Using Sonification to Assist Nerve-Impaired Individuals

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ABSTRACT

In this paper, I describe the entire process, experience, and findings of using sonification to assist nerve impaired individuals. I attempted to find individuals who have suffered some sort of nerve damage that prevents them from completing basic tasks. The tasks I attempted to find a solution for was measuring temperature, chewing and eating properly, as well as moving around objects near their vicinity. To find candidates suitable for researching and testing, I attempted to find individuals who suffered some sort of nerve damage in their life which meant the activities they could do with ease cannot be done so easily anymore. I have four research questions related to how the user would receive data, and how efficient overall it would be for them. Once all the data was collected and thoroughly researched, I determined that the system is suitable to assist nerve impaired individuals, but there is room for improvement and further growth.

INTRODUCTION

Many people who suffer from nerve damage often have trouble with muscle movements, internal organ problems, and even insensitivity to various temperatures. For example, someone who has trouble feeling things with their hands may not be aware if they touched something dangerously hot or cold. These limitations can be a minor annoyance in a best case scenario and a fatal accident for a worst case scenario. As of now, some solutions to remedy this include various medicines, physical therapy, and sometimes even minor surgery. However, these treatments may need to be continually taken care of rather than acting as a one time option. So to mitigate this issue, I prepared research on a sort of auditory solution so that nerve impaired users can be more aware of their surroundings, and can potentially avoid any dangerous situations.

The goals of my project can be condensed into three components.

1. Help the user to gain context of their immediate surroundings
2. Assist the user to complete basic tasks that they struggle with as a result of their nerve limitations
3. Inform the user by allowing them to receive a constant and steady form of data to help them be more aware of their day to day life

These are the three goals I sought out to complete with my project.

Users with nerve impairments are often restricted to their sense of awareness depending on their disability and can usually suffer from a lack of context given to their current situation. Take the brief example I mentioned earlier about the user not being able to measure temperature easily. For a user with say nerve damage on their hands, they can often struggle with gauging what the approximate temperature of a surface or object is. This can in turn lead to dangerous situations where the user can not make the ready conscious decision to determine whether or not it is safe to touch something, ergo a lack of context.

The next goal was the most active and most research-heavy component of the project. This is where I implement my project in hopes to assisting the user to complete a variety of basic tasks in which they normally struggle with. For the purpose of this project, I sought out to research and study three different, but important types of activities. The first activity would be to measure and gauge temperature. The second activity would be to assist the user for chewing food properly and informing them when it is safe to swallow the food. The third and last activity is to help the user to move around and let them know when obstacles are in their vicinity. Each of these three activities would be sonified in some way and reported back to the user.

The last goal bounces off the attributes of the second goal, but I feel that it is important enough such that it deserves to be categorized as its own goal. And that goal is constant inform the user with data related to their situation and environment. When a user wishes to perform an activity, I envision that the simulator will continuously let the user know of their current contexts and tell them of any potentially dangerous or cautious sudden changes related to the activity they are performing. This influx of information will help them to be more aware and hopefully more safe the more they perform these activities.

I intend to remedy these problems through the use of my simulator project. The hope is to help the user achieve all three of these goals, and the data emphasized in the following sections should help to assert this.

For this project, the domain I chose to work in was related to users who suffered some sort of nerve damage or just had trouble with their sense of feeling in general. These individuals were the prime candidates for my project as they fit at least one or more of the criteria I was looking for. These individuals ranged from those who could not strongly feel with their hands or feet, or often had trouble eating food and swallowing pills, as well as individuals who generally struggled with moving in tight and enclosed spaces. To source these individuals, I opted to look for areas where nerve-impaired individuals were in high concentration. Some of examples of high concentration areas included but were not limited to were hospitals, retirement homes, and even homeless shelters. Each of these areas were common place to find potential individuals to supply user-tested research for my project. And as a last little aside, I was intent on searching for individuals who had suffered some sort of nerve damage and as a result, cannot do basic tasks like they once used to. This is easier to work with as opposed to individuals who may have suffered nerve damage their whole life, and so do not have a reference for how an average person does these tasks. Nevertheless, any and all users who have some sort of nerve damage are prime candidates and ones who I am intent on studying.

In the context of the user's needs to successfully participate in the experiments, they are required to have a few devices related to

gathering and sonifying data as well as a few miscellaneous objects to help with the specific task to be performed. For the device aspect, I have a modified headphone for the user to wear so that they can receive contextual data for the activity. There will also be another apparatus similar to a ballpoint pen for the user to gather data and act accordingly. For the miscellaneous objects, I will provide food/objects for each activity. For the temperature activity, there will be a cup of lukewarm coffee as well as ice cream. The eating activity involves some crunchy cookies and soft baked cookies as well. Finally for the moving activity, I will use an assortment of common objects like a backpack, a cable, a chair, and even some toy racecars. These are all necessary to get as much accurate data as possible and to hopefully help the user pass all the basic tasks.

During the research process, I have a set of research questions that I hopefully can have answered by the end of the experiments and results.

1. "Will the user be able to tell if the system reports an error?" I am approaching this project with the mindset that everything should go according to plan but I have yet to cover any slip ups or potential problems I or the participant might encounter.
2. "Does the user have some sort of control over what kind of sounds they can hear?" I initially chose to have an option solely for the user to decide what type of sounds they wish to hear. Two options were pure sound beeps and a sophisticated voice A.I. But after reconsideration and possible further testing, it might be better to combine the two and go with that.
3. "For the two sound types - beeps and voice AI - why are there two and is one better than the other?" Bouncing off the last question, it came to me that having two separate systems come with their own benefits and drawbacks, but for the sake of this project, I will only consider the benefits of both in a unified system.
4. "Will the sounds themselves of the system inhibit the user's ability to perform basic tasks?" This will potentially be answered in live testing and the data I gather should be able to back up whether or not the sound data inhibits the user rather than helping them.

These research questions will provide essential data for how well my project is overall, and will also help to calibrate and make adjustments as necessary.

METHODS

For the experiments, there are a few things I illustrated before to ensure the success of each activity to be performed.

To the potential user/participant, I will introduce myself that I am a college student who is looking for someone with nerve impairments which prevents them from doing basic tasks efficiently. I will explicitly mention that I wish for them to perform some tasks which will help me to record data on their performance. If they fully consent to my procedures, we can then begin the experiment.

First, I briefly go into more detail about the nature of my project. I will describe it as a sound system that gets various forms of data and continuously translates it into sound data that gets read back to the user. Their behavior and performance will affect the overall success rate of the tasks, so they will also keep that in mind.

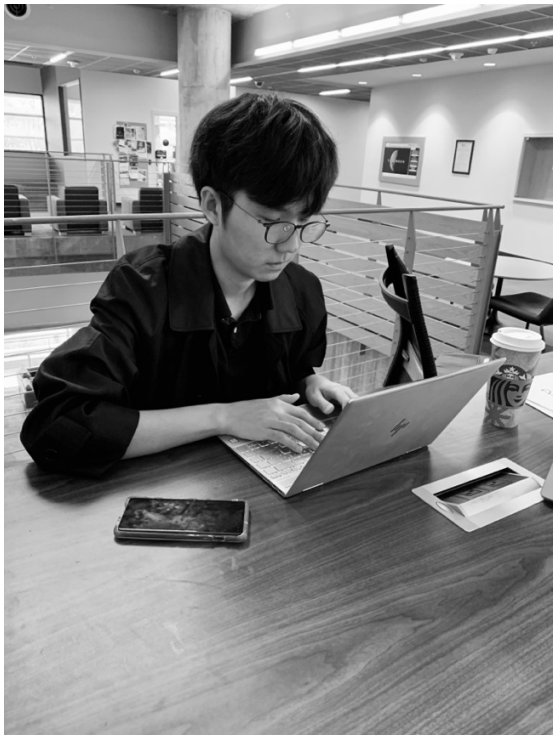
I will provide the user with the modified sound devices (headphone and pen apparatus) so they can familiar with how they work first. When the user performs a task using the devices, the pen apparatus will collect data and then the headphone will inform the user of the context of their situations. All the user has to do is select what type of task they will be doing, perform the activity as usual but act accordingly to the data read back, and when they are satisfied with the data received, they can conclude the activity.

The data that gets recorded is varies depending on the task, but since only three distinct activities will be monitored, it will be easy to pick out specific data values to read. For example, the temperature activity will mainly record the sound of the object that gets recorded and depending on the value recorded, it will alert the user whether or not this area is safe to touch. The chewing activity will monitor the overall success of the individual eating properly. Lastly, the moving activity will record data in an echolocation fashion and inform the individual of dangers that are in their vicinity.

Now, with the basic overlay of the processes laid out and exactly what data will be recorded, I can explain more in depth the processes for each task.

Task 1: Measuring Temperature

The first task the user will do is to use the modified pen device to tap different materials to get a sense of the current temperature. I will offer various types of objects to the user, as well as the lukewarm coffee. For the experiment, the user will activate the pen by tapping it near something, and based on the sound it makes, it will convert into readable data for the user that determines the temperature of the material and what ranges this material can be in the safe area to touch. For example, if they were to use it on a table, it would record the sound of the table being tapped, convert it into readable data, inform the user what temperature it is and let them know if it is safe to touch. Because different materials carry different sounds, the device can determine the conductivity of the material and see if it is safe for the user to touch. During this task, I will measure how long it takes for the user to get used to the pen and what things they measure as well as the temperature of the materials received.



Task 2: Chewing and Eating

The second task that I will record is eating. For this, the user will eat the cookies that I have provided them with. I have both soft, chewy cookies and hard, crunchy cookies. Both are essential for this task as they can provide different results since the chewing patterns are different. Both foods could be liable for choking, but hard and crunchy foods can be a bit more dangerous. With that out of the way, the user is now ready to perform the task. This time, an external microphone is used to collect the audio. It can be held in one hand while the other eats the food, or the microphone can be attached to the ear, which is close to the mouth. The data that gets collected is the sound of the chewing and it is used to help the user know if they are chewing properly or not. If they are, they receive a nice constant stream of sounds that informs them that they are on the right track. But if it sounds like the user is not chewing properly (the food is next to the teeth and not between it), then the system will inform them that they need to readjust the food in their mouth. They could use their tongue, cheeks, or even their fingers but the main point is to get the food back into place. Once the user is done eating, they can end the task on the simulator.

Task 3: Moving Around Objects

The next and last task involves moving around various objects that have been scattered around the user's vicinity. In more realistic uses, this would work better for outside environments such as hiking paths, walking paths, uneven terrain areas where obstacles are not as easily seen, but for the sake of proof of concept, this alternative should work fine to get data. I will place the miscellaneous objects around the user (the backpack, cable, chair, and small toys) near their walking area. Some will be close to them and others will be a bit farther. Keep in mind that the user can be able to fully see the objects around them and so, should not be in any real danger. The user will select the "moving" activity on the simulator, and use the ballpoint pen apparatus to listen to the audio closely. When the activity starts, the user will drop the pen near them, and in a process similar to echolocation, it will determine what sounds get absorbed by nearby objects. The device informs them what objects are nearby and if any are in dangerous proximity (for tripping). I will measure how long it takes for the user to get used to the pen for this specific activity, how often they might hit an obstacle, how successful they are at overcoming the obstacles, and overall how long it takes for them to complete the task.

In applying these experiments, the most important aspect is of course finding the correct individuals who unfortunately suffer from nerve impairments. But unfortunately, it is not as easy to find individuals who are within the specific criteria ranges I am looking for. For example, one of the activities I wish to record data for involves individuals who can not eat properly, and it is not easy to find an individual who fits this description, much less find someone who is willing to participate, which I fully understand. Nevertheless, there are ways to mitigate these issues by creating small adjustments and modifications. Take for example the activity of feeling temperature. I can use thick gloves to represent that lack of feeling accurate temperature, and this should be suitable to measure temperature, at least for that exercise.

RESULTS

To gather data for this project, I sought out to find three individuals who matched the criteria I was looking for. I specifically wanted to find one participant for the temperature activity, one participant for the chewing activity, and another participant for the moving activity. For each of these activities, I guided them clearly and monitored them closely for their performance and success rate. And based on the results that are obtained, I can then tweak, adjust, and reflect on the project fundamentally in the next section and make changes that I feel would enhance the project and improve all the weak areas.

Temperature Activity Results

To start, I will discuss the results I measured for the temperature activity. Earlier, I mentioned that it was hard to find individuals who fit the description I needed, much less find someone who was willing to participate. So to gather data for the context of this activity, I found an individual who did not have any nerve damage, and had them wear gloves to simulate a lack of feeling and lack of accurate temperature readings. When the participant measured various objects of variable temperatures, the common trend was they measured areas that were within a safe range to touch. Rarely did the individual measure something within a temperature that was too cold or too hot. However, the individual did manage to activate one of the emergency warnings for when they tried to measure the temperature of their hot coffee. The system informed them that what was being recorded was beyond a safe temperature to touch, and they needed to proceed with caution. Below is a chart labeling various surfaces and what temperatures, if any, are within a dangerous range. One anecdote I recorded from the participant was "I feel like this definitely has potential, but the things that I recorded

	Temp Recorded (in Fahrenheit)	Times Recorded (Integer)	Dangerous to touch? (Boolean)	Can it be dangerous? (Boolean)
Table	76F	6	No	Yes
Coffee	176F	1	Yes	Yes
Coffee Steam	212F	2	Yes	Yes

Chewing Activity Results

For the chewing activity, the data I collected was mainly for what kind of food the individual was chewing and how well they were able to chew it. Again, it was hard to find an individual for this, so I enlisted another individual who did not have any major chewing problems, and had them chew in a different, unnatural way. Normally when food gets stuck to the sides of the teeth, we use our tongues and cheeks to rearrange it because we know there is food there. But for an individual who does not know this, they can be chewing incorrectly. So chewing in an unnatural way without using the tongue or cheeks should imitate the same effects. The data I recorded was how long it took for them to chew the food, how successful they were, how many times food was stuck in their mouth, and I will compare overall how success each type of food chewing was. From the data I was able to obtain, it seems that foods that are more harder and crunchier tend to result in lower success rates. The sprinkled donut was actually somewhat of an outlier as the donut itself was soft and chewy but the sprinkles were hard and crunchy. And the success rate is something I measured against comparing how long it takes to chew normally vs chewing with this modified pattern. The participant made an anecdote saying that "chewing felt very tedious and annoying when I was not able to use my tongue or cheek. I felt like my jaw was going to fall off." The chart below illustrates the data I collected from the experiment.

	Time to Eat (in seconds)	How many times food was stuck? (Integer)	Success Rate (percent)
Soft Cookies	52 seconds	3	73%
Hard Cookies	97 seconds	7	67%
Sprinkled Donut	128 seconds	5	63%

Moving Activity Results

The third and last activity was related to gathering data relating to how successful the individual is for moving around objects scattered around them. The data I collected was how many objects I placed around them, the danger level for that object, the success rate of moving around these objects, how well the device was able to sonify data, and overall what the success rate of the user was. The overall success rate is based upon the object currently studied in correlation with the past objects as each object includes said object with the inclusion of the past objects. Based on the data gathered, the user was able to move fairly easily around the larger objects like the chair and backpack, but had a bit of trouble with the smaller obstacles, like the wire cable and toy cars. However, they were able to successfully overcome all the obstacles presented in front of them. The caveat though was the time to overcome each obstacle was in inverse proportion to how successful they were. The chart below shows the various data collected.

	Amount Placed	Danger Level	Success Rate of Moving around the object	Success Rate overall
Chair	2	3	100%	100%
Backpack	1	4	87%	93%
Cable Wire	1	7	72%	86%
Toy Cars	4	9	45%	76%

DISCUSSION

Overall the data collected was consistent with the hypotheses I had come up with delving into deep research (they are not explicitly mentioned as they were more or less my personal thoughts). Although I did not get full satisfactory results across the board for each activity, I was able to reach a baseline for how each activity is performed and what could be improved upon in future implementations. Before proceeding with the processes for this project, I had four distinct research questions that I had hoped to answer. After conducting each activity and analyzing the data thoroughly, I feel confident that I have a sufficient answer for each and every question. Much of the data overlapped when trying to answer the questions, which is helpful to establish and justify connections for how everything is co-related.

1. "Will the user be able to tell if the system reports an error?" Currently, I did not have any viable way to report errors as I was not exactly sure what errors, if any, I or the participant would come across. But the areas in which there needs to be improvement could also open the door to see what kind of errors could show up as well. This is something that needs to be tested for specifically and most likely I would have to create specific tests to catch these errors.
2. "Does the user have some sort of control over what kind of sounds they can hear?" After much consideration, I think my post-initial idea of merging the two unique sound types for the user to hear would be the best option. Like earlier stated, it would be most beneficial to have the best of both worlds by integrating the positive aspects of the beep sounds and the positive aspects of the voice AI together.
3. "For the two sound types - beeps and voice AI - why are there two and is one better than the other?" After doing the heavy work and research, I have found that the participants respond faster to the beeps. This makes sense since a quick beep is much contextually informative and faster than having to listen to the full speech provided by the voice AI. However, in more serious and specific contexts, it is important to have the voice AI so that the user can be informed of other data like temperature values for example. All in all though, both are highly important and necessary in their own regards.
4. "Will the sounds themselves of the system inhibit the user's ability to perform basic tasks?" This is quite possibly the most important question that I was hoping to reach a sufficient answer for. During the testing, I did not find any noticeable differences or hindrances on the participant while they were performing each activity. However, in certain activities for when I was recording the time it took to complete a certain activity, I noticed that the participant would stop what they were doing in order to listen to the voice AI. But this is more or less of a nitpick rather than a fundamental fault on anyone. In the end, they were able to perform the task asked of them given the restriction that was placed upon them (chewing a certain way, wearing certain gloves).

While I am happy with the results I have collected from these experiments, I am not fully confident in how well it would translate to an individual who suffers from real nerve impairments. For each of these activities, I relied on using modifications and alternatives to represent the most realistic scenario. For example, I am not sure how well wearing thick gloves is close enough to represent nerve damage in the hand. Maybe it is exactly accurate or exactly inaccurate, but again this is something that needs to be explored in further testing. And also the environment I provided and self contained, meaning that I as the researcher was in full control of everything the participant encountered (because the experiments relied on a Wizard Of Oz style approach). But in practical applications, this may not always be the case. For example, it is not always certain that an individual can expect to see every obstacle that is in their path. There could be hidden cracks in the ground, tiny rocks or branches that pose a tripping hazard, or anything along those lines. Testing that is much more difficult and imposes a much more inherent risk on the participant, which is something that should not be risked. But all in all, these results are definitely indicative that a sound based

solution for nerve impaired individuals is viable and should be more studied in the future. There are risks and not every edge case can be covered, but the groundwork is there and it just needs to be built up and improved upon going forward.

CONCLUSION

For this project, I chose to do research on some sort of sound based solution to assist nerve impaired individuals. I would gather data sonically from the environment around the individual based on the activity they were doing, and translate it into data that provides context that they otherwise would not be able to have due to their disabilities. I conducted research and experiments on three consenting individuals, one for each activity performed. The three activities that were performed were measuring temperature, chewing and eating food properly, and moving carefully around objects. I gathered various kinds of data, and this helped me to answer four research questions I created prior to experimenting. From the data and results gathered, I conclude that there is definitely potential for a sound based solution, but there needs to be more field testing and practical applications added. Some further activities to research would be free running, intricate hand activities like sewing or writing, and even large scale activities like heavy lifting. If I were to continue with this project, I would tighten and finalize the data I have gotten already with further testing as I feel it is the foundation for further applications. Then once I am comfortable with that, I would start looking for new ways to integrate my system into different contexts and applications.