Pitch Perception Using Virtual Channels

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Introduction

The performance of cochlear implant (CI) users is limited mainly by two factors: The amount of information that can be delivered by the electrical stimulation of the cochlea, and the amount of information that can be received by the user. The maximum amount of spectral information that can be delivered by a CI system depends primarily on the number of electrodes in the implant. In this study, it was investigated whether it is possible to increase the amount of spectral information delivered for a given number of electrodes.

Electrode interaction is the undesirable effect, where the electrical stimuli sent to two electrodes interact to distort the intended perception. It may be possible, however, to use this effect to deliver additional information by stimulating two neighboring electrodes in a suitable manner. It is hypothesized that if two neighboring electrodes are stimulated simultaneously, the user will perceive a pitch that is between the two pitches perceived when the two electrodes are stimulated individually. Thus, a ‘virtual electrode’ or a ‘virtual channel’ can be generated, which corresponds to a frequency band in-between the frequency bands of the two individual electrodes.

Method

• Five subjects implanted with the six-electrode Ineraid array participated in the study.
• Five experiments were conducted, where pairs of neighboring electrodes (1&2, 2&3, 3&4, 4&5 and 5&6) were stimulated simultaneously with a 50 ms burst consisting of symmetric, biphasic pulses with a duration of 40 μs/phase.
• In each experiment, the ratio of the amplitudes of the pulses sent to the two neighboring electrodes was varied: 4:0, 3:1, 2:2, 1:3, 0:4.
• Prior to each experiment, these five conditions were balanced for loudness at the maximum comfortable level using feedback from the subject.
•After loudness-balancing, the subject was allowed to listen to the five conditions until she/he felt ready to start the experiment.
•Finally, the subject was presented with 30 repetitions of each condition in a random order (150 total presentations). The subject was asked to rank the pitch of each stimulus on a scale of 1 to 5.

Results

Cumulative confusion matrices for five subjects (number of trials = 150) for each electrode pair:

Electrodes 1 & 2

	4:0	3:1	2:2	1:3	0:4
4:0	80	41	17	6	6
3:1	38	59	37	10	6
2:2	8	44	68	23	7
1:3	6	9	39	63	33
0:4	6	6	17	48	73

Electrodes 2 & 3

	4:0	3:1	2:2	1:3	0:4
4:0	72	57	13	8	0
3:1	30	43	57	20	0
2:2	5	43	37	52	13
1:3	0	9	43	50	48
0:4	0	1	11	54	84

Electrodes 3 & 4

	4:0	3:1	2:2	1:3	0:4
4:0	60	57	31	2	0
3:1	38	50	53	9	0
2:2	5	28	51	58	8
1:3	0	1	39	68	42
0:4	1	0	13	35	101

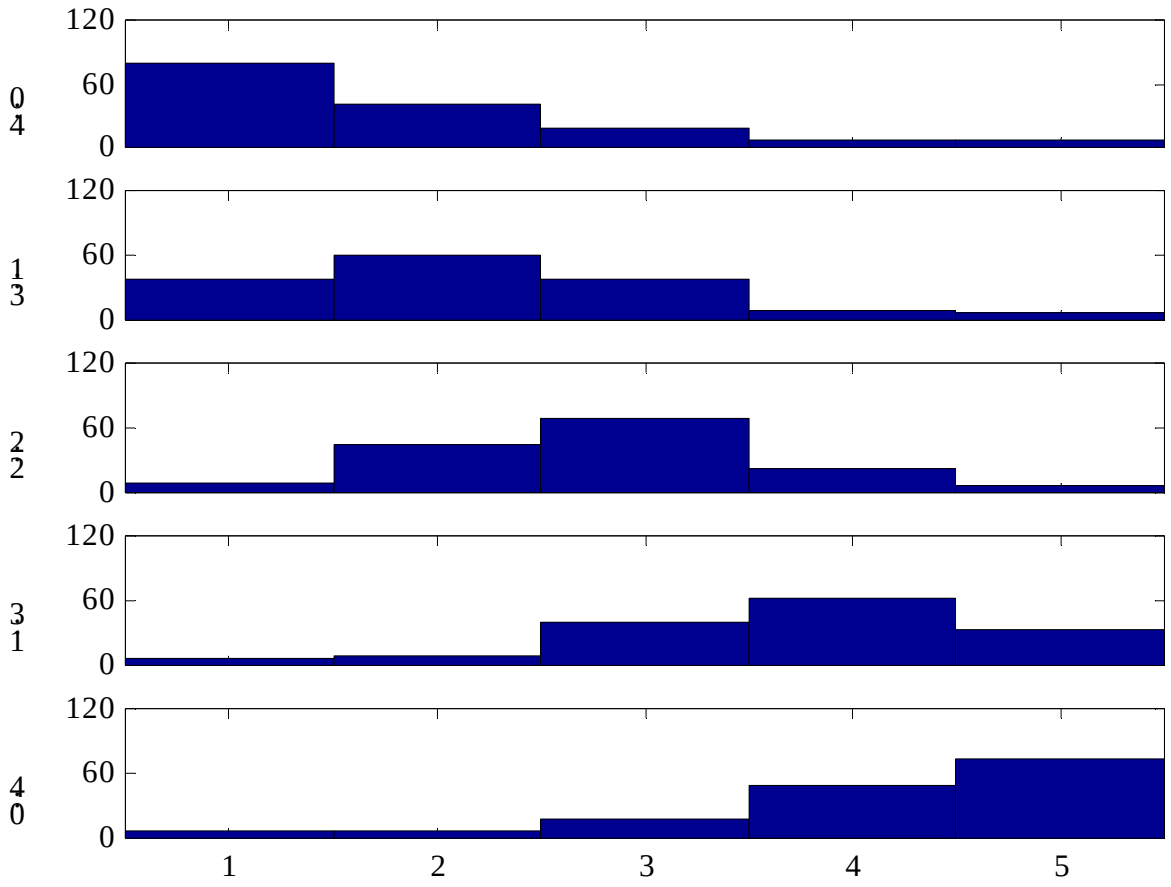
Electrodes 4 & 5

	4:0	3:1	2:2	1:3	0:4
4:0	73	40	22	14	1
3:1	20	68	45	17	0
2:2	11	20	70	44	5
1:3	4	2	28	87	29
0:4	2	0	6	27	115

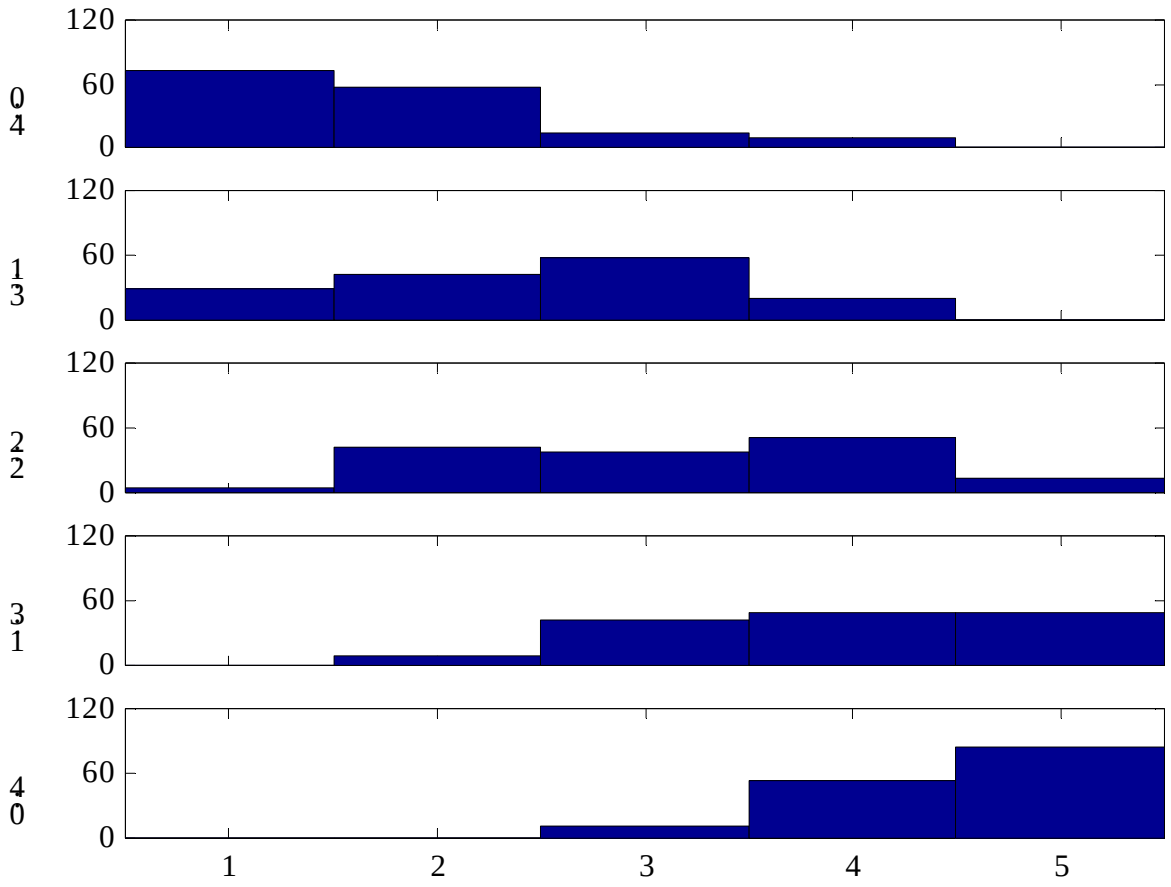
Electrodes 5 & 6

	4:0	3:1	2:2	1:3	0:4
4:0	77	25	38	9	1
3:1	26	65	53	6	0
2:2	3	31	49	60	7
1:3	0	3	21	94	32
0:4	0	2	12	23	113

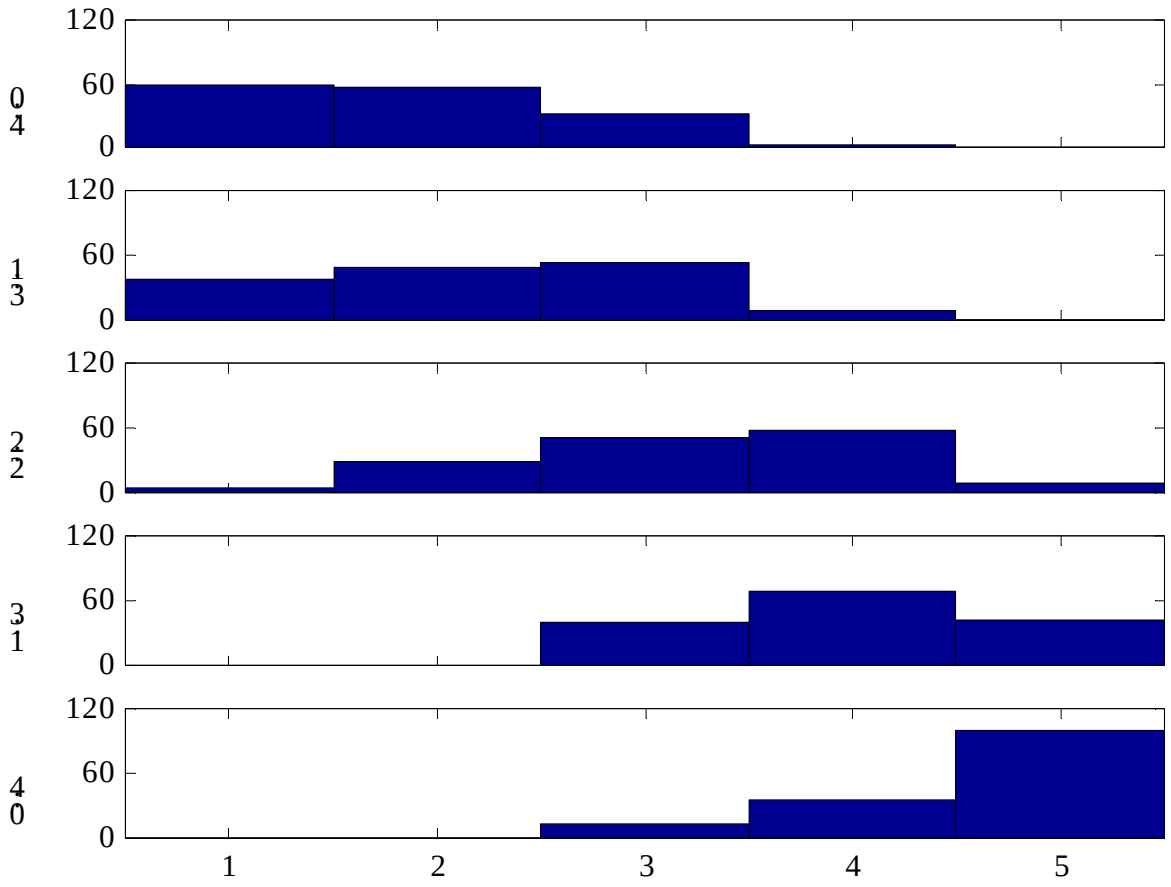
Results for Electrodes 1 & 2



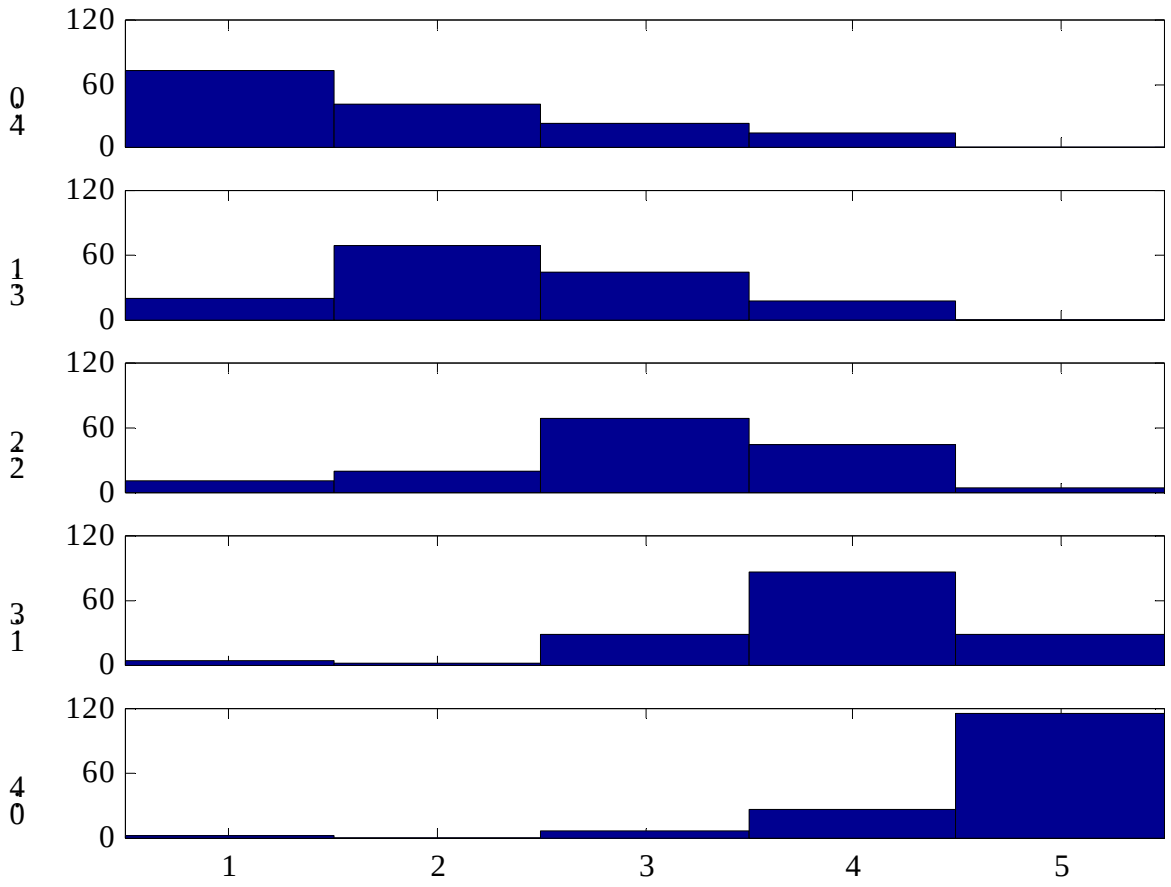
Results for Electrodes 2 & 3



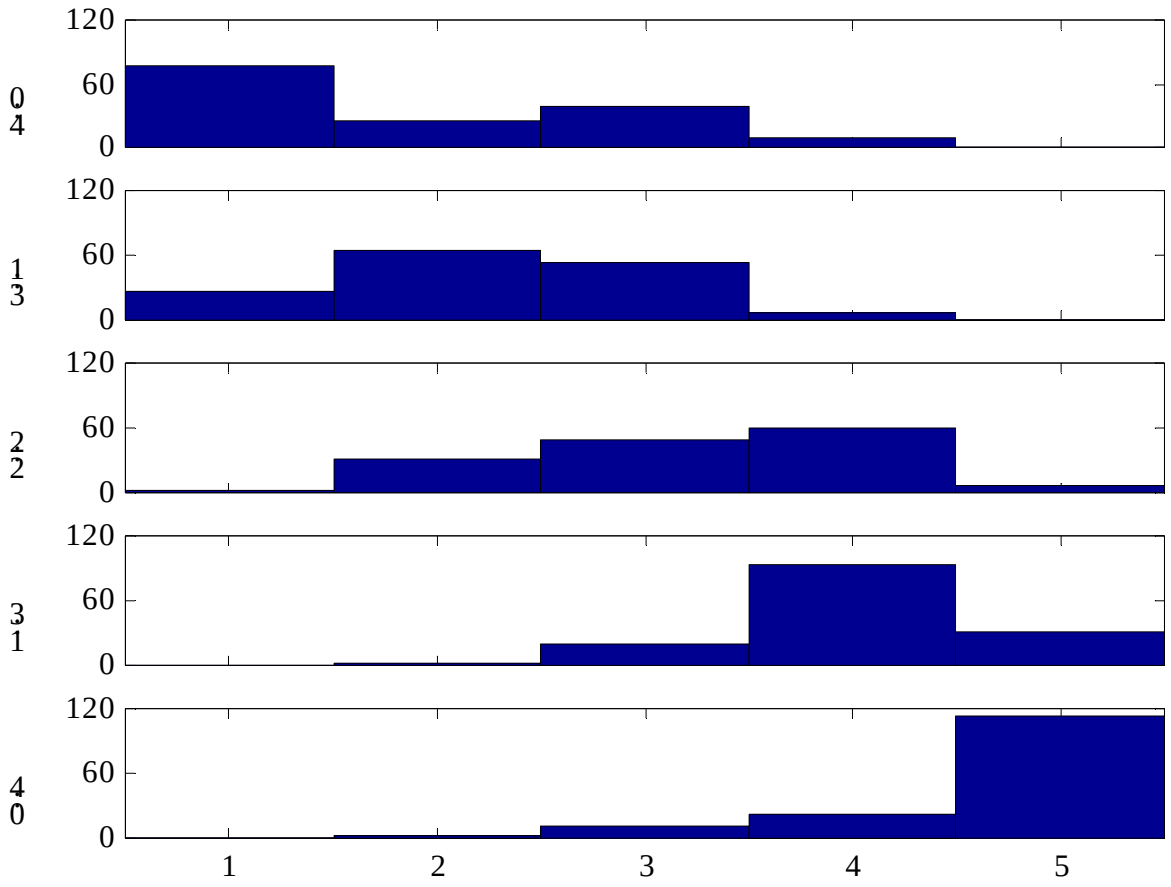
Results for Electrodes 3 & 4



Results for Electrodes 4 & 5



Results for Electrodes 5 & 6



Discussion

• Four out of five subjects reported that, for each pair of electrodes, the five different conditions represented five different pitches. Subject 4 was not able to differentiate between the conditions for the electrode pair 1&2.
• Four out of five subjects reported that the test was more difficult for the more basal pairs of electrodes than it was for the more apical pairs. Subject 4 reported the same pattern with the exception of pair 1&2.
• These results suggest that the idea of 'virtual electrodes' or 'virtual channels' can be used to increase the amount of spectral information delivered to a CI user with a fixed number of electrodes. The challenge is to design a speech processing strategy that can exploit this idea without reducing the amount of temporal information delivered to the user, i.e., without reducing the stimulation rate.

Acknowledgments

Research supported by Grant No. R01 DC03421 from NIH-NIDCD.