Evaluation of voice pitch control in songs with different melodies using tactile voice pitch feedback display

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Abstract: It is difficult for the deafblind or the hearing impaired to control the pitch of their voice, because they cannot perceive it. In particular, it is very difficult for them to control their voice pitch when singing, because they need to maintain a stable tone. We have developed a voice pitch control system to assist their singing by means of a tactile display. In a previous study, two deafblind subjects using this system could control their voice pitch with accuracy comparable to hearing children while singing "Frog Round," even though successive notes in the song's melody were adjacent in the musical scale. In the present study, pitch control accuracy is investigated for "Frog Round," as well as another song in which successive notes are separated by wider intervals in the musical scale, for comparison. No differing tendencies were found in the interval deviations of the pitch for different musical notes or changes in the musical interval. This result shows that our voice pitch control system is effective to control voice pitch not only for songs with adjacent notes but also for songs with separated notes.

Keywords: Voice pitch, Deafblind, Hearing impaired, Tactile display, Singing

1.Introduction

A tactile aid that presents vocal information as tactile stimuli can serve as an assistive device for the hearing impaired [1], [2]. For deafblind persons, who are completely blind and completely deaf and therefore cannot make use of visual information, a tactile device is the only means to perceive vocal information. Voice pitch frequency is important information for recognizing a change in accent or intonation. Moreover, it is also important for recognizing musical notes, an ability required to sing a song. Tactile aids that present voice pitch using tactile stimuli are used for understanding context or assisting lip reading [3], [4]. Only a few studies have examined the presentation of a musical scale using a tactile display for voice training in adjusting musical intervals using tactile feedback. In light of this, we developed a voice pitch control system that uses a two-dimensional tactile display

[5]. Our research showed that two deafblind subjects using this system could control their voice pitch with as much accuracy as hearing children while singing the song “Frog Round” [6]. However, in this song, successive notes in the melody are notes adjacent on the musical scale. To confirm the pitch control accuracy of our voice pitch control system, it was necessary to evaluate its use with a different song as well. In the present study, we investigated the pitch control accuracy of deafblind persons while singing “Frog Round” and another song in which successive notes are separated by wider musical intervals, in order to compare a song with successive notes adjacent in the musical scale and a song with successive notes separated by wider intervals in the musical scale.

2. Voice pitch control system

The voice pitch control system consists of a personal computer (PC) and the main unit of the tactile display. The subject places the center of the first joint of his or her right index finger on the tactile display to perceive the stimulus from the display.

A schematic view of the voice pitch control system is shown in Figure 1. In this system, the target musical scale is first set using a PC. Next, a deafblind person vocalizes, attempting to produce the same musical scale as the target. The voice input is transmitted through a microphone connected to the PC. The musical note corresponding to the calculated voice pitch frequency is displayed on the PC. Similarly, a vibrotactile stimulus is presented corresponding to the position of the musical note on the tactile display. The tactile display shown in Figure 1 consists of 64 piezoelectric vibrators in four rows (16 × 4 rows). The two rows on the left side of the tactile display present the target musical scale, whereas the two rows on the right side present the musical scale corresponding to the voice pitch frequency of the user. When the target musical interval (left side) and the musical interval of the user’s voice (right side) are in the same position, the user’s pitch is on-key. One stimulus pin corresponds to a semitone with an equal temperament of 12 degrees. The male voice ranges from C4# to A2#, whereas the female voice ranges from C5# to A3#. A more detailed description of the voice pitch control system appears in our previous study [6].

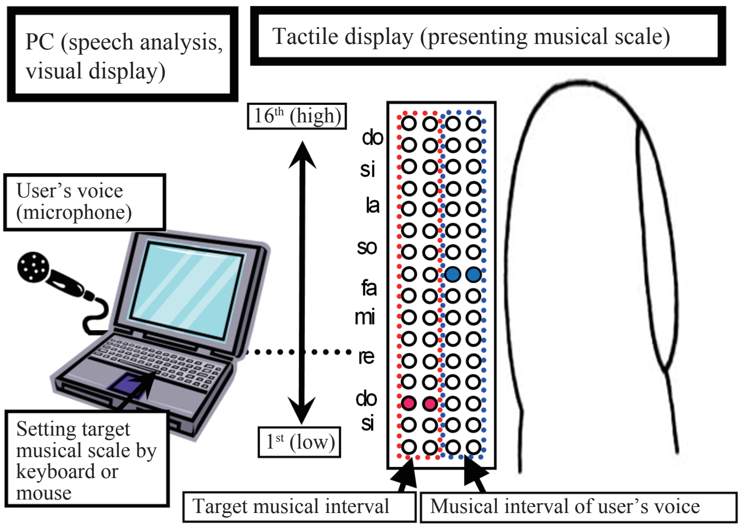


Figure 1. Schematic diagram of the voice pitch control system.

3. Method

3.1. Subjects

The subjects participating in the experiment were two deafblind persons. Subject A is a 69-year-old woman who is completely blind and deaf, having lost her vision and hearing 28 years ago. Prior to becoming deafblind, she played the samisen, a traditional Japanese stringed instrument. Although she does not receive feedback from hearing, she continues to perform on the samisen in her home and at concerts. Due to her experience as a musician, she is familiar with the musical scale, and she was interested in the tone interval of her own voice. Although she had lost her hearing 28 years ago, her pronunciation remains nearly as clear as that of a hearing person.

Subject B is a 42-year-old man with congenital visual impairment and an acquired hearing impairment; he has been completely blind and deaf for ten years. Although Subject B's pronunciation is not quite as clear as that of a hearing person, it is not difficult to understand his speech. As Subject B played the piano as a schoolchild, he is familiar with the musical scale.

The average hearing levels of Subject A are 113.3 dB in the right ear and 115.0 dB in the left ear. The average hearing levels of Subject B are 115.0 dB in the right ear and 112.5 dB in the left ear. These data show that both subjects are profoundly hearing impaired.

3.2. Procedure

The experimenter explained the content of the experiment to the subjects and obtained their written consent. The songs "Frog Round" ("Kaeru-no-uta" in Japanese) and "Tulip" (a Japanese nursery rhyme) were used in the experiment. The musical notation for "Frog Round" is shown in Figure 2. The musical notation for "Tulip" is shown in Figure 3. "Frog Round" was used in our previous study [6]. In "Frog Round," successive notes in the melody are adjacent notes in the scale. To confirm the pitch control accuracy of our voice pitch control system, we needed to evaluate it with another song in addition to "Frog Round." "Tulip" was chosen because the subjects had mostly memorized the melody of this song, and the intervals between notes are generally larger than single steps on the musical scale, while the range of tones is not too large; thus, this song is not very difficult to sing.

Figure 2. Musical notation for "Frog Round" ("Kaeru-no-uta" in Japanese).

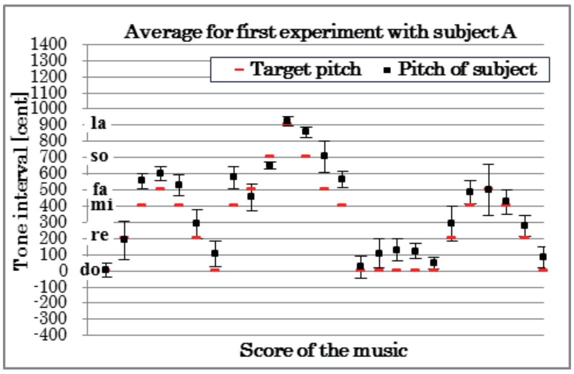
Figure 3. Musical notation for "Tulip."

Evaluation experiments were repeated four times for each subject approximately every two to three months. "Frog Round" was used in the first and the second experiment. "Tulip" was used in the third and the fourth experiment. Prior to the data measurement part of the session, the subjects trained for about two hours in the following manner. First, the target musical note was increased sequentially from C3 ("do") to C4 ("do"). Second, in line with the subjects' request, the target musical note was changed. Third, with the target musical note fixed at C3, the subjects rehearsed singing the selected portion of the song about five times. The data measurement procedure was as follows. First, the target musical note was fixed at C3 ("do"), which was the first note of this song. Second, the subject sang the note several times so that the voice pitch corresponded to C3 ("do"). Third, after the subject perceived that his/her voice pitch corresponded to C3, the subject sang the melody of the song. This trial was repeated five times per experiment.

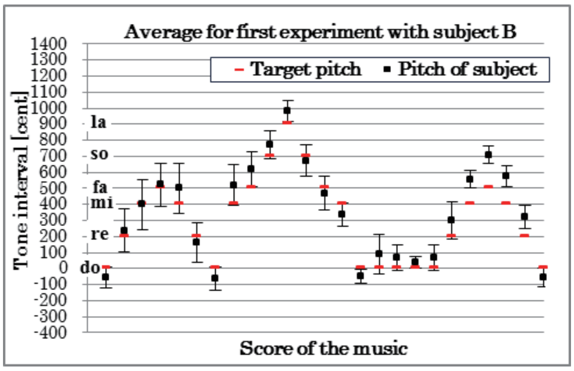
4. Results and Discussion

Figure 4(a) shows averaged data from the first experiment with Subject A singing "Frog Round." The horizontal axis is the musical scale corresponding to the notation shown in Figure 2. The vertical axis is the musical interval with a cent value based on C3 ("do"). Here, 1 semitone equals 100 cents. C3 ("do") equals 0 cents, D3 ("re") equals 200 cents, E3 ("mi") equals 400 cents, G3 ("so") equals 700 cents, and A3 ("la") equals 900 cents. The horizontal red lines show the target musical interval, and the black squares show the voice pitch of the subject. The error bars show the standard deviation. Figure 4(b) shows averaged data from the first experiment with Subject B.

Although there was a certain amount of deviation between the target musical interval and the voice pitch, both subjects sang mostly in tune with the melody. Both sets of averaged data from the second experiment with Subject A and Subject B show the same tendency.

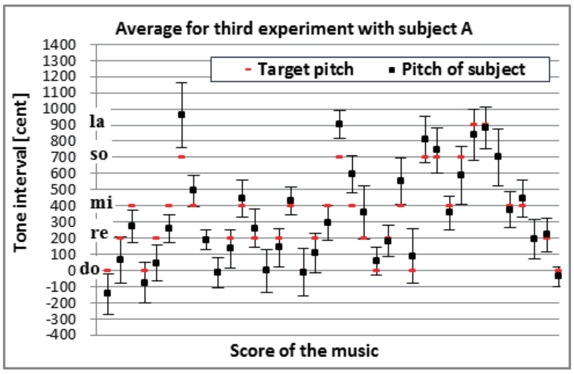


(a) Subject A

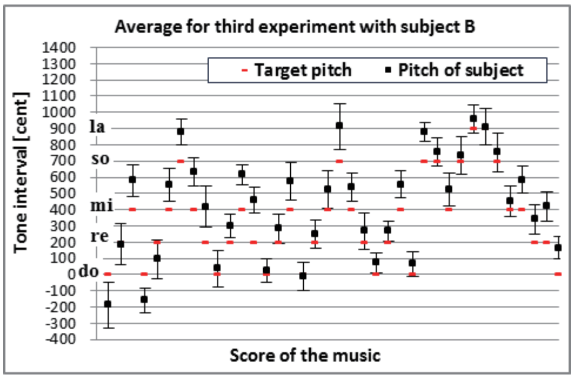


(b) Subject B

Figure 4. Averaged data for the first experiment with "Frog Round."



(a) Subject A



(b) Subject B

Figure 5. Averaged data for the third experiment with "Tulip."

Figure 5(a) shows averaged data from the third experiment with Subject A for "Tulip." The horizontal axis is the musical scale corresponding to the notation shown in Figure 3. Figure 5(b) shows the average data from the third experiment with Subject B. Based on the voice pitch data, both subjects sang mostly in tune with the melody, the same as in the first experiment. The sets of average data from the fourth experiment with Subject A and Subject B also shows the same tendency.

Interval deviation was calculated as the absolute difference between the target musical interval and the voice pitch of the subject. The average interval deviation for the two subjects in "Frog Round" (first and second experiment) was 110.9 [cent] (SD: 79.1). The average interval deviation for the two subjects in "Tulip" (third and fourth experiment) was 109.9 [cent] (SD: 79.0). Our previous study on "Frog Round" using the same system showed an average interval deviation of 117.5 [cent] [6]. These results show that the value of the average interval deviation is not remarkably different between songs with adjacent notes and those with separated notes. We found that when the subjects trained using our tactile feedback system, the proprioceptive sense was maintained; thus, the interval deviation was smaller than before tactile feedback training [7]. In other words, in the absence of auditory feedback, one is able to sing to a certain level using proprioceptive feedback, which is formed by the correspondence between the musical scale and the proprioceptive sense. Our results in this study may also be influenced by this proprioceptive feedback. In future work, we will investigate the effect of changes in melody on voice pitch control accuracy to estimate the effect of proprioceptive feedback.

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