The Development and Application of the Wearable Device for the Deaf Performers

Tzu-Hua Huang, University of Taipei, Taiwan
Yi-Jiun Li, University of Taipei, Taiwan

The Asian Conference on Education & International Development 2023
Official Conference Proceedings

Abstract

This research aimed to develop a vibrating bracelet to meet the needs of deaf actors, exploring the influence of communication methods and empathy while working with them. The study identified the limitations and expertise of the actors, reviewing the action instruction method and performance guidance. Through performance training, the study aimed to understand the abilities and cultural peculiarities of the deaf. The vibrating bracelet was developed to collect data and strengthen the content of the drama according to the needs of the deaf actors, and interviews were conducted to understand the impact on their communication methods. The study aims to cultivate inclusive art performing arts creation and performance talents. During testing, the "excited" and "smooth" heart rates were used as the judgment results and compared with the facial expression recorded videos and line graphs. Emotional nodes of the deaf students during rehearsals were compiled as emotional judgments according to the results. It was initially defined that a heart rate of 83 bpm triggers a long vibration to indicate the performer's "excited" emotion. If the bracelet detects the performer's emotion as "gentle," the type of vibration will be defined before concluding the study. The comprehensive curatorial performances will promote the concept and method of "inclusive art" and practice and discuss the spirit of equal rights in art.

Keywords: Vibrating Bracelets, Deaf Performers, Inclusive Art, Emotion Recognition, Empathy, Creative Practice Research

1. Introduction

User-centered design (UCD) is a critical approach for designing effective human-computer interactions (Fleming & Levie, 1993; Liang & Hsu, 2001). It involves continuously assessing whether the various components of a system meet the user's needs and operational objectives to align the final system as closely as possible with the user's mental model. In psychology, emotional states and cognitive processes are usually based on physiological signals such as heartbeat, dermal signals, eye tracking, and brainwave maps (Gerjets et al., 2014; Krumpe et al., 2018; Poh et al., 2010). However, accurately collecting and analyzing these physiological signals with current information devices remains a challenge, especially in educational settings where such devices often require equipment to be set up on the student's body to detect physiological signals, creating a barrier to teaching. Nonetheless, these physiological signals, including brain area features, can be used to identify pleasure states and accurately identify human emotions. For example, enhanced vibrotactile multimedia technology can stimulate the audience's visual, auditory, and tactile senses, which can also be applied in the performing arts arena, especially for audiences with partial sensory limitations. Inclusive Arts aims to make art accessible to all people because "art exists for all people" (Nixuan Zhou, 2019) and should be a source of warmth and inspiration. By considering the perspective of people with disabilities in the creation of art, artists can transcend the senses and create a mature and progressive viewing-friendly space (Claire, 2018).

The human senses play a vital role in perception, with humans relying on multiple senses, namely sight, hearing, taste, smell, and touch, to perceive their surroundings. Traditional multimedia only engages two senses, namely hearing and sight, but the human experience of watching multimedia content can be enhanced by engaging more than two senses simultaneously. Multimedia content that engages more than two senses at the same time is called mulsemedia, and recent interest in multimedia aims to provide an immersive, real-world environment during multimedia interaction. Multisensory media can provide a new dimension for developing immersive systems in various areas, including education, healthcare, advertising, and home entertainment. Recent advances in wearable sensing technologies have enabled researchers to analyze the impact of multimedia on human emotions and behaviors, with devices involving touch, smell, and taste in addition to vision and hearing used to construct multimedia environments. A framework has been proposed for conveying multisensory effects into a hybrid system (Fleming & Levie, 1993).

Audio information can be conveyed effectively through tactile stimuli, which has led to the development of electro-haptic stimulation (EHS) as a new approach. Research has shown that EHS can significantly improve speech noise performance, sound localization, and sensitivity to sound properties such as pitch (Fletcher, 2021). As the number of people with hearing loss is predicted to nearly double in the next 30 years, tactile technology can offer significant benefits, especially for those with severe hearing loss who use artificial electronic ears. An effective tactile device can improve spatial awareness, help in hearing in noisy environments, and provide an inexpensive way to obtain the benefits of a second AI without the need for a second expensive surgery (Huang, Sheffield, & Lin, 2017). However, to provide benefits to users, optimal signal processing strategies and device configurations still need to be established. Over the next five years, the number of researchers in this area is expected to increase significantly, and advanced neuroimaging methods such as near-infrared spectroscopy and brainwave mapping may be applied to understand the underlying mechanisms behind auditory and tactile enhancement (Fletcher, 2021). The development of tactile stimulation technology may also lead to the reduction of auditory work and improve speech use, and the benefits of tactile stimulation on hearing may become clearer with further research. Therefore, based on the above research theories, the application of auditory and tactile related techniques and systems can be enhanced in the field of performing arts for people with hearing loss. The development of an effective, inexpensive, comfortable, discreet, and easy-to-install tactile device can offer significant benefits to those with hearing loss, especially for enjoying performing arts.

This research aims to develop a new type of "barrier-free interactive performance" by integrating interactive content technology with performing arts, through the use of wearable devices such as vibrating bracelets, networks, and interactive interfaces. The main objective is to understand the needs of deaf performers and deaf audiences during performances and communication, and to improve communication with deaf performers during performances by using technology to increase the accessibility of art to deaf audiences. The specific research questions are:

(a) How can wearable devices, such as vibrating bracelets, be used to assist deaf performers in their performances and improve communication with them?
(b) What is the impact of the use of vibrating bracelets by deaf performers on the performance venue, in terms of audience engagement and overall experience?
(c) What is the effectiveness of the performances by deaf performers who use vibrating bracelets to assist their performance, in terms of artistic expression and audience reception?

2. Literature review

2.1 Deaf Performance and Technology Art

The life experience, lifestyle, language, thinking, behavior, and psychological characteristics of deaf individuals are unique and shape their culture. Sign language is the primary means of expression in the drama of the deaf, and it challenges established prejudices and mainstream cultural appearances. Deaf individuals have dual or multiple narrative abilities and can serve as both narrators and performers. To promote cultural equality and universal design, new technologies can be used in various artistic and cultural fields to create a friendly and easy-to-use environment for individuals with sensory and behavioral disabilities. Assistive technology has evolved from a narrow focus on equal rights to a broader sense of inclusive technology, providing substantive equality without discrimination. In the future, captioning could be part of the overall design, with personalized options such as preferred language, font style, and size. Augmented reality (AR) or mixed reality (MR) could personalize captioning and integrate audio input to meet the needs of users with different needs (Chen, 2019).

2.2 The Importance of Tactile Sensation as a Substitute for Hearing

According to Fleming & Levie (1993), the design of any computer hardware and software must take into account the user's senses (vision, hearing, touch, smell, motor coordination, etc.), cognition (intelligence, motor control, memory, motivation, etc.), and individual differences (age, gender, education, learning style, etc.); sensory media can be used in different areas such as education, healthcare, advertising, and home entertainment. The development of immersive systems in different fields such as education, healthcare, advertising and home entertainment provides new dimensions. In addition, recent advances in wearable sensing technologies provide researchers with a broad scope to analyze multimedia and its effects on human emotions and behaviors, detailing devices that involve touch, smell, and taste in addition to vision and hearing to construct multimedia environments. Whenever a person is subjected to certain emotional stimuli, their feelings are conveyed through physiological cues such as brain activity, heart rate, facial expressions, body posture, or changes in sound. These cues are used to link an individual's emotional state to external stimuli. The use of speech, facial expressions and their integration for emotional recognition has been explored. Since these brain area features have been used to identify pleasure states, it has been found that olfactory augmented content can more accurately identify human emotion than traditional multimedia. Vibrotactile-enhanced multimedia is used as a visual, auditory, and tactile stimulus. Heart rate and eye tracking data were used to analyze the effect of vibrotactile-enhanced multimedia on user perception. Overall, we can conclude that tactile-enhanced multimedia content can be more effective in evoking user emotions and, for affective computing, can improve the accuracy of emotion detection when presenting such content to users.

2.3 The Relationship between Heart Rate and Emotions

When individuals are exposed to emotional stimuli, their feelings are communicated through physiological cues, such as brain activity, heart rate, facial expressions, body posture, or changes in voice. Traditional methods of emotion recognition using speech and facial expressions have limitations, such as privacy concerns and camera positioning. Therefore, researchers have explored emotion recognition from physiological cues, such as brain activity, skin conductance, and heart rate. Brainwave maps have been increasingly used for emotion recognition due to the availability and ease of use of low-cost wearable headsets. Emotional markers in brainwave maps are not easily deceived by voluntary behavior and can accurately identify the emotional state of the mind. Changes in skin conductance are also observed in different emotional states.

Alternative aids, such as wearable bracelets, can partially alleviate the language learning, communication, and navigation deficits of the deaf, blind, and deaf-blind. Haptic feedback provided by these bracelets can give vibrotactile cues to deaf people with disabilities and monitor their physiological activities. This allows for more effective interaction between performers with disabilities and deaf people, ultimately increasing performance efficiency. The smart bracelet can also monitor and measure specific parameters, such as heart rate, blood oxygen, EEG, and ECG to detect and collect signals that can help understand emotional ups and downs. Heart rate feedback can be used to mediate anxiety through wrong heart rate feedback. However, more research is needed to analyze the accuracy of long-term physiological data collection and analysis.

Sorgini et al. (2018) suggest that haptic feedback can provide information to the physically impaired. Similarly, Yağanoğlu (2021) and Dong et al. (2021) found that wearable bracelets are low cost and lightweight, making them a potential alternative aid for deaf people with disabilities. Shu et al. (2018) also note that more research is needed to analyze the accuracy of long-term physiological data collection and analysis.

3. Research methods

In the initial phase of this study, students were chosen to participate in a dance class at an educational institution in December. The data on their heart rates was collected using bracelets, and emotional nodes were identified through data analysis. The vibration frequency that corresponded to these emotional nodes was defined and incorporated into the bracelet for future development.

In the first part of the study, eight performers (three deaf and five hearing) will send and receive vibration signals during their performance, enabling them to feel each other's emotions through vibrations, in addition to sign language and visual cues. In the second part, which will take place next year, the audience will wear bracelets during the performance to feel the performers' emotions and enhance their empathy. The facial recognition system will be used to compare and analyze the audience's emotions.

The primary goal of this research is to conduct a comprehensive field analysis. Through interviews, the researchers intend to gain a deeper understanding of the perspectives, opinions, and interpretations of deaf performers, related theatre professionals, and critics. This will also aid in gaining a more dynamic and complete knowledge of the overall field shaping and changes, which is crucial for conducting field research and analyzing the findings. The research process is outlined in Figure 1.

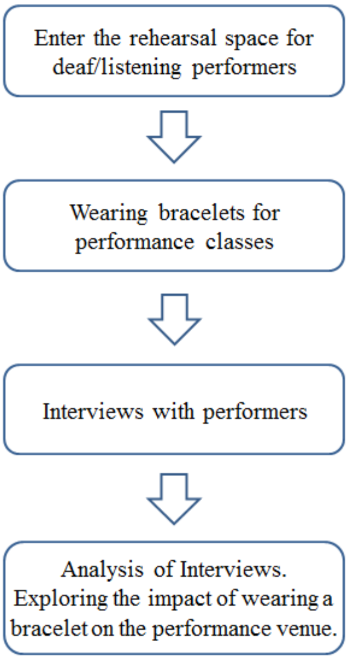


Figure 1: Research flowchart of master research.

3.1 Research subjects

This study was conducted in a performance program at Taipei School for the Hearing Impaired to observe the deaf population. Through the course, we discovered the physical feasibility and extensibility of the deaf students and selected student performers for future performances. This research is an experimental performance combining the use of vibro bracelets and performance, and the process of receiving and sending messages and vibrations to assist in the emotional communication between deaf performers. The subjects of this research are three deaf students and five students in the dance class of Double Park Junior High School.

3.2 Instruments

This year's research focuses on interviewing deaf students, developing a vibrating bracelet, detecting heart rate and applying it in the exhibition, and developing an emotion recognition system to be used in conjunction with the vibrating bracelet next year. The research tools are as follows.

3.2.1 Interview outline

In this study, the interviews were divided into pre and post technology use. Before technology use, two questions were designed: the first part was basic questions, and the second part was about the performers' limitations and imagination, to understand the performers' limitations and imagination about technology use before technology use. After technology use, the first part was to explore the impact of technology-assisted performance on the venue, to understand the personal feelings of the performers and the impact of their past experiences on the use of technology on their performance and the venue; the second part was to explore physical concerns, the impact of technology integration into performance on their own bodies and their own views on the changes; and the third part was to suggest future applications, suggestions and expectations for the application of technology in the venue after integration into performance. The outline of the visit is shown in Table 1 and Table 2.

Items	Topics
1	Basic Questions
1-1	Gender/Age/Grade
1-2	Hearing Impairment Level "A. Can't use sign language but use spoken language (mild), B. Can use sign language but use spoken language (moderate), C. Can't use spoken language but use signed language (severe)
1-3	Frequency of exposure to performing arts
2	What arts-related activities have you participated in so far? (e.g. exhibitions, movies, performances...) etc.)
3	What difficulties did you face when you were exposed to art activities? What are your bad experiences? (e.g. unfriendly spaces...) etc.)
4	During the dance classes, did your listening skills affect your understanding of the classes? (Skip to question 6 if you have not used it before)
5	Continuing from the previous question, can you briefly explain?
6	Have you ever used aids in dance classes, such as floor vibrations, hearing aids, etc.? etc.? (If not, skip to question 8)
7	Has the use of aids such as hearing aids in dance classes ever been affected by too much movement? (Like too much movement and hearing aids fall off)
8	In what way do you understand the content of the dance classes in order to perform the corresponding dance movements?
9	What percentage of the dance classes did you need the teacher's help to translate and understand? How does it affect the rehearsal?
10	How did you feel about participating in the dance classes?
11	What did you learn the most from the dance course?
12	What was your most impressive activity in the dance program?
13	What part of the class did you find difficult or disturbing?
14	Continuing from the previous question, what adjustments or improvements would you like to make?

Table 1: Interview outline before wearing a vibrating bracelet

Items	Topics
1	Have you had any innovative experiences or feelings after wearing a vibrating bracelet in a performance? Describe what it was like?
2	How did you feel the difference between wearing the bracelet and wearing it before?
3	Do you feel the emotions of others more after using a vibrobracelet than before wearing a vibrotactile bracelet?
4	Do you feel a change in the way you communicate after wearing a vibro bracelet?
Cognitive Load	
Items	Topics
1	Wearing a vibrating bracelet to rehearse a performance and feel the emotions of others requires many things to be considered at the same time.
2	Wearing a vibrating bracelet is very complicated to feel the emotions of others.
3	Wearing a bracelet not only reduces other external influences, but also allows you to feel others' emotions properly.
4	With the bracelet, I can understand the flow of emotions more correctly.
5	Wearing a vibrating bracelet contains elements that allow me to feel emotions.
6	It is difficult to use the bracelet to feel emotions in rehearsal.
7	The design of the bracelet makes it very difficult to feel emotions during rehearsals.
8	It is difficult to identify the emotional feelings and connect key messages during rehearsal while wearing the bracelet.

Table 2: Interview outline after wearing a vibrating bracelet

3.2.2 Vibrating Bracelet

At this stage, we asked the three body teaching team to guide emotional dance movements in the performance rehearsal, and let the students play and conceive the movements, as well as to collect data related to the students' heart rate, etc. At present, we have conducted three heart rate collections, each time for about 90 minutes, with each second as the unit of data recording. In addition to the analysis of the corresponding emotional data, the frequency of vibration corresponding to the emotion will also be discussed as the basis of the subsequent bracelet vibration and corresponding emotion, after confirming the frequency of corresponding emotional vibration, the manufacturer will import it into the vibration bracelet. The bracelet data collection software was developed by Walden Digital Technology Co., Ltd. and was mainly used to collect data from the rehearsal of the Kai Chung students. The data collected was analyzed using the Mongodb database with the Studio 3T GUI interface. The development process is shown in Figure 2.

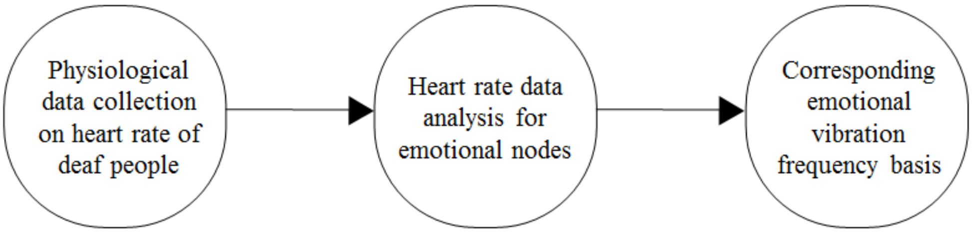


Figure 2: Vibrating bracelet development process

This bracelet was developed with the assistance of Stronghold Research. The message transmission instructions are shown in the diagram. During the performance, the main performer will send heart rate physiological signals to the data collection server software via the Gateway receiver. The software is responsible for data storage and bracelet message reception and transmission settings. Its main function is to identify emotional nodes and send corresponding emotional vibration messages to other performers and viewers via the Gateway (one-to-many transmission of vibration messages). During the vibration period, the physiological data of other performers and viewers will still be sent to the data collection server software via Gateway. The stored physiological data can be compared with the emotion recognition system software for difference analysis.

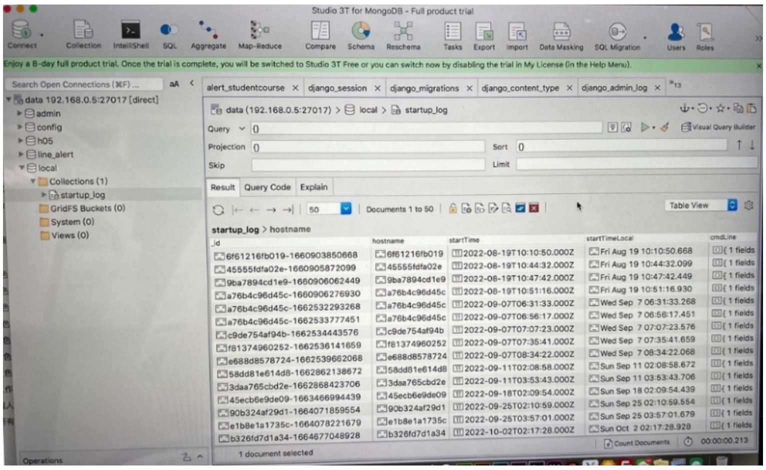
The system consists of 10 vibration bracelets, 2 Gateway message receivers, 1 AP signal base station, 1 mini PC, 1 set of Dashboard signal collection software, and a keyboard, mouse, and monitor. To set up the system, connect the mini PC to the AP and start the Dashboard system. Then, turn on the message receiver and connect it to the network via the AP. Once the message receiver changes from colored light to white light, the system will begin collecting physiological data from all the powered-on bracelets.

The show will start with eight performers (three deaf and five hearing) at the end of this year. In addition to the performers, more audience members will wear the bracelets in next year's show, and the signals will be transmitted in the same way. Next year's performance will also feature an emotion recognition system, mainly used to compare the emotions of the audience's faces when wearing the bracelets and to analyze the data of their feelings.

The data collection software interface allows users to confirm data collection and the real-time status of each bracelet. Users can also set physiological alert ranges based on their condition, and the color of the interface will change if the data is abnormal. After collecting the data, Studio 3T and MongoDB are used to export the data.

4. Result

In this study, the heart rate data of the three subjects were analyzed by using a bracelet to detect the heart rate of deaf performers, and by analyzing the heart rate data of the deaf performers through their exciting movements and slow movements during rehearsals. The heart rate data were collected by the bracelet second by second, and the data were analyzed in order of size, and the top third of the data (high heart rate) was selected. The "agitated movements" among the high heart rate data were retained for analysis to define the heart rate benchmark of the performers during the "agitated movements". The data were collected in three sessions, 9/11, 9/18 and 9/25. Heart rate physiological data were collected from three students at Taipei School For The Hearing Impaired, the MongoDB database is exported to Studio 3T software (as shown in Figure 3) as a csv file of the ring physiological data，The physiological data on heart rate of students from Taipei School For The Hearing Impaired were collected on 9/11, 9/18 and 9/25. The total number of heart rate data and the corresponding quantities are shown in Table 3.



Enjoy a 8-day full product trial. Once the trial is complete, you will be switched to Studio 3T Free or you can switch now by disabling the trial in My License (in the Help Menu).

Query {}

Projection {}

Sort {}

startup_log > hostname

_id	hostname	startTime	startTimeLocal	cmdLine
6f61216fb019-1660903850668	6f61216fb019	2022-08-19T10:10:50.000Z	Fri Aug 19 10:10:50.668	{ 1 fields
45555fdfa02e-1660905872099	45555fdfa02e	2022-08-19T10:44:32.000Z	Fri Aug 19 10:44:32.099	{ 1 fields
9ba7894cd1e9-1660906062449	9ba7894cd1e9	2022-08-19T10:47:42.000Z	Fri Aug 19 10:47:42.449	{ 1 fields
a76b4c96d45c-1660906276930	a76b4c96d45c	2022-08-19T10:51:16.000Z	Fri Aug 19 10:51:16.930	{ 1 fields
a76b4c96d45c-1662532293268	a76b4c96d45c	2022-09-07T06:31:33.000Z	Wed Sep 7 06:31:33.268	{ 1 fields
a76b4c96d45c-1662533777451	a76b4c96d45c	2022-09-07T06:56:17.000Z	Wed Sep 7 06:56:17.451	{ 1 fields
c9de754af94b-1662534443576	c9de754af94b	2022-09-07T07:07:23.000Z	Wed Sep 7 07:07:23.576	{ 1 fields
f81374960252-1662536141659	f81374960252	2022-09-07T07:35:41.000Z	Wed Sep 7 07:35:41.659	{ 1 fields
e688d8578724-1662539662068	e688d8578724	2022-09-07T08:34:22.000Z	Wed Sep 7 08:34:22.068	{ 1 fields
58dd81e614d8-1662862138672	58dd81e614d8	2022-09-11T02:08:58.000Z	Sun Sep 11 02:08:58.672	{ 1 fields
3daa765cbd2e-1662868423706	3daa765cbd2e	2022-09-11T03:53:43.000Z	Sun Sep 11 03:53:43.706	{ 1 fields
45ecb6e9de09-1663466994439	45ecb6e9de09	2022-09-18T02:09:54.000Z	Sun Sep 18 02:09:54.439	{ 1 fields
90b324af29d1-1664071859554	90b324af29d1	2022-09-25T02:10:59.000Z	Sun Sep 25 02:10:59.554	{ 1 fields
e1b8e1a1735c-1664078221679	e1b8e1a1735c	2022-09-25T03:57:01.000Z	Sun Sep 25 03:57:01.679	{ 1 fields
b326fd7d1a34-1664677048928	b326fd7d1a34	2022-10-02T02:17:28.000Z	Sun Oct 2 02:17:28.928	{ 1 fields

Figure 3: MongoDB database using Studio 3T software to export hand-loop physiological data

	9/11	9/18	9/25
Total number of heart rate data (pens)	4,768	6,845	5,266
High heart rate data number	1,589	2,281	1,755

Table 3: Data Collection Date and Number of Data

For the first session, which focuses on the 9/11 event, each student collected a total of 4,768 data points. The study then took the top one-third of the data (1,589 data points) and specifically looked at the heart rate data during "exciting movements." In this study, "exciting movements" are defined as completing one cycle of movement within 1-3 seconds, with large and abrupt limb extensions, fast movement speed, and large displacement distance. "Smooth movements," on the other hand, are defined as movements that last for more than 3 seconds, with smaller limb extensions, slow and gentle limb extensions, or slow movement speed and smaller displacement distance. The results collected by the three students are shown in Table 4.

	S1	S2	S3
Number of heart rate data during excited movements (counts)	311	186	98
Average heart rate (beats per minute)	104.2	87.1	70.6

Table 4: Number of Excited Action Heart Rate Data and Average Heart Rate (9/11)

According to Table 4, there were 311 data points for student 1's excited exercise heart rate, with an average heart rate of 104.2 beats per minute (bpm); 186 data points for student 2's excited exercise heart rate, with an average heart rate of 87.1 bpm; and 98 data points for student 3's excited exercise heart rate, with an average heart rate of 70.6 bpm. According to the definition of the Ministry of Health and Welfare in Taiwan, the heart rate for children and adolescents aged 6 years or older in a quiet state ranges from 60 to 100 bpm. In this study, heart rate data were collected from students during "excited exercise," so the heart rates were generally higher than the minimum standard defined above (60 bpm). However, student 3's average heart rate was closer to the performance in a non-excited or calm state. After interviewing student 3, it was found that because the first rehearsal was the first time the student wore the wristband during the course, the student was generally unfamiliar with the wristband's operation. Moreover, after the rehearsal, student 3 also stated that the wristband did not display the screen correctly multiple times during the course, indicating a possible malfunction. This could explain why student 3's data differed from the other students, and the student's heart rate data for the first class was not adopted. The second course was held on 9/18, and each student collected 6,845 pieces of data. The first third of the data (2,281 pieces) were selected, and only data collected during "excited exercise" were kept. The results collected by the three students are shown in Table 5.

	S1	S2	S3
Number of heart rate data during excited movements (counts)	433	316	250
Average heart rate (beats per minute)	82.5	94.26	86.94

Table 5: Number of heart rate data and average heart rate for excited actions (9/18)

Based on Table 5, the number of excitement-induced heart rate data collected for Student 1 is 433, with an average heart rate of 82.5 (beats/min); for Student 2, the number of data collected is 316, with an average heart rate of 94.26 (beats/min); for Student 3, the number of data collected is 250, with an average heart rate of 86.94 (beats/min). The results of this study were all based on heart rate data collected from students during "excitement-induced" activities, so the heart rate generally exceeded the minimum standard defined by the Ministry of Health and Welfare (60 beats/min) for children and adolescents aged 6 and above in a quiet state. On 9/25, which was the third session of the course, each student collected 5,266 data points, and the first third (1,755 data points) were selected and only data collected during "excitement-induced" activities were retained. The results of the data collected by the three students are shown in Table 6.

	S1	S2	S3
Number of heart rate data during excited movements (counts)	262	517	534
Average heart rate (beats per minute)	91.84	104.78	91.25

Table 6: Number of Heart Rate Data and Average Heart Rate for Exciting Actions (9/25)

According to Table 6, Student 1 had 262 data points for heart rate during "exciting activities," with an average heart rate of 91.84 beats per minute (BPM); Student 2 had 517 data points with an average heart rate of 104.78 BPM; and Student 3 had 534 data points with an average heart rate of 91.25 BPM. The data collected for this study were all taken during "exciting activities," so heart rates were generally higher than the minimum standard set by the

Ministry of Health and Welfare in Taiwan (60 BPM). Upon analyzing the data for the three students, and excluding the data for Student 3 during the first class, the lowest heart rate recorded was 82.5 BPM. This study will use a heart rate of 83 BPM as the threshold for triggering vibration to indicate "excitement." In the future, we will continue to investigate heart rate data during "calm" emotions and define the corresponding vibration pattern.

5. Conclusion

Through interviews with three performers from Taipei Municipal School for the Hearing Impaired, we gain a deeper understanding of deaf students. Deaf students face difficulties in understanding things without auditory aids, and without internal guidance from teachers, they may not participate in extracurricular or artistic activities. Additionally, varying degrees of hearing impairment also lead to differences in their ability to understand. Fully deaf students generally have lower comprehension abilities compared to students who can hear some sounds. In terms of technological support for performance, the students hope that vibrating objects can assist them in understanding course content during class. In future plans, in addition to deaf student performers, the research will also continue to explore the relationship between deaf artists and technological assistance, as well as the impact of audience empathy.

References

Chen, Y., Wang, Q., Chen, H., Song, X., Tang, H., & Tian, M. (2019, June). An overview of augmented reality technology. In *Journal of Physics: Conference Series* (Vol. 1237, No. 2, p. 022082). IOP Publishing.

Claire (2018).ting yishu, mo yishu, wen yishu - taipei shuwei yishu jie teshu daolan. https://vocus.cc/article/5c02a4a0fd89780001e558f0

Dong, M., Fang, B., Li, J., Sun, F., & Liu, H. (2021). Wearable sensing devices for upper limbs: A systematic review. Proceedings of the Institution of Mechanical Engineers, *Part H: Journal of Engineering in Medicine, 235(1)*, 117-130.

Fleming, M. L., & Levie, W. H. (Eds.). (1993). *Instructional message design: Principles from the behavioral and cognitive sciences*. Educational Technology.

Fletcher, M. D. (2021). Using haptic stimulation to enhance auditory perception in hearing-impaired listeners. *Expert Review of Medical Devices, 18(1)*, 63-74.

Gerjets, P., Walter, C., Rosenstiel, W., Bogdan, M., & Zander, T. O. (2014). Cognitive state monitoring and the design of adaptive instruction in digital environments: lessons learned from cognitive workload assessment using a passive brain-computer interface approach. *Frontiers in neuroscience, 8*, 385.

Huang, J., Sheffield, B., Lin, P., & Zeng, F. G. (2017). Electro-tactile stimulation enhances cochlear implant speech recognition in noise. *Scientific reports, 7(1)*, 2196.

Krumpe, T., Scharinger, C., Rosenstiel, W., Gerjets, P., & Spüler, M. (2018). Unity and diversity in working memory load: Evidence for the separability of the executive functions updating and inhibition using machine learning. *Biological psychology, 139*, 163-172.

Liang Chaucer-Chaoyun & Hsu Ming-chieh (2001). Design Issues in the Field of Human-Computer Interaction. *Instructional Technology & Media, 58*, 54-66.

Poh, M. Z., McDuff, D. J., & Picard, R. W. (2010). Advancements in noncontact, multiparameter physiological measurements using a webcam. *IEEE transactions on biomedical engineering, 58(1)*, 7-11.

Shu, L., Xie, J., Yang, M., Li, Z., Li, Z., Liao, D., ... & Yang, X. (2018). A review of emotion recognition using physiological signals. *Sensors, 18(7)*, 2074.

Sorgini, F., Caliò, R., Carrozza, M. C., & Oddo, C. M. (2018). Haptic-assistive technologies for audition and vision sensory disabilities. *Disability and Rehabilitation: Assistive Technology, 13(4)*, 394-421.

Yağanoğlu, M. (2021). Real time wearable speech recognition system for deaf persons. *Computers & Electrical Engineering, 91*, 107026.

Zhou Ni-Xuan (2019).chuangling fangsongju: bianlao de jiben quan li: ren duneng xiang you de "gongrong yishu". https://ankemedia.com/2019/17905

Contact email: anteater1029@gmail.com