The aim of this study was to develop an electronic musical instrument that can be played by severely disabled people with quadriplegia to improve their QOL. Conventional wind, stringed, and percussion instruments are unsuitable for quadriplegics, since such instruments require delicate movement of the upper limbs. Therefore, we have developed an electronic musical instrument that can be played by tongue movement. This instrument consists of an input device in the mouth and a tone generation component mounted on a PC. A signal is generated at the input device in the mouth, and then sent to the tone generation component. Next, it is converted to a MIDI command, which orders a MIDI sound source to generate a tone. The input device is a polyethylene terephthalate (PET) board fixed to the palatum with switches configured in the shape of an array. Tone control can be performed by depressing switches with the tip of the tongue. The PET board is fabricated into a three-dimensional cross so that it is fixed firmly on the palatum. Furthermore, a tone matrix is implemented in the tone generator in order to generate many tones with the group of small switches configured on the input device. Moreover, this study experimentally investigated how much switch depression movement by the tongue was required to follow a given tempo. Three subjects participated: two with experience playing either the violin or piano and one with no experience in playing a musical instrument. In the experiments, all subjects could play music at a tempo of 120 beats per minute. Furthermore, the effectiveness of this electronic musical instrument was proved by subjects actually using it to play a musical piece.

1. Introduction

As an advanced means of mutual communication, music is an active function (singing/ playing instruments) as well as a passive function (listening). Music is a common global language, and performance of music is widely appreciated as a means of rich self-expression. However, playing conventional common wind, stringed, and percussion instruments, such as violin, piano, and trumpet, require delicate limb movement. Such instruments are therefore unsuitable for severely disabled people, such as quadriplegics. Although some development of musical instruments for disabled people is underway, a musical instrument that requires no limb movement has not been developed.

Lately, improvement in electronic technology has spread to electronic musical instruments that can play various tones. This introduces an environment wherein music can be performed relatively easily. Thus a new welfare musical instrument is now expected by designing its playing means according to the degree of various disabilities[1]. However, performance using existing electronic musical instruments parallels movements used with conventional musical instruments, such as key depression and twanging. This makes participation by disabled people in musical activities difficult.

The aim of this study was to develop and evaluate an electronic musical instrument playable by severely disabled people with quadriplegia to improve their QOL.

2. Electronic Musical Instrument that Employs Tongue Movement

To develop an electronic musical instrument playable without use of the limbs, we focused on the tongue as the sole means to play the musical instrument. As the tongue can exercise skillful movements in speaking or swallowing, it can be expected to deal with a complicated operation, such as playing music[2]-[4].


The present electronic musical instrument consists of an input device in the mouth equipped with a touch-play interface operated with the tongue and a tone generation component. A signal is generated at the input device in the mouth, and then sent to the tone generation component mounted on a PC. Next, it is converted to a MIDI command, which orders a MIDI sound source to generate a tone.

Figure 1 is a schematic diagram of this electronic musical instrument.
The input device in the mouth is mainly constituted of a polyethylene terephthalate (PET) board on which push button switches (6 mm x 6 mm; hereinafter referred to as depression switches) are configured into an array. This is fixed onto the palatum so that tone control can be performed by depressing switches with the tongue. Each switch is activated with a force of 1.27 N. The size of the oral cavity allows configuration of five switches in the mouth. The PET board is fabricated into a three-dimensional cross so that it is fixed firmly on the palatum. Thus, the input device is fixed at multiple points onto the palatum. Figure 2 shows an example of how the input device is installed in a model of the palatum. The whole input device is covered with an antibacterial-treated 0.05 mm thick insulated sheet. Figure 3 shows a plan of the input device.
A tone matrix was designed for this electronic musical instrument in order to provide means of tone generation required for music performance with the limited number of switches. A conceptual diagram is shown in Figure 4. Depressing the chord shift switch (FS) shifts chords assigned to scale control switches (MS1-MS4) in turn, so that a musical piece that requires many chords can be performed.

2.2. Evaluation of Tongue Motion Function

This study investigated the degree that tongue motion could be employed to operate this electronic musical instrument. An experiment was performed to find out whether switch depression by the tongue could follow a given tempo. Subjects were a 33-year-old male with 20 years' experience playing the violin (Subject 1), a 22-year-old male with 10 years' experience playing piano (Subject 2), and a 22-year-old male with no musical instrument experience (Subject 3). Subjects depressed switches in an order directed in advance in accordance with signals from a metronome blinking on a screen. Tempos employed were 60, 120, and 180 beats per minute (bpm). The experimental period was 10 s. The subjects could confirm hearing the signal of the metronome and tone that they generated. The subjects were only instructed on how to operate the input device. No training relevant to performance of the music was given.

The experimental result is presented in Figure 5. The horizontal axes in the graphs indicate the number of signal counts of the metronome, while the vertical axes express the delay of input by the subjects from the signal by the metronome in %.

The results for Subjects 1 and 2 indicate that the delay was less than 50% for all tempos, while Subject 3 could not follow the metronome signals at 180 bpm. By assuming that the subjects played a musical piece composed of simple notes (quarter notes) in this experiment, performance at a specified tempo is considered successful if the delay of input by the subjects from the signal by the metronome is less than 50%. Thus, the results suggest that a musical piece can be performed up to about 120 bpm using this electronic musical instrument.

2.3. Experimental Performance of Musical Piece

The musical piece "Twinkle, Twinkle Little Star" was performed at 65 bpm. The subject was the 22-year-old male who had no experience in playing a musical instrument. It was verified that an inexperienced person could perform this piece that contained six chords after only instruction of the operating procedure.

3. Conclusions

This study aims to develop an electronic musical instrument that requires no limb motion. We have developed an electronic musical instrument playable with tongue movement. The experimental performance of a musical piece demonstrated that this instrument could be played even when the number of tones exceeds the number of switches. Consequently, it is suggested that disabled people with disabilities such as quadriplegia or disabled limbs can participate in musical activities by playing a musical instrument. In order to add a sound-pressure control (volume control) function to improve performance flexibility, the development of an input device equipped with pressure sensitive switches is in progress. Moreover, based on this electronic musical instrument, we have been seeking how to apply this technology in oral rehabilitation.

![Figure 4: Tone matrix.](image-url)
4. References


*Figure 5: Experimental result.*