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The development of a multi-channel version of the EWAIF model has begun. The revised model is the IWAIF, or Intensity Weighted Average of Instantaneous Frequency model. The intensity is proportional to the square of the amplitude (or envelope) and in an earlier paper the PI had shown that envelope squared weighting worked at least as well as simple envelope weighting. Anantharaman's work, which he used as his masters thesis, led to a much more efficient calculation scheme. The model helps understand the intuitive notion that a signal's IWAIF value is its spectral center of gravity. Thus, EWAIF calculations may indeed have application to spectral shape discriminations.

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DEMODULATION PROCESSES IN AUDITORY PERCEPTION

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ANNUAL TECHNICAL REPORT

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Introduction

The overall goal of this project remains the understanding of human auditory processing of information conveyed by complex, time-varying signals such as speech, music or environmentally-important sounds. Specifically, we seek to model and understand the processing of amplitude and frequency modulation by the human ear. Initially, our work led to the development of a simple, signal processing model, the EWAIF model. EWAIF refers to the notion that simple discriminations between pairs of similar sounds may be based on the Envelope Weighted Average of Instantaneous Frequency. Since the EWAIF model was suggested to explain some unusual behavior by "profile analysis" listeners, it has been tested more rigorously by the profile analysis proponents. The results have been somewhat mixed. While EWAIF was never offered by this PI as a model of profile analysis, Green has incorporated an EWAIF section in his monograph. Tests of EWAIF predictions for profile analysis tasks have been reported by Green and his associates (Richards and Berg) and by Kidd and his colleagues. Also, Versfeld and Houtsma have reported on apparent failures of the EWAIF model for simple multi-tone signals.

Defending the "integrity" of the EWAIF model has distracted the PI from some of the work planned for the past year on this project. We may offer the excuse that at least the EWAIF model has been noticed and the basic ideas applied by our fellow psychoacousticians. It has been apparent for some time that the original EWAIF formulation was too simplistic to withstand rigorous testing by the psychoacoustics community. To that end, the PI has sought to develop a multi-channel version of the model to deal with true, wide bandwidth signals. Further, the incorporation of a temporal processing window seems essential for extension to formant tracking and dynamic signal processing applications.

The development of a multi-channel version of the model has been under the direction of Ashok Krishnamurthy. Working with a first year Electrical Engineering graduate student, Jayanth N, Anantharaman, he has developed a useful extension of the EWAIF model. An unexpected bonus for this effort, is the development by the graduate student, of a related calculation process which is computationally more efficient and intuitively more appealing than the original EWAIF. The revised model is the IWAIF, or Intensity Weighted Average of Instantaneous Frequency model. Intensity is proportional to the square of the amplitude (or envelope) and in an earlier paper the PI had shown that envelope squared weighting worked at least as well as simple envelope weighting. Anantharaman's work, which he used as his masters thesis, led to a much more efficient calculation scheme and to the intuitive notion that a signal's IWAIF value is its spectral center of gravity. Thus, EWAIF calculations may indeed have application to spectral shape discriminations.

To gain entry into the profile analysis research area, the PI encouraged Gail Whitelaw, a doctoral candidate in Audiology, to pursue a study of dichotic profile analysis for her dissertation project. The intent was to determine whether so-called profile analysis was a peripheral or central processing task. Since virtual pitch for complex tones has been shown to be derived from a "central spectrum" (in Houtsma and Goldstein landmark work in 197#), we reasoned that a central process might be required for the determination of a profile. The study was designed to produce profiles in complex sounds only after the information had been combined between the two ears. The dissertation was completed in June 1991, after preliminary results had been presented at the May 1991 Acoustical Society meeting in Baltimore. A manuscript based on the work is in preparation.

A series of FM glide-slope discrimination experiments was conducted over the early portion of the past year. Within the roving frequency paradigm, we discovered a hysteresis phenomenon that seemed almost artifactual until it appeared in related work published by Cullen (1991). An explanation for the slope hysteresis is not readily apparent, but we are encouraged to note that the roving frequency paradigm removes its influence on the slope discrimination task.

In June 1991, at the international meeting in France, Versfeld and Houtsma presented a test of EWAIF predictions that appeared to fail totally. Further, in personal communication, they reported a (then) forthcoming further test that challenged the basis of EWAIF predictions. Since mid-summer, we have conducted replications and extensions of Versfeld and Houtsma's work in an effort to understand the reasons for this apparent failure. We have been partly successful.

Roy Patterson was awarded a Distinguished Visiting Professorship by the Ohio State Graduate School. He spent six weeks in residence in the fall quarter and will return for an additional eight weeks in May- June 92. Funding is provided entirely by the university with no requirements for teaching or other routine service to the institution. We have used the time to continue the collaboration on the integration of EWAIF/ dynamic processing ideas with the SAI model.

List of research objectives and current progress

1. Step vs. Glide discrimination

The manuscript based on this early work continues to "languish" in the word processor. John Madden has been added as a co-author and a major rewriting has been undertaken. Submission in Spring 1992 is expected. Software for roving frequency step vs. glide discrimination has been developed. Collection of pilot data for this phase of the project will be undertaken in Spring 1992.

2. Multi-channel EWAIF model

Anantharaman's thesis was completed in December 1991 and defended in January 1992. A manuscript for submission to JASA is in the works and will be submitted by March 15, 1992. Anantharaman will continue to work on the extensions of the model to include a time window as well as multi-channels.

3. Single step vs. glide experiments

No further progress to report.

4. FM transitions with amplitude contours

These data will be the first modeled in the shot-term running IWAIF model to be developed by Anantharaman. Publication of results is delayed until the modeling is completed.

5. Glide direction and slope discrimination

Chen Yeh Hsu plans to base his dissertation work on modifications of the Patterson Holdsworth ASP model to account for listener performance in this task. Work should be under way in late April 1992 with completion planned for December 1992. Preparation of the manuscript for publication of the experimental results is planned for Spring/Summer 1992.

Participating Professionals

Lawrence L. Feth, PhD	Principal Investigator
Ashok K. Krishnamurthy, PhD	Co-Investigator
Chen Yeh Hsu, M.S.	Grad. Research Assoc.
Patricia Burton, M.A.	Grad. Research Assoc. (9-12/91)
Gail Whitelaw PhD	Grad. Research Assoc. (1-6/91)
Joel Treadway, B.S.	Grad. Research Assoc. (to 6/91)
Jayanth N. Anantharaman, M.S.	Grad. Research Fellow (no cost to this project)
Ina R. Bicknell, M.A.	Grad. Research Assoc. (no cost to this project)

Publications and Presentations

Temporal resolution of frequency-modulated signals by hearing-impaired listeners, J. P. Madden and L. L. Feth. J. Acoust. Soc. Amer. 89, S2008 (1991).

Dichotic profile analysis, G. M. Whitelaw,C. Y. Hsu and L. L. Feth. J. Acoust. Soc. Amer. 88, S1912 (1991).

Identification of Initial Stop Consonants Processed by the Patterson-Holdsworth Model, R. A. Fox and L. L. Feth. In Proceedings of the 9th International Symposium on Hearing, Carcans France, (1991).

Temporal resolution of frequency-modulated tones, J. P. Madden and L. L. Feth. Presented at the annual meeting of the American Speech-Language-Hearing Association, Atlanta, GA. (1991).

Temporal Resolution in Normal and Hearing-Impaired Listeners using Frequency Modulated Stimuli - J.P. Madden and L.L. Feth. to appear in J. Speech and Hearing Res. April (1992).

Auditory Temporal Acuity using Frequency Modulated Sinusoids - L.L. Feth and J.P. Madden. to be submitted to J. Acoust. Soc. Amer. (1992).

Using the Ariel DSP-16 as a Signal Generator for Psychoacoustics Experiments - C-Y Hsu and L.L. Feth, to be submitted to Behav. Res. Meth., Comp. & Instru. (1992).

IWAIF: Intensity Weighted Average of Instantaneous Frequency Model for Frequency Discrimination - J.N. Anantharaman, A.K. Krishnamurthy and L.L Feth, submitted to J. Acoust. Soc. Amer. March (1992).

Patents and Inventions

No patentable inventions have resulted from this work

Statement

Work on some of the main objectives of this project has not been initiated in the sequence originally planned. As with most research projects, answers to the initial questions raised many new and sometimes more challenging questions that the PI decided to pursue. A request for an unfunded extension of the project period from 1 Dec 91 to 31 May 92 was initiated to permit the completion of some work in progress and to provide time for writing up results and development of a competing renewal application for the continuation of the project. A competing renewal application should be ready for submission to AFOSR by July 1, 1992.