Auditory Perception and Cognition

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1. Peripheral interactions in auditory temporal processing

Sponsors
National Institutes of Health, National Institute on Deafness and other Communication Disorders (NIDCD) – R01 DC 03909

Project Staff
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A. Relating speech perception to psychoacoustic measures of cochlear integrity

It has often been difficult to find good predictors of speech reception in measures of psychoacoustic performance. In some ways, given the complexity of speech, this is not surprising. On the other hand, there are some aspects of hearing loss, such as the loss of frequency selectivity and compression, which might be expected to play a significant role in the difficulties faced by hearing-impaired listeners. This project investigates a potential link between speech reception in complex backgrounds and psychoacoustic measures of cochlear nonlinearity. Before embarking on the speech reception issues, it was first important to establish reliable and repeatable measures of cochlear nonlinearity in humans. A study, currently under review (Rosengard et al., 2004), investigated two such measures and compared them in terms of within-subject reliability. Preliminary work on relating these measures to speech reception was reported at the spring meeting of the Acoustical Society of America in New York.

B. Estimating cochlear status via phase effects in masking

The threshold of a sinusoidal signal embedded in a complex-tone masker can depend dramatically on the phase relationships of the masker components. In earlier papers we showed that peripheral compression in a model was necessary to produce the large effects of masker phase found empirically. We have now followed this up by measuring masker-phase effects in hearing-impaired listeners. To test the hypothesis that the size of the masker-phase effects were related to the amount of cochlear compression, we also measured auditory filters shapes in the same subjects. Auditory filter bandwidths have been shown to be highly correlated with other behavioral measures of cochlear compression. Our results showed a strong correlation between auditory filter bandwidth and maximum masker phase effect, in line with predictions based on the effects of cochlear compression.

C. Changes in auditory performance with mild and moderate cochlear hearing losses

A common symptom of cochlear hearing loss is the worsening of frequency selectivity. However, many studies have shown that frequency selectivity only reliably worsens with hearing losses of 40 dB or more. Our hypothesis is that the relative insensitivity of measures of frequency selectivity is due to current measurement techniques, and not to the inherent robustness of frequency tuning in the cochlea. To test this, we used a forward-masking paradigm, which avoids the confounding of suppression and masking effects to provide a more sensitive measure of frequency selectivity (see Shera, Guinan & Oxenham, 2002; PNAS 99:3318-23). Results from subjects with mild-to-moderate hearing loss suggest that changes in frequency selectivity can indeed be reliably observed with hearing losses as mild as 20-30 dB. We now plan to extend this work in collaboration with Dr. Shera, by measuring frequency tuning independently in the same subjects using otoacoustic emissions.

2. Complex pitch perception in complex environments

Sponsors
National Institutes of Health, National Institute on Deafness and other Communication Disorders (NIDCD) – R01 DC 05216

Project Staff
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A. Exploring temporal models of pitch perception

In an earlier study (Bernstein and Oxenham, 2003), we found that harmonic resolvability was not a sufficient condition for good pitch perception; the resolved harmonics had to be low-order harmonics that would normally be resolved for them to play a dominant role in pitch perception. Most current temporal models of pitch perception fail to account for the degradation in perceived pitch when the lower harmonics are removed. Our work was aimed at determining whether this constituted a “fatal” flaw in such models, or whether the predictions could be brought into line with the experimental results by reasonable alterations to the model. We used the model of Meddis and O’Mard (1997; J. Acoust. Soc. Am. 102, 1811-1820). We found that the model inherently “preferred” unresolved over resolved harmonics, in direct contrast to the experimental results, but that much of the discrepancy could be resolved by employing a CF-dependent weighting function within the autocorrelation analysis, which limited the ranges of periodicities evaluated at each CF.

B. Effects of simulated cochlear-implant processing on F0 discrimination in anechoic and reverberant conditions

We recently reported that simulations of cochlear-implant processing, using a noise-vocoder technique produced a dramatic deterioration in performance for speech presented in complex acoustic backgrounds, such as a single competing talker (Qin and Oxenham, 2003). We speculated that this may be primarily due to a loss in the salience of F0 cues through the loss of temporal fine-structure information. This study investigated the effects of noise-vocoder processing on pitch perception more directly. F0 difference limens were measured in anechoic and in reverberant conditions for numbers of frequency bands ranging from 1 to 40. Thresholds were highly impaired, especially with small numbers of frequency bands (and hence wide bandwidths). Reverberation had a detrimental effect only for small numbers of bands, as would be expected through reverberation’s smearing of the temporal envelope but not of the steady-state fine structure.

C. Pitch of transposed stimuli

We have recently discovered that transposed stimuli [van de Par and Kohlrausch (1997); J. Acoust. Soc. Am. 101:1671-1680] provide temporal information on the order of microseconds to the binaural system, but fail to provide similar information to the pitch system. Moreover, while simple (single-frequency) pitch is impaired in transposed stimuli, complex pitch is non-existent. In other words, listeners are not able to integrate harmonic temporal information across different cochlear locations if the temporal information is presented to the wrong locations.

D. Pitch of low- and high-order harmonics: Different mechanisms?

There have been a number of proposals that low-order, resolved, and high-order, unresolved, harmonics are processed via different neural mechanisms. It was suggested that this related to whether the harmonics were resolved or not, but this now seems doubtful, given the work of Bernstein and Oxenham (2003). Nevertheless, the question remains whether different mechanisms govern pitch perception in these two regions. Possibly the strongest version of a two-mechanism theory was forwarded by Carlyon and Shackleton (1994; J. Acoust. Soc. Am. 95, 3541-3554). They reported that comparing the simultaneous pitches of resolved and unresolved harmonics was poor in comparison to when both complexes were either resolved or unresolved. They interpreted their results in terms of two pitch mechanisms: comparisons of the outputs from each mechanism were hampered by a so-called “translation noise”. Unfortunately, their data cannot be taken as evidence either way, as a number of other issues, not related to translation noise, can account for their data. We have provided a more rigorous test of this hypothesis by comparing sequentially presented pairs of tones that are either both resolved, both unresolved, or of mixed status. No evidence for translation noise was found. This does not rule out the existence of two mechanisms, but it does suggest that pitch is coded in a uniform way at the point at which comparisons take place.

E. Significance

The results from the first study have important implications for models of pitch perception. They help to define the limits to which temporal models of pitch can be taken. By explicitly and quantitatively testing proposals that have so far only been made qualitatively, the simulations show to what extent temporal models can be “rescued” in the light of current data that apparently favor more place-based models. The second study has implications both for our understanding of normal hearing and for cochlear-implant processing. It demonstrates, for instance, that reverberation may have a detrimental effect on implant users’ pitch perception that is not found for normal-hearing listeners. The data also provide further support for providing a greater number of independent frequency channels to implant patients. The third study is of a fundamental nature and addresses the age-old question of whether place or timing information is most important in conveying frequency information. It may also have implications for cochlear-implant processing, as it suggests that timing information alone may not be sufficient to accurately code frequency. The fourth study addresses basic issues of pitch coding in the auditory system, which should eventually provide us with a better understanding of how the neural code for pitch is formed.

Publications

Journal Articles, Published

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