Melody recognition at varying frequency ranges in cochlear implant users

Introduction

Cochlear implants allow individuals suffering from severe hearing loss to hear by utilizing a speech processor, a microphone, a transmitting coil, and an electrode array. Sounds get picked up by the microphone and are converted into electrical signals by the speech processor. These electrical signals are then sent to the transmitting coil, which relays these signals onto the electrode array. The electrode array is surgically placed in the cochlea where it mimics the hair cells of the organ of Corti by stimulating the auditory nerve. The number of activated electrodes can be altered using the speech processor. Studies manipulating electrode number allow for a closer look at how each additional electrode contributes to the hearing process. Such studies help further improvements in the design of cochlear implants.

Background and Purpose

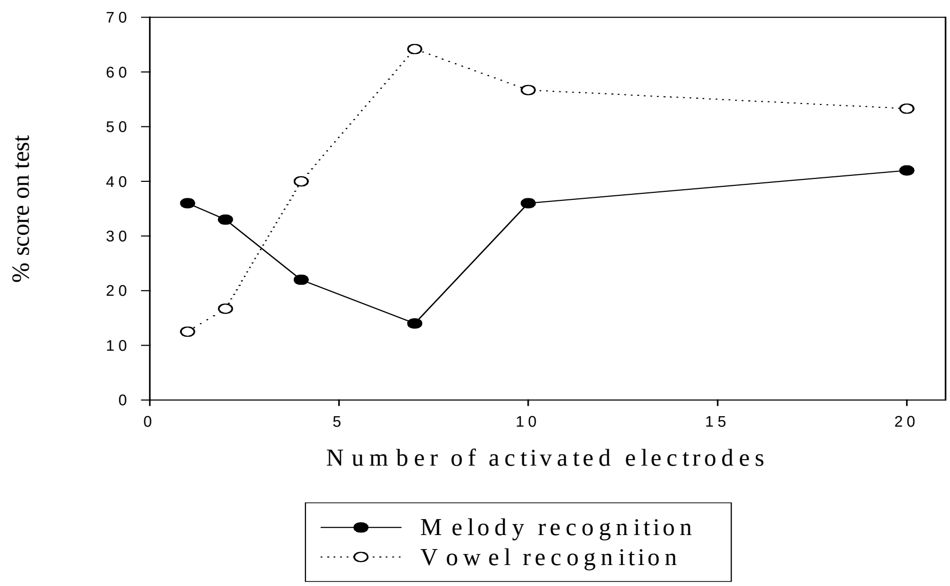
Though cochlear implant users perform similarly to normal hearing individuals when listening to clear speech (Liu et. al. 2003), studies have shown that implant users have significantly poorer performance recognizing melodies than do normal hearing individuals (Kong et. al. 2003). For the past four months I have been working with cochlear implant users to compare their ability to recognize melodies with their ability to recognize speech. I used a test with 12 melodies played 3 times each in random order to test melody recognition. In order to assess speech recognition I used a test with 20 vowel sounds played 6 times each and a test with 20 consonant sounds played 8 times each. I then administered each of these 3 tests 6 times, changing the number of activated electrodes for each trial. The trials included activation of 1, 2, 4, 7, 10, or 20 electrodes.

Past studies have manipulated the number of electrodes stimulated in cochlear implants to determine the contribution of individual electrodes to the recognition of vowels, consonants, and sentences (Fishman et. al. 1997, Friesen et. al. 2001, Garnham et. al. 2002). Both the Fishman et. al. (1997) and Friesen et. al. (2001) studies found that hearing performance for the recognition of vowels and consonants did not improve significantly once 7 electrodes had already been stimulated. Basically, researchers were finding that as more electrodes were stimulated hearing improved until a saturation point, beyond which stimulating additional electrodes lead to no additional improvement in hearing performance. In the midst of this research, it is important to consider that some of the electrodes which appear to have little function in consonant and vowel recognition may have a more apparent function for other hearing tasks such as listening to music.

The melody recognition data I collected did show that some of the additional electrodes that were not contributing to the improvement of consonant and vowel recognition were in fact contributing to the improvement of melody recognition. I also found that melody recognition scores were almost as high with 1 or 2 electrodes activated as they were with 10 or 20 electrodes activated. Thus, instead of the characteristic increase in consonant and vowel recognition followed by a plateau around 7 electrodes, melody recognition showed more of a U shaped curve. The graph below illustrates the disparity between vowel recognition and melody recognition for one cochlear implant subject.

Figure 1. Melody recognition vs. vowel recognition as a function of electrode number.

The focus of my present research is to continue collecting melody and speech data while also trying to determine what is causing this U shaped curve for melody recognition. I turned to the current literature about pitch perception for a possible answer. Pitch perception relies both on the "place code" and the "temporal code" (Zeng 2002). Basically, pitch is determined both by the place along the cochlea where stimulation occurs (the place code) and by the frequency of stimulations (the temporal code) (Zeng 2002). Whether temporal cues or place cues are more important has been a topic of much debate. The Zeng (2002) study found that temporal cues were important for pitch perception up to 300Hz in cochlear implant users. The Oxenham et. al. (2004) study focused on the other side of the debate. That study (Oxenham et. al. 2004) illustrated the importance of place cues since temporal information at the wrong

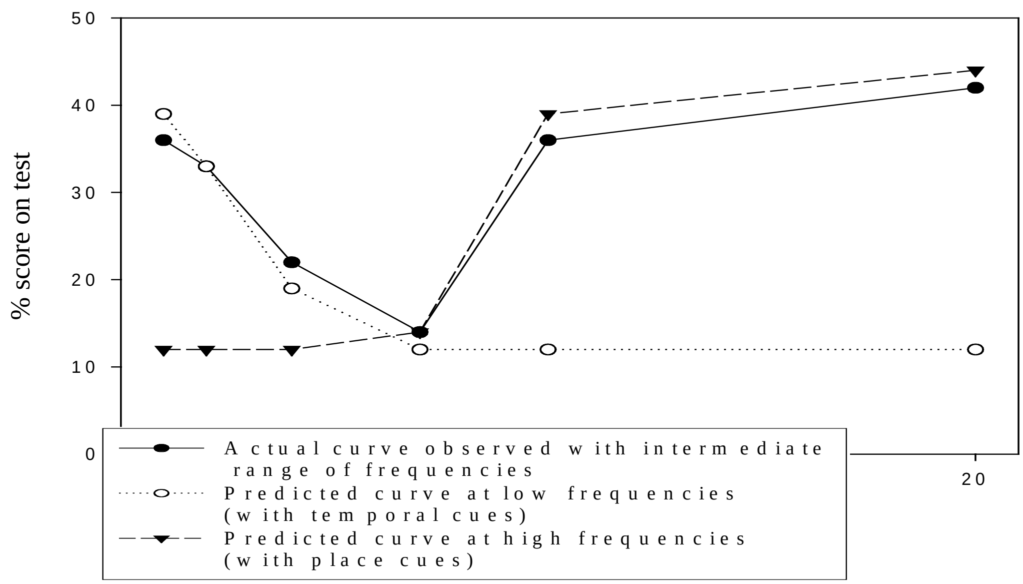


location along the cochlea leads to significantly poorer pitch perception.

Objective

My hypothesis is that with fewer electrodes (1 or 2) activated temporal cues are most important since the cochlea is only being stimulated at one or two spots. However, with more electrodes activated (10 or 20) place cues are most important since the cochlea is stimulated at many different locations. Place cues and temporal cues can be correlated to general frequency ranges using the Zeng study (2002). Considering that the contribution of temporal cues to pitch perception diminishes beyond 300 Hz (Zeng 2002), place cues should have a greater contribution to pitch perception at higher frequencies. Thus, the characteristic U shape I observed using a melody test with an intermediate range of frequencies may be explained as the superposition of two other curves: one for melody recognition at lower frequencies (with mostly temporal cues) and one for melody recognition at higher frequencies (with mostly place cues). Based on this prediction the low performance of subjects with only 4-7 electrodes activated may result because this range of electrodes does not exhibit optimal place cues or optimal temporal cues. A graph illustrating the pattern I hope to elucidate is shown below.

Figure 2. Theoretical depiction of the effects of frequency ranges on melody recognition.



Procedure

To test my hypothesis, the program on the speech processors of the implant users involved in the study has to be modified. I received training last year to learn how to make these modifications using WinDPS software from Cochlear. This software allows the clinician to manipulate the number of activated electrodes while still maintaining the same frequency ranges that are available when all the electrodes are activated. Whenever electrodes are deactivated the C levels (which correspond to the level of comfortable loudness) have to be reassessed for each electrode. Then the electrodes have to be balanced to ensure that the C levels are similar for each electrode.

The program on the speech processors will be modified to simulate having only 1, 2, 4, 7, 10, or 20 electrodes. For each of the above conditions, implant users will be given time to adjust to their new processors. After the adjustment period they will be given 2 types of melody recognition tests. A Graduate student from the Department of Cognitive Sciences has developed both of these melody recognition tests as well as the melody recognition test (with an intermediate range of frequencies from 200-500Hz) that I have been using throughout the year. The first set of tests for this summer will be done with melodies presented at low frequencies (100-250Hz). The second set of tests will be presented at high frequencies (400-1000Hz). Each type of melody test will be administered for all 6 conditions. The melody recognition tests all include 12 common melodies. These 12 melodies will be played three times each in a random order. Individuals are scored based on how many times they recognized a particular melody out of the three chances they were given. The 12 songs being used include: *Old MacDonald had a farm*; *London Bridge is falling down*; *Twinkle, twinkle, little star*; *Mary had a little lamb*; *This old man*; *Yankee Doodle*; *She will be coming round the mountain*; *Happy birthday*; *Lullaby, and goodnight*; *Take me out to the ball game*; *Auld Lang Syne* (New Year's song); and the *Star spangled banner*.

Responsibilities

1. Use WinDPS software from Cochlear to adjust programs on the speech processor for each trial
2. Run both types of melody recognition tests on subjects
3. Analyze data for both presentation and manuscript presentation

Timeline

Month	Expected progress
July	Adjust programs on speech processors and begin running melody test at low frequencies
August	Finish running melody tests at low frequencies and start running melody tests at high frequencies
September	Finish running melody tests at high frequencies, start data analysis, and begin manuscript preparation

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