was found.

Keywords: cerebral palsy, musical instrument, user interface, piece of music, disability.

Adv Biomed Eng. 6: pp. 1–7, 2017.

1. Introduction

Persons with movement disorders caused by brain damage, such as cerebral palsy (CP) and brain disease, have difficulties participating in daily life activities. (For simplicity’s sake, we use “client” instead of “ill or disabled person” in this paper.) Rehabilitation approaches such as physiotherapy and occupational therapy are usually employed to improve movement disorders. Music therapy, a rehabilitation program in which clients can enjoy playing music, is highly valuable and attractive because of the high motivational value of making music. Recently, Schneider et al. [1] showed that use of electronic drums was effective in improving stroke patients’ movement patterns and quality of motion. This therapeutic approach, or music-supported therapy (MST) [2], was used more recently in a preliminary study in adults with CP, in which keyboards and pianos were used [3, 4].

Some clients wish to play musical instruments themselves.

However, it is difficult or impossible for clients with severe disabilities to read a score and play conventional musical instruments such as violin and flute. Thus, musical instruments designed especially for the elderly or the disabled have been developed, for example, “Music Table” [5], “Swing Bar Guitar” [6], and an electronic glove “MusicGlobe” [7]. Although we searched for relevant scientific reports from PubMed and related websites, we could not find any musical instrument, with which people with severe neural and motor function impairment can easily play pieces such as “Eine Kleine Nacht Music” and “Amazing Grace.”

With this background, we have developed a novel musical instrument that allows clients with neural or motor impairments to play and enjoy playing together [8, 9]. This instrument is called Cyber Musical Instrument with Score or “Cymis.” It consists of a personal computer (PC) and various user interfaces. Pre-programmed musical scores are stored in a PC so that previous experience in playing a musical instrument is not required. In 2008, a field experiment commenced, and in 2016, 19 facilities including hospitals, special schools, and nursing homes were using Cymis. The use of Cymis for more than 7 years and the considerable number of facilities using it seem to reflect the feasibility and usefulness of Cymis.

In the present study, we aimed to demonstrate that Cymis is highly useful for improving the quality of life of severely disabled persons in nursing homes. We examined the accessibility to Cymis, progress in clients’ performance, psychological effects of playing the instrument on clients, and factors concerning care plans. Preliminary reports have been published [9, 10].

Received on July 12, 2016; revised on November 21, 2016; accepted on November 30, 2016.

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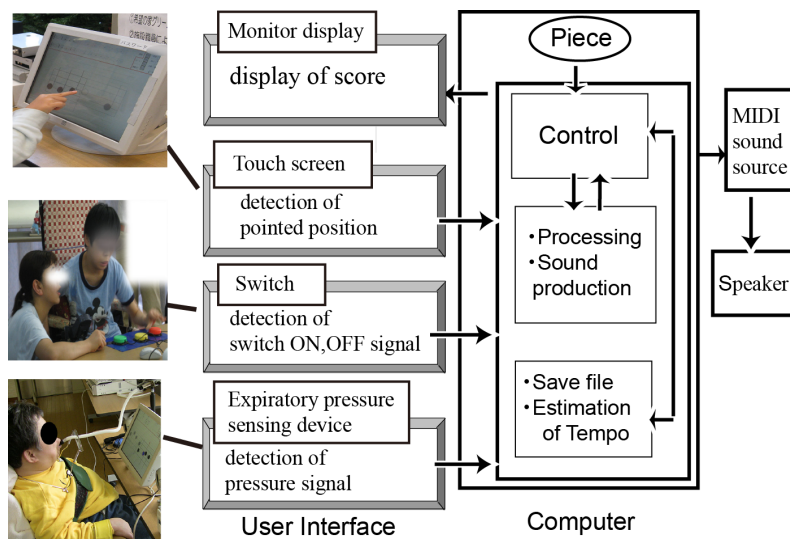


Fig. 1 Outline of Cymis (Cyber Musical Instrument with Score).

2. Methods

2.1 Structure of Cymis

In the present study, we used a PC (Windows XP), a touch screen (Touch Panel Systems, 17-inch touch monitor, Surface Acoustic Wave touch), a Musical Instrument Digital Interface (MIDI) sound source, speakers, and user interfaces (Fig. 1). We developed various user interfaces for the motor impaired. A switch with an air bag could respond to force ranging from approximately 4 mN to 6 N. A switch with a three-axis accelerometer (0.66 V/G) was used to detect small movements of the severely motor impaired. An analog device, made of an expiratory pressure sensor, was used by a client who could not voluntarily move the upper and lower limbs [8]. Two original computer programs were created; one for making a pre-programmed score, and the other for executing performance. Signal flow of the performance is shown in Fig. 1. The music score is displayed on a monitor (Fig. 2). A signal from the user interface is sent to the PC, which then executes subsequent processing to create the MIDI control signal. Finally, the signal is sent to the MIDI sound source to produce sound.

A maximum of 16 musical parts can be performed simultaneously; one part is played directly by the client and the other parts are performed automatically at the client's tempo estimated by the PC. The estimation is done by a conventional smoothing filter.

2.2 Performance styles

In general, a unit of performance is one note; that is, performance is executed note by note, referred to as note mode. Additionally, we created two specially designed modes: beat mode and measure mode. In beat mode, the unit of performance is a beat, and all the notes within a beat are performed automatically at an estimated tempo. The beat mode is effective for mild or moderate impairment. In measure mode, the unit of performance is a measure. All the notes within a measure are automatically performed at a pre-set tempo. This mode is designed for the severely disabled.

The three user interfaces are switch, touch screen, and expi-

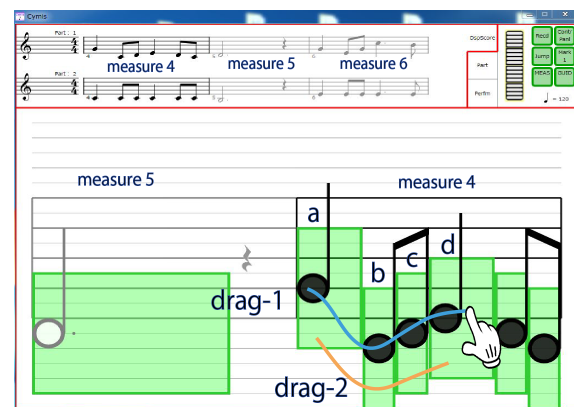


Fig. 2 Monitor display while playing a piece of music.

ratory device. Combining note, beat, and measure modes with user interfaces, there are six performance styles, mode 1 to mode 5 and mode ex, as shown in Table 1.

There are two types of note mode; mode 1 (touch screen, note head) and mode 2 (touch screen, box). A touch screen is used in both cases. An example of a display is shown in Fig. 2, in which measure 4 is performed. To perform in mode 1, each note head is touched in turn. In mode 2, a larger square (box) is used instead of a note head (green squares in Fig. 2). Touching any point within the square corresponds to touching the note head. Performance is much easier with mode 2 than with mode 1. A fast passage with many semiquavers is too difficult for a client to play correctly by pointing at a note head or a square. Dragging as shown by drag 1 in Fig. 2 is permitted in mode 1. This is identical to pointing at the note heads a, b, c, and d sequentially. Dragging as shown by drag 2 in Fig. 2 is permitted in mode 2.

There are two types of beat mode; mode 3 and mode 4. In mode 3, a touch screen is used. A client points at a red square on the touch screen, corresponding to a beat. The red square moves from left to right with pointing. In mode 4, a switching device is used. The order of touching the switch is fixed in multiple switch-

Table 1 Performance style and Cymis rating scale.

| performance style | user interface | unit of performance | Cymis Rating Scale for upper limb | impairment of voluntary upper limb movements | ICF b760 |
|--|------------------------------------|---|-----------------------------------|--|----------|
| | | | 0 | none | 0 |
| mode-1 | touchscreen (note head) | note | 1 | very very slight | 1 |
| mode-2 | touchscreen (box) | | 2 | very slight | |
| mode-3 | touchscreen (box) | beat | 3 | slight | 2 |
| mode-4 | multiple switch | | 4 | moderate | |
| | | single switch | | | |
| mode-5 | single switch | measure | 5 | severe | 3 |
| mode-ex | expiratory pressure sensing device | note | | complete | 4 |
| ICF (International Classification of Functioning, Disability and Health) | | | | | |
| | b760 | control of voluntary movement functions | | | |

es. Because of this rule, performance with multiple switches is much harder than with a single switch.

Mode 5 is the measure mode, in which a single switch is used. A preset number of measures are performed automatically, regardless of the client's involuntary touching of the switch during performance. This particular mode is useful for the severely disabled.

Mode ex is a note mode, in which an expiratory pressure sensing device is used. An analog pressure signal is used as an input to Cymis. Pointing at the note is not required. This mode is highly useful for clients with complete impairment of voluntary limb movements.

2.3 Performance procedure

Performance procedure is usually as follows. (1) A performance style is selected, and then a computer program for the performance is executed in the PC. (2) A piece of music to be performed is selected. There are more than 100 pieces, including children's songs, Japanese folk songs, Japanese ballads, popular songs, and classical music. (3) A score of the selected piece is displayed on a monitor (**Fig. 2**). (4) The client operates a user interface to produce sound from a speaker.

Additionally, the client can choose an instrument for each part from among 128 preset MIDI instruments, adjust MIDI parameters, and record the performance as a standard MIDI file.

2.4 Participants

Participants were clients in a nursing home (Social Welfare Organization Kibounoie Takarazuka Green Home). For convenience, this home is referred to as "the facility" in the present paper. Field experiments were commenced in 2009 in this facility. In 2015, the facility housed 54 clients, with an average age of 58.6 ± 11.5 years, an average disability level of 5.89 (disability level 6 is highest, 0 lowest: 48 clients were at level 6, 6 clients at level 5); 32 clients had cerebral palsy. Participants were clients who played Cymis from 2009 to 2015.

This study was conducted in accordance with the ethical principles of the Helsinki Declaration and after obtaining informed consent from each subject. The study was approved by the Ethics Committee of Osaka Institute of Technology, and Committee concerning the Control of Personal Information of Social Welfare Organization Kibounoie. All data were handled in accordance with the law for the protection of computer-processed personal data held by administrative organs.

2.5 Investigation of the accessibility of Cymis

As for accessibility, we investigated the number of clients who were able to use Cymis and maintain the performance during a certain period. After a client finished making music, care workers recorded in a notebook the title of the piece, performance style, and physical conditions. The record, referred to as Cymis Note, was saved from 2009 onwards. The contents of this record was used in assessments described in sections 3.2 and 3.3.

2.6 Investigation of Cymis performance progress

Progress of performance was mentally important for the clients because they became happy and were motivated to continue playing. It was also important from a physiotherapeutic perspective because progress strongly reflected improvements of clients' upper-limb motor control function. Progress was easily assessed by examining the performance style in the Cymis Note. For example, a client's progress was shown by changing performance from mode 3 to the more difficult mode 1, or a client was capable of generating much richer musical expression with mode 1 than with mode 3. Therefore, when investigating performance progress, we proposed a "Cymis Rating Scale for upper limbs" (CRS), the score of which is almost the same as the mode number of performance style (**Table 1**). As supplementary information, subjective assessment of impairment and score of b760 in ICF are given in **Table 1**. Rough relations between performance style, CRS, and ICF are displayed in **Table 1**. For example, clients with severe impairment (b760 score 3) or those with CRS 5 were able to play

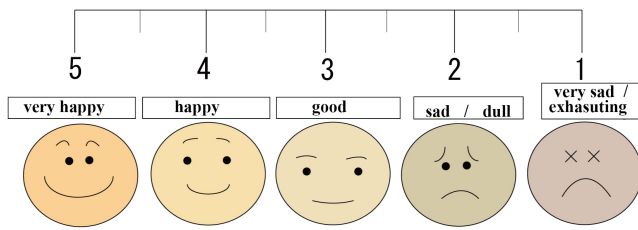


Fig. 3 Face Scale for Cymis.

in mode 5.

2.7 Psychological assessment of performance

To examine whether clients enjoyed Cymis performance, subjective psychological assessments were conducted using our original five-level Face Scale. The Face Scale is shown in Fig. 3. The face is simplified and colored to express “very happy” to “very sad.” A care worker showed a client this figure both before and after performance and then asked, “What is your feeling now?” The client answered vocally or by indicating a face. Between 2011 and 2013, 38 clients were assessed once a month for 13 months.

2.8 Investigation of care plans

In 2015, 19 clients selected Cymis for their care plans. This fact itself implies that Cymis was useful and important for those clients. The purpose of this investigation was to reveal basic reasons of selecting Cymis from mental and psychological points of view. Fifteen clients suitable for the investigation were examined. The procedure was as follows.

First, some dominant factors influenced clients to add Cymis to their care plans. These factors were referred to as “care plan factors.” Six care plan factors (CP1, CP2,... CP6) were selected, based on interviews and discussions between care workers and clients. CP1: Favoring Music. I like music. I want to perform music. CP2: A sense of accomplishment (enjoying a feeling of accomplishment). Although I was unable to play music before, I became able to play music. It was great fun playing Cymis by myself. CP3: Recognition by others. I was recognized or respected by others. It was fun playing Cymis in front of everyone. CP4: Communication. I could communicate with care workers and others in the performance. CP5: Motor control. It was good for training or improvement of motor function of upper limbs. CP6: Fulfilling activities of daily life.

Second, carrying on a dialog with a client, a care worker determined his/her CPi value (a value of care plan factor CPi), ($i = 1, 2... 6$). Larger CPi value means that the factor has greater significance. For each client, CPi value for each factor was calculated as a ratio to the sum of six CPi values taken as 1.

Third, analysis was conducted to identify the most important factor by averaging all clients. As a fixed care plan factor, we calculated the sum of CPi values over 15 clients. The sum is referred to as “SCPi value.” Finally, we obtained six SCPi values for the 6 factors, which were used for assessment. Each SCPi value was calculated as a percentage of the summed SCPi values for 15 clients taken as 15.0.

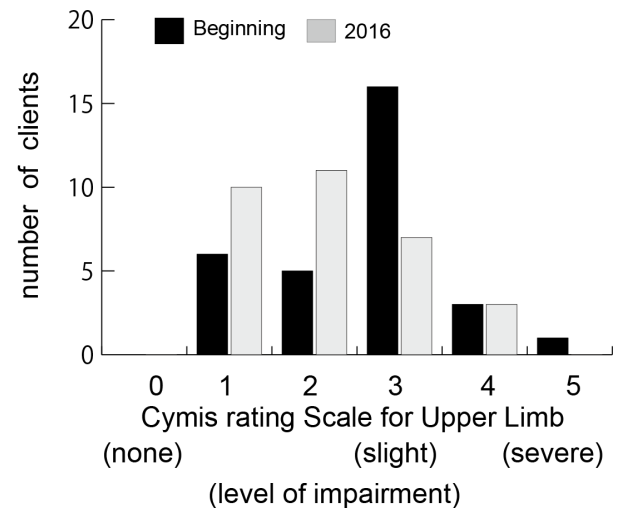


Fig. 4 Distribution of Cymis Rating Scale scores of 31 clients.

3. Results

3.1 Accessibility of Cymis

By examining the Cymis Note, we confirmed the accessibility of the severely disabled to Cymis as follows. Thirty-four clients (63% of 54 clients) played Cymis in 2016. The playing period averaged 5.6 ± 2.2 years. They played Cymis for 15 to 20 minutes almost once a week. The touch screen was used by 20 clients (59%), the switch by 13 (38%), and the expiratory device by 1 (3%).

3.2 Progress of Cymis performance

Each client's performance (CRS) in January 2016 was compared with that at the beginning in the Cymis Note. Of 31 clients, 13 (42%) showed progress in performance (decrease in CRS); 17 (55%) showed no change (5 of whom once showed progress, but regressed to their original condition); and 1 (3%) showed deterioration in condition (increase in CRS).

Distributions of CRS at two different times are shown in Fig. 4. Closed bar represents each client's beginning status, and open bar represents status in January 2016. As a whole, the 2016 distribution seems to move slightly to the left on the CRS axis. This shift might indicate that some clients' impairments improved to some extent.

3.3 Psychological effects of performance

Psychological assessment was conducted for 395 performances. In 208 performances (53%), the Cymis Face Scale score increased, indicating that clients were happier after performance than before. “No change” numbered 139 (35%) performances, and decreases in the Face Scale score numbered 48 (12%). Decrease occurred when clients became either physically tired or could not perform as smoothly as they expected due to pain or fatigue.

Figure 5 is a histogram plotting the number of performances against the score of the Cymis Face Scale. Closed and open bars represent “before” and “after” performance, respectively. As a whole, distribution of scores after performance moved slightly to the left (happy), compared to that before performance.

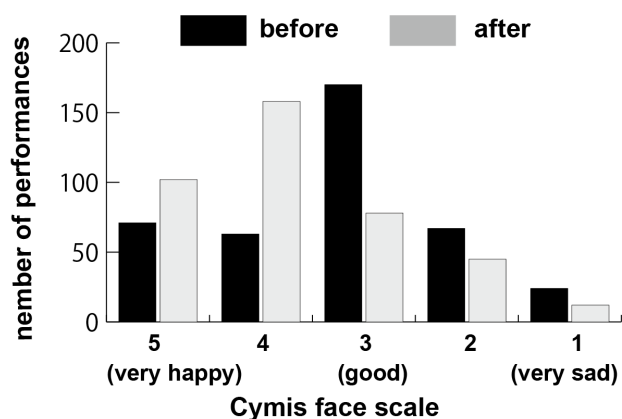


Fig. 5 Psychological assessments using Face Scale before and after Cymis performance.

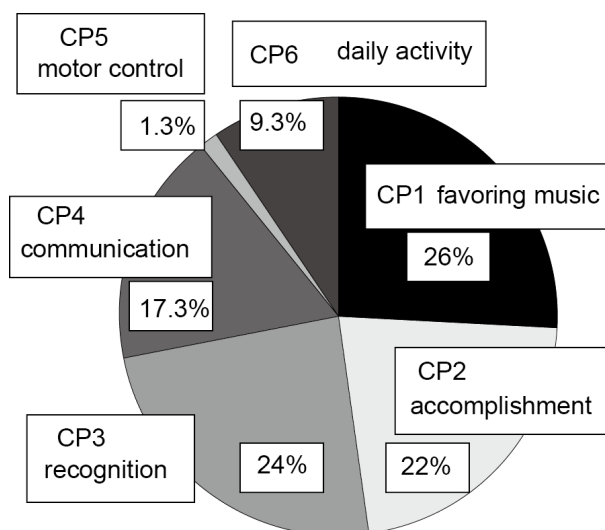


Fig. 6 SCPI values (%) for care plan factors CP1-CP6.

3.4 Care plan factors

Values of care plan factors were obtained from 15 clients assessed by four care workers. Then, SCPI values were calculated. **Figure 6** displays these results. The values of SCPI1 (favoring music), SCPI2 (accomplishment), and SCPI3 (recognition) were almost identical (22–26%) and greater than those of the other three factors (1.3–17.3%). From the care plan perspective, CP1, CP2, and CP3 were rated as significant factor for choosing Cymis by many clients, while CP4 (communication) and CP6 (fulfilling activities of daily life) were considered important by some clients, and CP5 (motor control) by a few clients.

4. Discussion

Clients sometimes responded by showing us their moving words and behaviors. Five memorable clients are selected. Details are given in Appendix.

Furthermore, we want to emphasize that a large number of clients have been using Cymis in many facilities for a sufficiently long time. In 2008, only four clients in the facility of this study began playing Cymis as a preliminary field experiment, but that

number gradually increased. In 2016, 34 (63%) of 54 clients played. Nineteen clients (35%) added Cymis to their care plans. Notably, 19 facilities including nursing homes, hospitals, and special schools were experimentally using Cymis.

Although clients make earnest requests to play music, most cannot play either a conventional musical instrument or an artistic piece by themselves. Cymis is the first musical instrument that enables such clients to play music through pre-programmed scores, various user interfaces, and performance methods. Recently, we found an interesting German band on YouTube (2015), who effectively used an iPad touch screen as a user interface for the severely disabled. This implies that tablets would be very effective for helping people play music despite their motor impairment.

MST has been shown to induce motor skill improvements in stroke survivors [1, 4]. Consequently, research interest has been increasing in utilizing music playing for upper-limb rehabilitation for stroke [2] and early childhood CP [4]. However, there are few reports of MST in older adults with CP. In the present study, some older CP clients showed improvements in CRS (Cymis Rating Scale for upper limbs), probably implying improvement in upper limb motor control function, as well as progress in Cymis performance.

One client, aged 58 in 2008 experienced remarkable change. At the beginning of using Cymis, she could only move her left middle finger by 1–2 mm every tens of seconds. A year later, she was able to move it more than 10 mm. Since 2010, she has been able to play music more smoothly with frequent finger movements for more than 15 mm. This might show the therapeutic effect of Cymis. Auditory feedback may facilitate learning and performance, and the musical context may make the therapy engaging and rewarding.

We often found clients smiling sweetly after performances. The clients' feelings were clarified quantitatively by conducting psychological assessment using the Cymis Face Scale on 395 performances, demonstrating that most clients became happier with Cymis performance. While the Face Scale used in the present study is much simpler than the delicate face scale used for pain assessment [11], it appears to be useful for simple psychological assessment.

For each client, care plans were remarkably important because they provided direction for individualized care and reflected the client's specific needs. In 2015, approximately one-third of the clients (19 of 54 clients) added Cymis to their care plans. Obviously, this number shows the importance of Cymis among many activities of daily living, but further study is necessary to demonstrate their improvements. Care workers' assessments revealed that many clients loved music, and that they sensed accomplishment with their own performance and recognition or respect by other people.

5. Conclusion

In conclusion, a large number of nursing-home clients with severe disabilities were able to play Cymis easily and continued the enjoyable activity of music performance, which might not otherwise be possible. Further study is necessary to demonstrate improvements in the activities of daily living of nursing home clients.

Acknowledgement

The present study was partly supported by the Japan Society for the Promotion of Science KAKENHI Grant No. 26381347, Mitsubishi Foundation (2011, 2013), and Daido Life Welfare Foundation (2014). We thank graduate students of Akazawa Lab at Osaka University, in particular, Fujii H, Hoshino Y, Kato D, Matono H, and Kamitani Y, for work on software and hardware. We also thank Kajiyama S, Kitamura T, and Kajimoto Y, for developing user interfaces, and Takehara T, Aoki T, and Yoshizato T, for creating the scores. We also thank Horai M, the participants, and the music group of Kibounoie for their support.

Conflicts of interest

We have no conflicts of interest relationship with any companies or commercial organizations based on the definition of Japanese Society of Medical and Biological Engineering.

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