NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

BNS 79-24645 Chowning

The panel summary was:

"The panel's opinion of this interesting proposal was that the technological approach to the parametric study of reverberation was basically a worthy idea but that so many details are subject to question that full funding should not be awarded at this time. Among the problems were: (1) the heavy dependence on matching as the psychophysical procedure (some discrimination testing would make the notches more interpretable); (2) the weakness of the proposal in terms of basic psychoacoustic theory (the Haas effect has been studied by numerous investigators but its role in echo processing is not given serious consideration; the possible role of low-level real reverberation in the testing environment should be considered in light of the fact that detection and localization can be effected by extremely low-level "off-ear" stimulation); (3) the results may be very useful in deciding how to process recorded music to simulate concert halls or rooms, but how they will be integrated into general theories of binaural hearing is not at all obvious. The panel felt that the interesting techniques for parametric simulation of reverberation could be employed in experiments that avoid the above criticisms, but that some further thought about the designs and data interpretation were needed, perhaps in consultation with a psychoacoustics expert specializing in binaural hearing. Funding for an initial one-year period was recommended to continue the development of the procedures and collect some data, during which time a proposal addressing the above problems might be prepared."

competitive renewal proposal

July

The reviewers, then, raised some serious issues, but were in agreement that this research project was potentially very important, that it may contribute important new data to the understanding of localization of auditory signals, and that the psychophysical techniques were worthy of further development. As a result, the Sensory Physiology and Perception Program recommends support for one year so that the Principal Investigator and his associates can continue studying auditory processing (they currently have a National Science Foundation award that will terminate in April, 1980 to study related topics) while they prepare a new proposal addressing the issues raised in the review process. The research to be conducted in the interim year,

as agreed upon with the Principal Investigator, involves the development of the psychoacoustic techniques and the conduct of preliminary experiments. This proposal was not submitted to any other agencies.

NATIONAL SCIENCE FOUNDATION

PROPOSAL EVALUATION FORM

NSF Form 1B (10-78)
Supersedes Forms 173 and 9

PROPOSAL NO.	INSTITUTION	PLEASE RETURN BY
BNS-7924645	STANFORD UNIV	

PRINCIPAL INVESTIGATOR	NSF PROGRAM
CHOWNING JOHN	SENSORY PHYSIO & PERCEPTN

TITLE

AUDITORY DISTANCE PERCEPTION UNDER NATURAL SOUNDING CONDITIONS

COMMENTS (CONTINUE ON ADDITIONAL SHEET(S) AS NECESSARY)

In my opinion the problem is of fundamental importance. Very little research has been conducted on cues for auditory distance, and while the intensity ratio of direct to indirect sounds has, for decades, been implicated as a primary cue, only recently has this variable been manipulated systematically. Psychologists have failed to realize the profound significance of the cues for auditory "depth", cues which enable us to hear sounds outside our head. (The problem of externalization of visual objects was confronted nearly 200 yhears ago.)

The research facilities certainly appear adequate for the proposed task. The investigators are indeed skillful and have a firm purchase on the multi-faceted aspects of the phenomenon of auditory distance.

My main concern centers about the experimental procedures. Take Part A. I realize that several stimulus factors interact in the process that leads to the perception of auditory distance. Nonetheless, the listener's task which requires manipulating reverberation density, ratio of early to late energy, low-pass characteristics of the room, etc., is incredibly complex. One wonders how closely the multiple adjustments could be replicated. I also fail to understand the rationale for three types of playback conditions. How would the results from each condition differ, and why? My concern about the complexity of the experimental procedures and the demands on the observers extend to the remaining sections of the proposal. That only experienced listeners will participate does little to allay my apprehension. Lest one gets the impression that I question the competence of the investigators in the area of psychoacoustical research, let me say that I consider their work on perception of timbre as first-rate. Among other considerations, the listener's task did not involve an extensive array of stimulus manipulations.

RATING: ☐ EXCELLENT ☐ VERY GOOD ☒ GOOD ☐ FAIR ☐ POOR

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COMMENTS (CONTINUE ON ADDITIONAL SHEET(S) AS NECESSARY)

Quality of Research

This is a very good proposal. There has been very little research until now on the perception of depth or distance in auditory space primarily because of the difficulty in controlling and manipulating reverberation in an acoustic environment. Chowning's lab is probably the best equipped in this country to perform this manipulation. This fact is implicit in the proposal, in that they are not asking for large sums of computer hardware money. The three experiments proposed are 1) a check on the quality of the reverberation simulator; 2) a study of perceived distance as a function of simulated reverberation, amplitude and signal spectrum; and 3) a paired comparisons test on five simulated speaker distances. These seem to be well planned, both in terms of hardware and psychophysical experimental design. I have some concern in the first experiment as to how independent the proposed adjustments will appear to the subject. That is, will the adjustment of reverberation ratio in his example strongly influence the preceding adjustment of reverberation time This is an empirical question, to be sure, but greatly influences the difficulty of task presented to the subject.

A further comment concerns the cues defined in the introduction. I think it is important to differentiate between cues and context effects. I would prefer to reserve the word "cue" for something that can by itself lead to distance perception, such as reverberation. Other attributes, such as "familiarity", or visual information concerning speaker location, cannot by themselves give any distance perception, and thus are more correctly labeled as context effects. This distinction becomes immediately clear when one tries to write down a mathematical model for the distance perception process.

Qualification of Principal Investigators

Obviously well qualified. They are the leaders in reverberation studies in this country.

Budget

Very reasonable. Requests for equipment are minimal, because most of the equipment is already available. The largest item in the budget is salary for one research assistant, plus the inevitable benefit package, plus overhead.

RATING: ☐ EXCELLENT ☑ VERY GOOD ☐ GOOD ☐ FAIR ☐ POOR

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As pointed out in the Research Proposal, many previous studies of distance perception have eliminated, in particular, the influence of reverberation, and for the good reasons mentioned. The present proposal, therefore, has the merit of addressing efforts in this direction. And, since the Principal Investigators seem to have done their background "Homework" rather well and have rather adequate facilities for carrying out the proposed study, it would appear that their qualifications are in the range of good to very good, possibly excellent. Also, their cost extimates do not appear to be excessive.

My first reaction to the title "Auditory Distance Perception Under Natural Sounding Conditions" (my underlining) was that the study was to be made under natural (nature's) settings: "1. of or pertaining to nature. 2. existing or formed by nature. 3. as formed by nature without human intervention." --such as for the Jungle (rain forest) studies of Carl F. Eyring during World War II. Perusal of the "Summary of Proposed Work" and the Introduction, however, indicated that what was primarily intended was----"12. having a real or (man made) physical existence" which suggested such acoustic facilities as concert halls, auditoriums, broadcast studios, theaters, cathedrals, class rooms, etc.

Which of the above (or other types of enclosures) are to be included in the Research Proposal is not made clear although "Concert halls" and "in several different types of reverberant spaces in northern California" are mentioned. Perhaps they also intend to include man-altered natural environments such as out door theaters, Hollywood Bowl type facilities, etc. It would have been helpful had a few sentences been included early in their Research Proposal (and

RATING: ☐ EXCELLENT ☒ VERY GOOD ☐ GOOD ☐ FAIR ☐ POOR

in time, in the research report) as a reader orientation assist in this regard. Also, an early word about the probable range of distances to be covered would have been helpful.

In view of the wide range of signal "quality" that reaches a listener from the same source when placed, in turn, in various possible surrounds (from cathedrals to concert halls to broadcast studios to anechoic space), there is a need for an early more explicit definition of such terms as "in nature", "natural sounding", "natural listening environment", etc. Also perhaps a somewhat less frequent use of some of these terms would be desirable or perhaps alternate replacement terms might be used part of the time.

The statement (p9): "The sound pressure level of the direct signal is inversely proportional to the distance of the sound source." does not necessarily hold in the usual sense of square-law intensity decay. For, Consider the extremes of (1) a speaking tube and (2) a sound-lock corridor, as examples. In the former, the rigid walls so confine the signal that, for all practical purposes, essentially all of the energy entering the tube remains as direct signal with the result that level vs distance falls off very slowly. In the latter case, the "heavy" absorption of the walls, ceiling, and carpeted floor introduces a startling amount of attenuation even at short distances as demonstrated at the 1939-40 World's Fair for visitors who walked through such a corridor. The more usual man-made listening environments are, of course, within these extremes. Outside facilities such as hillside theaters (and to some extent inside facilities) avoid excessive near-head audience attenuation with distance (with or without sound reinforcement systems) by taking advantage of the increasing elevation of increasingly distant rows of seats. Thus indeed (as discussed in considerable detail in the Proposal) the perception of distance is affected by many factors. I believe that the present Research Proposal has the potential of adding significantly to our understanding in a number of these areas.

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Supersedes Forms 173 and 9

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79-24645	Stanford University	

PRINCIPAL INVESTIGATOR	NSF PROGRAM
John Chowning, James Moorer, John M. Grey	Senosry Physiology and Perception

TITLE

Auditory Distance Perception Under Natural Sounding Conditions

COMMENTS (CONTINUE ON ADDITIONAL SHEET(S) AS NECESSARY)

The proposal addresses an important question, and brings innovative use of digitalized sound to the analysis of auditory distance cues. However, there seems to be a missing step. After the production sessions in which natural reverberations are matched, discrimination trials should be done, since the matched artificial signals are useful only if they can not be discriminated from the natural sounds.

Data analysis is presented very casually, as an afterthought.

The budget seems rather large. Why is so much staff needed?

RATING: ☐ EXCELLENT ☒ VERY GOOD ☐ GOOD ☐ FAIR ☐ POOR

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PRINCIPAL INVESTIGATOR	NSF PROGRAM
Chowning, J.	

TITLE

Auditory distance perception under natural sounding conditions

COMMENTS (CONTINUE ON ADDITIONAL SHEET(S) AS NECESSARY)

The P.I.'s have in this proposal brought together their areas of expertice in music, signal processing and psychoacoustics to study auditory distance perception in simulated acoustical environments where the cues for distance can be manipulated independently. The sounds are computer simulated and apparently can be made to match quite well the natural environments within which listeners find themselves. Subjects will be asked to adjust acoastic variables in the synthesized sounds with respect to natural environmental sounds. In the end the P.I.'s wish to develop a model. This is an interesting and important problem in psychoacoustics and the P.I.'s appear to have the backgrounds and equipment to carry out the work. I am concerned about who will do it. None of the P.I.'s have a major commitment to the study and one wonders if this is to be turned over to the unnamed Research Assistant.

RATING: ☐ EXCELLENT ☑ VERY GOOD ☐ GOOD ☐ FAIR ☐ POOR

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I. General Remarks

Previous studies of human sound localisation have in the main dealt with a somewhat restricted definition of localisation in that the primary focus of attention was on factors influencing the perception of source azimuth and (to a lesser degree) elevation. The factors involved in estimating source distance - obviously included in making a complete judgement of a sound source's apparent spatial position - have generally been left unstudied for reasons which the authors of the proposal have indicated: previous researchers could not satisfactorily control the numerous acoustical variables influencing the percept of source distance; nor could subjective responses be analysed satisfactorily to reveal the precise relationships describing how these acoustical variables generate and interact with the relevant psychophysical cues. Consequently, no complete model of this process could be reasonably proposed or tested.

The applicants propose making a highly original, systematic, and fairly comprehensive investigation of this neglected and complicated aspect of auditory localisation and thus, at least begin to rectify the situation described above. More specifically, they have proposed experiments in which they will attempt to clarify the relative importance of some of the acoustic cues (e.g. reverberation factors, intensity, and spectral features) which are likely to influence auditory judgements of distance. In

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COMMENTS (CONTINUE ON ADDITIONAL SHEET(S) AS NECESSARY)

This is a well-written and nicely packaged proposal which requests support of a two-year program of research on auditory distance perception. The project is to be under the direction of John Chowning, Professor of Music at Standord University, and is to be conducted in the facilities of the Center for Computer Research in Music and Acoustics. John Grey, a psychoacoustician (and musician), and James Moorer, an engineer (and musician), are listed as Co-Principal Investigators. The budget consists of nominal (15%) support for the latter two investigators, a graduate student (100%) and two support persons (20% each).

Chowning is an established musician, and is internationally renowned for his contributionss to computer music. There is no evidence in his background of any training or experience in psychophysical research. Given that Chowning is the P.I., his lack of expertise in psychophysics may limit the potential success of the project. However, Grey's strengths will obviously compensate for Chowning's weakness. John Grey is a young and already well-respecte scientist with a recent (1975) Ph.D. from Stanford in Psychology and Hearing and Speech. His major research interest appears to be musical timbre perception (as revealed primarily by multidimensional scaling experiments), and he has published several articles on that topic. He is certain to make major contributions and the project in the area of experimental design, data analysis, and interpretation. Without Grey's association, the project could not succeed

The participation of James Moorer is also felt to be essential. Moorer is a recent (1975) Computer Science Ph.D from Stanford with considerable experience and several publications in the areas of digital signal processing most relevant to the proposed research. Since ever facet of the proposed research depends heavily on digital signal processing, Moorer's skills are essential.

To summarize, in the opinion of this reviewer, the project personnel seem quite adequately prepared to conduct the project and in fact, to make significant contributions in the area. Judged on the basis of participating personnel, then, there is every reason to believe the project will be productive.

The research plan outlines a three-phase approach to the study of auditory distance perception. The objective which appears to guide all three phases of the work is that of deriving a set of rules whereby natural-sounding distance cues may be simulated. The researcl does not appear to involve the search for answers to specific questions about hearing in general or about distance perception in particular. In the first experiments (Part A) listeners will make A-B comparisons between sounds played and then recorded in real rooms

RATING: ☐ EXCELLENT ☐ VERY GOOD ☐ GOOD ☐ FAIR ☐ POOR

and sounds digitally processed (e.g., by adding reverberation) so as to simulate room characteristics. The listeners' task will be to adjust six parameters of the digital processing (interactively) so that the perceived differences between the real and simulated room characteristics are minimized. While the experiments seem straighforward, the investigators' description of how the data are to be analyzed is vague at best. Since no specific experimental questions are articulated, one wonders what purpose the analysis is to serve. Moreover, since the six measures are not "levels" of an independent variable, discriminant analysis seems more appropriate than analysis of variance. Finally, given the apparent complexity of the listeners' adjustment task, it seems reasonable to expect that the order in which the adjustments are made may be important. The investigators apparently have not addressed this issue.

Part B of the research consists of three experiments in which listeners interactively adjust a single parameter of four digitally-processed sounds so that the four sounds, together with a reference sound, form an equal interval scale of apparent distance. In the first experiment, reverberation ratio will be adjusted. Then, using reverberation ratios derived from the first experiment, listeners will perform the same scaling by adjusting the relative sound-pressure levels of the four sounds. Finally, with both reverberation characteristics and relative levels fixed (as measured in the first two experiments), listeners will "fine-tune" their distance scales by adjusting the bandwidth (presumably simply through cut-off frequency of a low-pass filter) of the sounds. As in the case of Part A of the proposed research, the means by which the data from Part B are to be analyzed are unclear. Once again, the experiments are not guided by specific, testable hypotheses, so the purpose, or appropriateness of the proposed analysis of variance is not obvious. Some specific questions that the investigators may need to consider are: 1) How would the experiment be changed if listeners made their fine-tuning adjustments in a different order? The choice of the RR $\rightarrow$ AA $\rightarrow$ FS order in the proposal is not defended. 2) Would the same conclusions be reached if listeners were instructed to form a ratio scale rather than an interval scale? It may be that a ratio scale would be more revealing.

Part C of the research, which involves multidimensional scaling, will attempt to check the "naturalness" of the simulations derived from Parts A and B. Listeners will listen to 15 sounds pair-wise and rate the apparent distance between the members of each pair on a scale from one to 30. The scaling solution obtained by passing the data through an INPSCAL-like procedure will be compared to a similar solution obtained earlier with sounds recorded in real spaces. While many of the details of this part of the project are missing (e.g., how will the solutions be compared?), the intent is clear, and the methods of choice are obvious. Part C is perhaps the most well-motivated part of the project.

One must wonder what will be the end-product of the research proposed here, should it be funded. In most perceptual studies we could hope to learn some basic facts about the underlying processes or mechanisms. The proposal promises that this will be the case here as well, that we will learn about the processes mediating auditory distance perception. However, the experiments as described cannot deliver, in the opinion of this reviewer, any more than a set of rules whereby natural-sounding auditory distance effects can be simulated. Whether we will learn anything about hearing, by constructing or applying those rules, is an open question.