INTRODUCTION

Human balance is a complex phenomenon that requires the constant integration of many sensory inputs into precise corrective motions from the body. Maintaining an upright stance requires the body to constantly counter the gravitational forces with just enough corrective torque; too much or too little counter force in the wrong direction can further destabilize the system and lead to falls [1,4,5]. As such, it is important that the brain is constantly fed positional data from the three primary systems responsible for monitoring body balance: the visual system, the proprioceptive system, and the vestibular system [1].

Much of the sensory input for balance comes from the vestibular system. This is a complex sensory motor control system based in the inner ear that monitors the body’s equilibrium, position in space, and other bodily movements such as rotation and translation through space [1]. While both the visual and proprioceptive systems contribute to overall human balance and movement coordination, the vestibular system acts as the primary source of spatial awareness perception, in so much that the brain will override the other inputs when there is conflicting information; this further confirms the vestibular system’s central role in maintaining balance [1,2].

As aging occurs, however, the vestibular system starts to degrade through a process that is mostly unknown, but whose symptoms are widely and acutely felt. Dizziness and vertigo are the two most common complaints of an aging or malfunctioning vestibular system; these symptoms can be temporary or persistent and can lead to further complications such as falling, loss of independence, and depression [1,2].

Various groups have looked into alternative therapies to help restore, retrain, or augment the vestibular system and its functionality with regard to balance [3-5]. In particular, current research has been focused on using vibrational motors in conjunction with an accelerometer sensor to provide patients with real time feedback when they exhibit leaning that could lead to a fall [3,4]. Promising results have led many to consider developing technology using this system that could be easily worn by patients to help them regain their sense of balance and return to normal lives.

OBJECTIVE

The ultimate goal of this project is to develop a functioning wearable prosthetic that would assist in providing sensory feedback on the balance condition of an individual. Vibrational motors placed on the patient are intended to provide spatial feedback for patients that is gathered using an accelerometer placed near the patient’s center of mass.

Currently, the data encoding methods of the tactor motors is being tested in an effort of finding an effective and more meaningful method of providing the patient with spatial information than the currently used on/off binary response. For this research to be meaningful, the hardware being used needs to be characterized so that the exact output modes are known. Thus it is the goal of this experiment to characterize the actual output of the tactor motors and confirm any similarities or differences with the hypothesized output modes.

HYPOTHESIS/SUCCESS CRITERIA

The objective of this experiment was to test current hardware capabilities in outputting the coded signals. For this experiment, two possible signal encoding schemes were used; the first encodement, amplitude modulation (AM), was expected to be a linear increase in the tactor output amplitude as the input was increased linearly, with little to no change in the tactor frequency. For the second encodement, frequency modulation (FM), the frequency of the output signal was expected to linearly increase as the input signal was linearly increased with no change in the output signal amplitude.

For this experiment to be a success, some form of linearity in the relationship between the input and output signal needed to be observed. Deviations from ideal linear relationships could be tolerated if they were proven insignificant or could be easily characterized.

METHOD

For measuring the tactor output amplitude and frequency, a 1.5g triple access accelerometer (MMA7361L) was used to record the motion of the vibration in the z axis. The raw voltage data from the accelerometer was sent to a DAQ (NI USB 6009) where it was sampled at 48kHz, well above the predicted Nyquist frequency of 1kHz. The sampled data was then imported into MATLAB for analysis.

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For the frequency analysis, the data was first downsampled and then subtracted out of all subsequent data sets to remove any DC offsets inherent in the sensor and controller. The root mean square (RMS) amplitude of the vibrations was then obtained using a 100 point moving average filter. The resulting RMS data was then plotted over time for visual verification of the amplitude trend. The amplitude measurements were repeated across 5 samples to verify that all observations were consistent and not anomalies.

For the frequency analysis, the data was first downsampled by a factor of 15 to reduce the frequency range of the resulting spectrogram. A 10th order ChebyshevII filter with a cut off frequency of 40 Hz and a minimum -40 dB side lobe attenuation in the stopband was used to filter out DC level noise and other lower level frequencies since the lowest possible
output from the tactor was 50 Hz. A spectrogram was taken and the resulting plot observed for a linear frequency trend over time. The frequency measurements were repeated across 5 samples to verify that all observations were consistent and not anomalies.

RESULTS

The results of the amplitude analysis can be seen in Figure 1. The amplitude exhibited a fairly linear response to a linear input with a few deviations. There are three prominent spikes that occur at regular intervals constantly across the 5 sampled outputs as well as a nonlinear jump that also occurred at the same time across the 5 samples. The frequency did not alter with the amplitude change.

CONCLUSION

While the results were not exactly what was expected, they did allow for a better characterization of the overall system being developed. While future directions may lead to using different hardware in the final product to obtain better output fidelity, the hardware and software developed to enable these measurements will prove invaluable in any future hardware characterization tests. As prototyping continues and more studies are conducted to help further refine the coding algorithm, we find ourselves one step closer to realizing a functional prosthetic capable of enabling an aging generation to reclaim their balance and their lives.

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REFERENCES