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Research Article

Baby cry-sensitive armband design for parents with hearing loss

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Abstract: This study was carried out to design an armband for parents with hearing impairment or hearing loss. The study's main purpose is to design a warning system by taking advantage of the distribution of sounds at different intensity values and analyzing the quiet environment, speech sounds, and baby crying sounds in the propagation area. Sound analysis is carried out by collecting the data within the scope of the study and a vibration warning system is developed based on the analysis. Data is sent from the radio in the baby's room to the parent's armband via radio frequencies. The changes in sound data for a total of 20 seconds were analyzed. Based on these changes, it was determined that the amplitude of the silent environment was 600 delta, the speech sound environment was in the range of 1300-1600 delta and the baby crying sound could reach up to 1650 delta and above. It is seen that the speech sounds exhibit an increase of approximately 75% compared to the silent environment, while the changes in the baby crying sound increase by 102.5% compared to the silent environment. These increases indicate that the system can work effectively in wearable technologies.

Keywords: Hearing loss, healthy living, delta value, amplitude, wearable technology, vibration

1. Introduction

In today's world, wearable technologies have an important potential in critical issues such as providing instant patient follow-up, administering treatments, and minimizing misdiagnosis errors [1]. Over the years, the number of people with disabilities has increased with the increasing population. Out of every 1000 newborn children, 5.6 are born with hearing loss [2]. Depending on the living environment and environmental factors, this rate increases over time with the advancing age of individuals, leading to an increase in problems such as decreased hearing percentage, hearing loss, and severe hearing. In Turkey, more than 10 % of the population is thought to have hearing-related disorders [3]. Various technological devices such as listening and speech-to-text devices have been produced to minimize hearing problems [4]. On the user side, interest in wearable technology is increasing, especially in health, entertainment, and sports. In order to meet this interest, companies attach importance to wearable technology in their production. The wearable technology market is increasing day by day in line with the demands [5]. On the other hand, it is seen that the continuous use of these products by users is not widespread due to high costs. However, it is reported that if hearing impairment is not resolved, it will be a major economic problem in society. [6]. Wearable technology is a circuit or software integrated into a piece of clothing or an accessory that an individual wears. Wearable technology ranges from hearing aids to smartwatches and wristbands. It can also be expressed as a kind of technology field that emerged and became widespread due to the desire of doctors to monitor the conditions of their patients for a long time [7]. As a result, wearable technology is the integration of technology with clothes that a person can wear or items that can be used as accessories. The common feature of wearable technology products is that they can process the data obtained from the external environment in a compact structure and transmit them in an ergonomic way. [8]. Foreseeing that wearable technology will become more important in the coming years, many research centers or manufacturers support polymer chemists, physicists, and textile engineers to produce new technologies related to the subject and to continue their studies. In addition, these studies enable the spread of e-medicine technology [9]. Wearable technology in the health sector sometimes causes

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difficulties on the patient side. Information such as how patients should use the device, what they should pay attention to, and what routine maintenance, if any, should be provided. Otherwise, there may be disruptions in the treatment processes of patients [10]. In this case, it shows the importance of integrating innovations in treatment methods with the developing technology for a healthy life. In this case, it reveals the necessity of realizing the designs of products that users are familiar with and can easily get used to over time.

With its increasing popularity in the fields of health and medicine, wearable technology is of great importance not only in terms of medical diagnosis but also in terms of treatment follow-up and management. Thanks to the developing wearable technology, data on patient health or condition can be monitored and analyzed in real-time. This also applies to the quality of life of the hearing impaired. Hearing aids, wearable devices, transcription of speech, and environmental sounds with different sensory inputs such as vibrations or light signals [11]. One of the main benefits of using wearable devices is to create devices that can enhance environmental sounds or create personalized sound profiles for the hearing impaired to understand speech more easily [12]. Researchers working on behalf of hearing-impaired individuals believe that vibrating wearable devices can be an important tool for hearing-impaired individuals. These devices enable the user to encode the incoming sound signals with different vibration patterns. According to the research, vibration on the user side leads to the most accurate results in terms of functionality and usability [13]. Various applications and technological devices are being developed to improve the quality of life of hearing-impaired individuals and to ensure their participation in social life. Such devices include hearing aids, cochlear implants, vibrating alarm clocks, fire alarm clocks, etc. Technological devices are also used in the education of hearing-impaired individuals. Video-telephone systems, sign language interpreters, and software-based hearing aids are among the main devices. These devices improve the quality of life of individuals and facilitate their participation in education and social life [14]. The aim of this study is to realize the design of an armband with an excitation system for hearing-impaired individuals by revealing the differences in sound depending on the characteristics of intensity and propagation changes. The detected sound is first divided into sound frames. Then, delta (spread) and decibel values are obtained from the obtained sound signal. After various amplification processes on the sound, the differences between the sound emissions are detected. It is reported that if a detected sound repeats, it can be checked whether there is a match with the sounds in the database [15-16]. The focus is on the development of a functional warning mechanism by sending a warning to the armband according to the sound characteristics obtained. In addition, the fact that sound signals are converted into a mechanical effect and thus offer a feasible and economical solution to a critical health problem such as hearing loss reveals the unique nature of the study.

2. Materials and Methods

In the study, an independent receiver circuit and a transmitter circuit design are realized and the ground is prepared for the sound signals to form the excitation signals. The calculations are analyzed in decibels of the perceived sound and the delta value is calculated from the changes between the maximum and minimum sound intensities in the environment instantaneously. Here, the delta values of the sound in the same time periods are examined when the ambient sounds in the environment are silent, in the environment with speech sound, and in the environment with baby crying sound. In the study, a transmitter (radio) environment and a receiver (armband) are defined. The general aim of the study is to create an excitation mechanism by converting the difference obtained from sound signals into a physical effect. However, the vibration motors preferred as the excitation mechanism here are very small and produce a vibration effect at levels that do not cause discomfort. The operation of the two vibration motors is directly proportional to the sound intensity. While a single vibration motor gives a warning at low-intensity baby crying (1650-1800 delta), double motors are activated at higher levels of baby crying (1800 delta and above), increasing the effect of vibration. In order for the radio and armband data transmission to be effective, the system aims to increase the interaction between the baby and the parent by creating vibration in direct proportion to the intensity of the sound level in both single and dual motors. Thus, the receiver-side stimulation process is successfully realized. No vibration effect occurs in the quiet environment defined in the system. However, one of the vibration motors is activated when speech or small sounds are detected. Finally, when the baby cries, both vibration motors are activated depending on the propagation range of the sound, and the receiver-side excitation process is clearly realized.

As shown in Figure 1, it is aimed to initiate wireless communication with the baby's crying among the sounds that the microphone detects from the environment, and if the baby is crying, with a low or loud cry. Then, if the baby is not crying, the microphone will continue to analyze the data of the sounds in the room. If the baby is crying, the vibration motors in the armband are activated depending on whether it is low or loud. In this way, the parent is notified that their baby is crying. In addition, the system can operate full-time thanks to the continuous data reading of the microphone.

In the study, wireless communication is provided with radio frequencies. In these criteria, the nRf24L01 module was preferred as the communication module. Depending on the frequency and thickness of the obstacles between the transmitter and receiver, data transmission can be provided in the range of 20-200 meters. It can operate with 3.3V and 4mA. In short, it is a module with very low power consumption. The transmitter module provides frequency transmission at 2.4GHz. The working principle of radio frequencies is that the frequency sent from

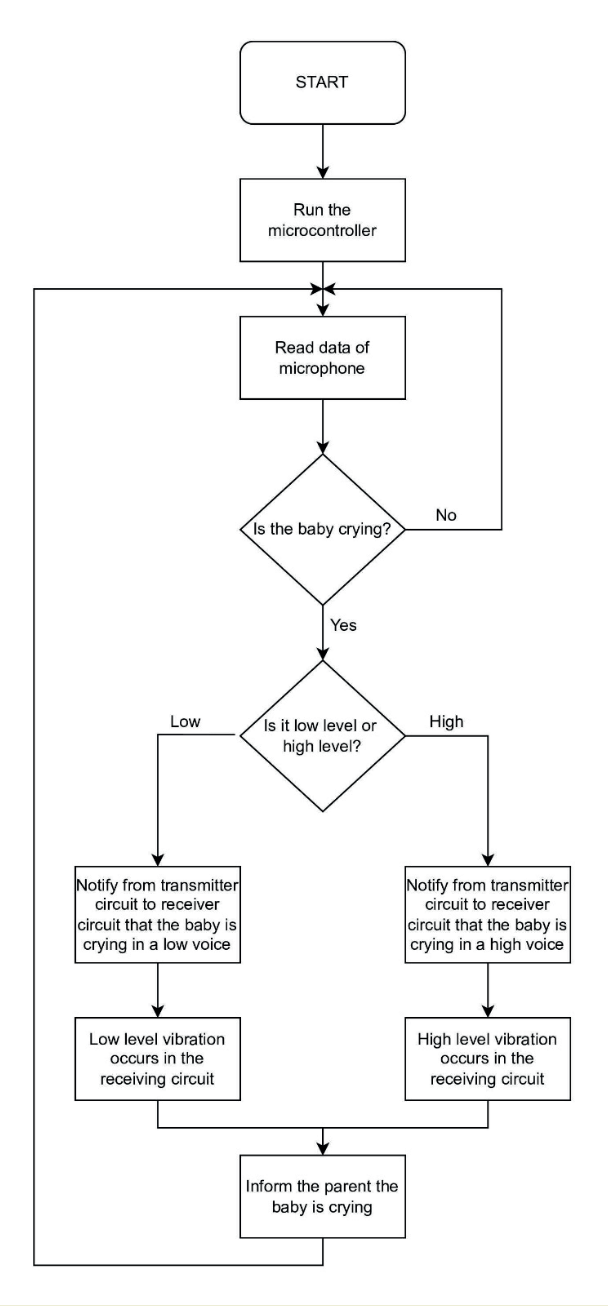

Figure 1. Flow algorithm of the research

the transmitter module is detected by the receiving module and the data is imported. In SPI protocol, the microcontroller performs serial communication over a single bus. The protocol works synchronously.

The circuit diagram of the transmitter medium is shown in Figure 2. A capacitor with a value of 100 µF is used for the transmitter module to receive a clean voltage without ripple. In order to minimize interference in data transmission, the system is generally prepared by soldering instead of wires. The stages of data transfer can be controlled by the button on the radio.

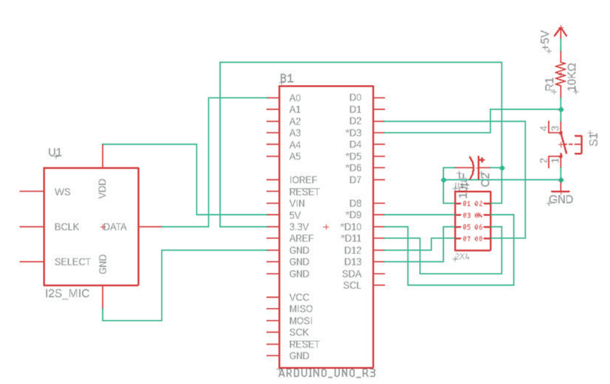

Figure 2. Transmitter circuit diagram

The small size of the modules will make it easier to integrate them into the receiving circuit (armband), and the weight of a few grams allows for ergonomic use. Elastic materials were emphasized in the design of the armband so that it can be worn and removed, battery replacement is easy and it has a size suitable for each person. In addition, the schematic representation of the electronically receiving circuit is shown in Figure 3. A 100 µF capacitor ensures that the receiver module works properly without fluctuations. 2 BJT type NPN transistors (BC547) are used to operate the vibration motors. Motor control is provided with the microcontroller triggering the transistors. The 5mm LED in the system is used for testing whether there is communication between the transmitter and receiver. In order to minimize interference during data transfer in the system, the system is mostly prepared by soldering instead of cable.

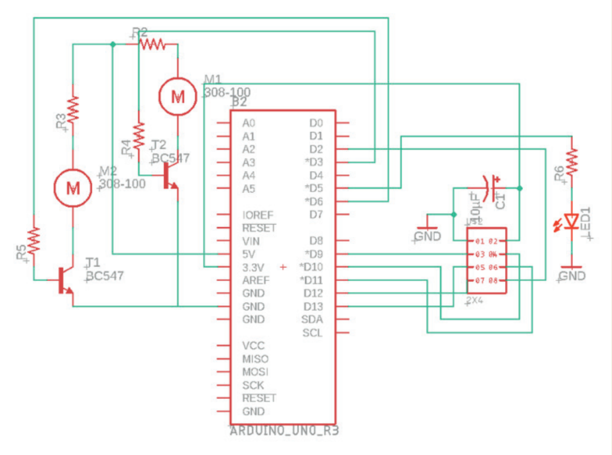

Figure 3. Receiver circuit diagram

Lithium-ion batteries are used to power the armband so that it does not run out of charge in a short time. A lithium-ion battery is 3.7V and the peak voltage can reach up to 4.2V. A 2500MAh battery was chosen for long-term charging of the armband. Thanks to the 2 lithium-ion batteries used in the series, it can easily supply the microcontroller, vibration motors, and nRF24L01.

There are various types of wireless communication. They have their own prominent features such as data transfer speed, range, and volume. In this study, the nRF24L01 module, which provides communication in SPI (serial peripheral interface) protocol with radio frequencies using a fast and cost-effective transceiver module within the domestic boundaries, was preferred. In addition to the economic advantages of this module, it is also advantageous in terms of ease of application.

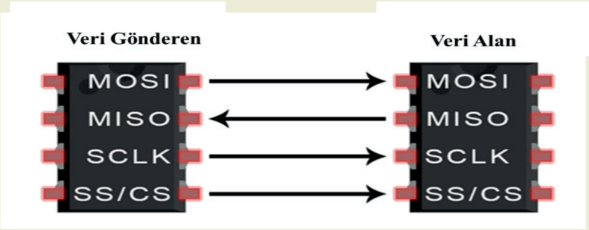

Figure 4. Pins and connections that enable communication between data sender and receiver

The module, which has 2 types with an internal antenna and an external antenna, can transfer data at a range of 20-25 meters inside the house in the tests performed. The 2.4 GHz frequency band wireless communication module requires only 3.3V voltage to operate. It provides 2 megabytes of data transfer per second. SPI protocol works as a transceiver (Figure 4).

As seen in Figure 5, the system basically consists of two components: the radio in the transmitting environment and the armband in the receiving environment. Here, the housing shell designs of the circuit designs were obtained using a 3D printer. Additionally, a design for the armband was made from materials (spandex) suitable for elastic wearable technology. The entire weight of the design attached to the arm here is 260 grams. This weight value aims to prevent fatigue or uncomfortable situations during long-term use. Finally, the vibration motors are integrated and fed simultaneously with the signals coming from the receiver circuit. In this way, it is aimed that one or two motors will work as a sleep mechanism depending on different environmental sounds.

3. Results and Discussion

After the designs determined within the scope of the study were realized, experimental studies were continued. Since the use of elastic materials is preferred in its production, it is a successful output in terms of physical dimensions that a design that can adapt to arm sizes in different tolerances has been put forward. On the other hand, if cost analysis is performed, it seems that the high cost of device designs for sound perception in individuals with hearing impairment can be solved by developing physically stimulated systems.

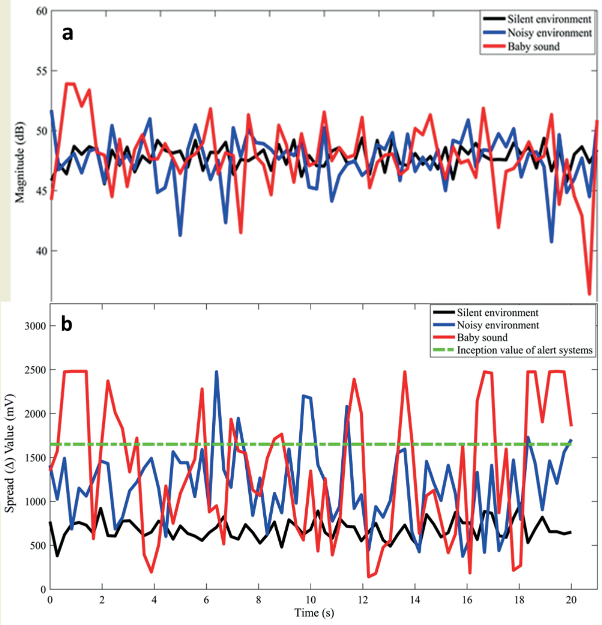

Figure 6. From different environments a) intensities b) propagation changes of sounds

Figure 6a shows the intensities of sound data from different environments. As can be seen here, the intensity range of the data obtained from the quiet environment is in the range of (45-48) dB. When the intensities of the noise values obtained from speech sounds are examined, it is seen that they increase up to 52 dB values. Finally, when the data obtained for baby crying are examined, it is determined that this value reaches even higher limits. It is also stated that these sound intensities are within reasonable ranges [17]. The microphone is located 50 cm from the sound source. Depending on this distance, it is thought that an increase in intensity values and differences between different ambient conditions may occur as it gets closer. In addition, it can be said that sufficient

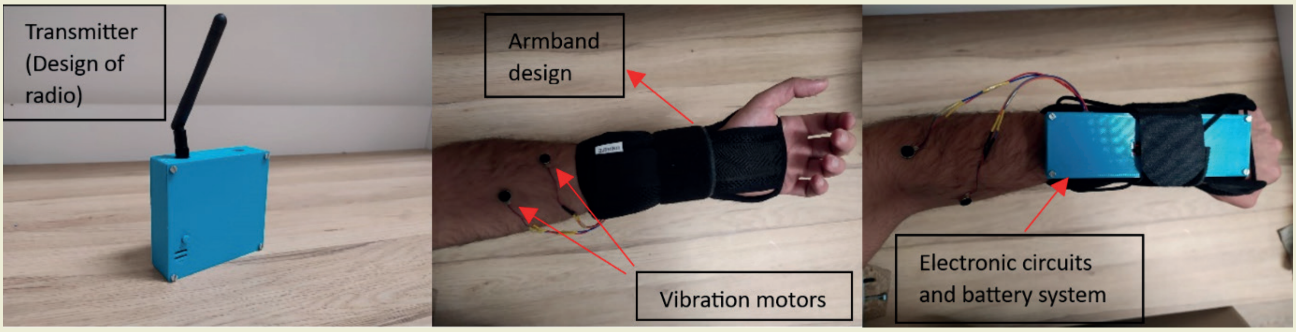

Figure 5. Components of the designed armband

separation can be achieved for these measurement results to be an input in the excitation mechanism. In this context, a study investigating the ability of hearing-impaired individuals to listen to and understand music, it is aimed to develop systems with tactile vibration stimulation for the perception of the disabled individual by examining the frequency characteristics of different types of songs. It is stated here that these processes can be achieved up to certain limit values in the frequency range where sound effects can be transformed into vibration effects [18]. Similarly, in this study, the noise levels of sound effects were recorded within certain ranges. As can be seen, vibration effects can be transferred to the user depending on the sound exceeding certain intensity levels. The differences in sound intensities over the whole time interval show a regular pattern. Figure 6. b shows the variation between the maximum and minimum values of the sound values obtained from the propagation differences for detailed analysis. Sound measurements were taken at 20-second intervals in environments where sound continuity is maintained. In this context, the differences between the maximum and minimum values of the sound data are determined and presented in the graph obtained in Figure 6b. It is clearly seen that the quiet environment has the lowest change amplitude. However, it can be stated that speech sounds exhibit an increase of approximately 75% compared to the quiet environment. In addition, the changes in the baby crying sound show an increase of 102.5% compared to the quiet environment. When the change in the baby crying sound over time is analyzed, momentary silence phases are observed in the baby crying sound at 4 s, 12 s, 16 s, and 18 s values. It is noteworthy that dialog tones at time intervals of 6.3 s and 10 s produce noise at the same levels as the baby crying sounds. Considering that the sensor systems are in the environment where the baby is present, this shows that an excitation mechanism can be developed in the excitation system not only against crying sounds but also against other ambient noises. These changes show that differences can be transformed into reactive results by creating a warning system. In this context, the initial value of the alarm system designed is determined as 1650 millivolts as the limit value (the green line in the graph shows this limit value). When the detected sound value exceeds this limit value, the first vibration motor in the armband activates and gives a warning. When this level increases to 1800 milli volts, the second vibration motor is activated and the excitation mechanism is supported. In this way, in abnormal noise values that occur in the environment where the baby is located, solution approaches are put forward, especially for parents who have hearing problems. It is clearly seen that the proposed method can work successfully, especially at night or in the sleep sections as the quiet hours of the day.

4. Conclusion

The results obtained within the scope of the study prove that excitation mechanisms can be successfully developed by converting audio signals into mechanical effects. In this context, the transformation of sound data into a mechanical effect in an economical form expresses the original and innovative aspect of the study. Considering the elastic material design, a production that is quite suitable for daily use has been realized. If the cost analysis of the materials used is carried out, it seems possible to develop effectively and serve existing users. When the results obtained by analyzing the sound types are analyzed, it is seen that the baby crying sound provides approximately twice the amplitude increase compared to the quiet environment. It was determined that the baby's crying sound increased by 15.5% compared to the speech sound. In addition, the amount of increase in sound intensities also supports this situation. In addition to baby crying sounds, speech sounds near the baby, outdoor noises, etc. can be detected in accordance with the proposed method. Considering the cost analysis of the designs realized within the scope of the study, it is thought that 50% improvements can be achieved compared to their existing counterparts. In this case, it is necessary to develop similar studies to increase the widespread use of wearable technology products. In addition, in today's technology, where remote monitoring technologies in the health sector have increased so much, it is envisaged that information with different functional features can be provided to the user from the external environment. There is a need to develop studies that transform sound signals into vibratory stimulation mechanisms to solve the problems of disabled individuals. This study constitutes an example of how stimulation systems can be designed at very low economic costs, especially compared to similar applications. In fact, it is stated that it is important for wearable technology devices to be usable and accessible as well as being developed [19]. It is thought that the results obtained in this study can eliminate this deficiency if they are improved in terms of both providing economic conditions and being familiar to the user. It is stated that technologies with wearable vibration sources can be beneficial for hearing-impaired individuals, that products designed as prototypes can be converted into ergonomic use in line with certain development processes, and that the discrimination between society and disabled individuals can be reduced [20]. Therefore, the use of wearable vibration-stimulated systems may be beneficial for disabled individuals to complete their deficiencies in seeing their own needs, and it also has a very important potential in terms of their adaptation to social life. With the proposed method, a different perspective on mitigating the effects of a critical problem such as hearing impairment has been tried to be brought to the literature.

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