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13. ABSTRACT (Maximum 200 words) A series of experiments have been conducted involving studies of precedence, head movements while localizing sound sources and their reflections. Several new findings have emerged suggesting important aspects of auditory processing in reverberant environments.					
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**Sound Processing in a Reverberant World:
FINAL Progress Report for 1996-99**

AFOSR-F49620-96-1-0101

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Sound Processing in a Reverberant World

Objectives: The primary objective of the grant is to better understand the role of head movement in processing sounds, especially in reverberant environments.

Status of Effort: The first experiments to measure head movements while subjects are localizing sounds they can hear and see and sounds they can only hear have been completed, and the results of these experiments were presented at the June meeting of the Acoustical Society of America (Yost and Mapes-Riordan, 1997). We have developed a new methodology for investigating precedence-like effects (Stellmack, Dye, and Guzman, 1998). We studied the role of masking in the precedence effect (Guzman and Yost, in press). We also have collaborated on a major review of the precedence effect (Litovsky et al, in press) in which attempt to establish a nomenclature and organizing theory for the many effects that are collectively referred as the precedence effect.

New Findings:

How do listeners weigh the information from the source and reflections in a precedence-like task:

Relative weights given to interaural differences of time (IDTs) of source and echo clicks were computed for a range of echo delays (1-256 ms) for stimuli presented over headphones. On each trial, source and echo IDTs were selected randomly and independently ($\mu=0$ and $\delta=100$ μ s). Listeners were instructed to indicate the direction of the IDT, left or right, of the source or the echo (in separate conditions). Weights were obtained by computing the correlation between the source or echo IDT and the listener's binary responses. In all conditions, little weight was given to the echo at short echo delays (<8 ms), but the echo was given weight equal to or greater than that of the source at intermediate echo delays (8-32 ms). For echo delays >32 ms, listeners gave greater weight to the source or echo, as appropriate. For all echo delays, when listeners were instructed to indicate the direction of the source IDT, the percent correct was lower when the echo DT varied across trials than when it was fixed at 0 μ s, indicating that the binaural information of the echo was not completely suppressed in any condition.

Masking and the Precedence Effect:

The present experiments investigate the influence of forward masking in precedence effect phenomena. A forward masking and a fusion threshold adaptive tracking paradigm were employed to obtain masked and fusion thresholds (respectively) in the presence of multiple click events (source plus echo clicks) in the free field under conditions of a reversal switch (in which the source click and echo click switch locations) and a lateral switch (in which the source click and echo click move one loudspeaker to the left). In the masking conditions, listeners detected the echo click in the presence of the source click. In the fusion conditions, listeners indicated whether they heard one or more than one distinct click. The relative level of the echo changed based on listener's response following a 1-up 2-down rule. Two tracks with randomly interleaving sequences were used. Results show that although the absolute values obtained are lower for masked than for fusion thresholds, the threshold patterns as a function of number of

click events are similar in the two conditions tested.

A review of the Effects of Precedence:

This work provides a review of recent psychoacoustical and physiological work (since the mid 1980's) on the effects of precedence. The "Precedence Effect" refers to a set of phenomena that exist when listening in reverberant environments. The basic finding has been that auditory perception is dominated by the first acoustic information to arrive at a listener, as if the information from the source takes precedence over that of later arriving echoes. That is, when a lagging (echo) sound is perceptually fused with that of a leading (source) sound, the perceived spatial location of the fused sound is dominated by the location of the lead, and the ability to make discriminations based on the lag is suppressed relative to the discriminations that can be made for the lead. Most of the recent findings and those of early experimenters can be categorized into measurements of fusion, localization dominance, discrimination suppression, build-up of precedence, and breakdown of precedence. When a lead-lag sound that is designed to simulate a source and its echo are repeated, many of the effects of precedence become stronger. Certain changes to the stimulus characteristics of a repeated lead-lag stimulus pair can result in a release of many of the effects of precedence. These measurements have been made both in the free-field and under a variety of headphone listening conditions. These effects of precedence have been measured in many animal models and across the life span for several animals. There is an emerging set of physiological measurements that are relevant to providing a fuller understanding of the effects of precedence. While no fully developed theory or model of precedence has been proposed, different attempts of providing models of precedence are reviewed.

Iterated Rippled Noise:

We have conducted several studies involving iterated rippled noise (IRN). IRN stimuli are generated when a source sound is added to multiple, exact copies (echoes) of the original sound. IRN sounds have a pitch/timbre that is related to the echo delay and the strength of this pitch/timbre is related to the number of echo copies and the amount of attenuation the copies undergo before they are added back to the original noise source. We have shown that the pitch/timbre of IRN stimuli and the strength of the pitch/timbre is not related to the spectral content of the IRN stimuli, but rather to the temporal regularity in the sound's fine structure. This temporal regularity can be revealed by constructing the autocorrelation function of the stimuli. We have shown that a computation model of auditory processing which produces a correlogram (an autocorrelation-like process) can also account for almost all of the data generated to date. Our current work has shown that the envelope of a sound consisting of a direct sound and a reflection cannot be the primary basis for determining the distinct pitch/timbre of the sound. This pitch/timbre is determined primarily by the stimulus' fine structure.

Personnel Supported: P.I.: William A. Yost, PhD, Investigator: Stanley Sheft, PhD, Raymond Dye, PhD; Technician: James Collier.

Publications:

Directly Related to the Grant:

1996

Yost, William A. and Guzman, Sandra J. Sound Source Processing: Is There an Echo in Here?, *Current Directions in Psychological Sciences*, 5, 125-131, 1996

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Inventions or patents: None

Honors: William A. Yost, Fellow, American Association for the Advancement of Science. Doctor of Science, *honoris causa*, The Colorado College, 1997