Standardization of Electrophysiological Measures of Hearing in Marine Mammals

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LONG-TERM GOALS

The primary goal of this project is to develop the technology and methods required to make quantitative, repeatable, and interpretable measurements of pinniped hearing sensitivity using averaged evoked potentials recorded from the surface of the head. This effort will advance understanding of marine mammal auditory physiology and provide tools necessary for the study of population-level and species-level hearing so that noise impacts in marine ecosystems can be better understood.

OBJECTIVES

The immediate goals for this project are to: 1) transfer available technology from ongoing research with cetaceans to establish an appropriate system for recording auditory evoked potentials in pinnipeds; 2) develop protocols for electrode placement and stimulus presentation that result in optimal evoked potential recordings; 3) measure the hearing sensitivity of individuals from multiple pinniped species using evoked potential methodology; 4) benchmark the evoked potential measures of hearing against standard behavioral measurements obtained for the same individuals; and 5) compare both behavioral and physiological hearing measures obtained for pinnipeds with those obtained under similar conditions for dolphins.

APPROACH AND WORK PLAN

Individuals from three representative pinniped species (California sea lions, *Zalophus californianus*, harbor seals, *Phoca vitulina*, and northern elephant seals, *Mirounga angustirostris*) are trained for voluntary participation in procedures for behavioral and electrophysiological assessment of hearing sensitivity. Both types of experiments take place in a highly controlled acoustic environment so that

direct comparisons of data can be accomplished. Behavioral data are obtained by measuring a subject's active responses to experimental sounds; in this procedure, the seals are trained to detect and report the presence or absence of different tones that vary in level so that an accurate hearing profile can be determined for each individual tested. This method is similar to that used in standard tests of hearing in children and adults. Electrophysiological data are obtained by passively measuring a subject's neural responses to experimental sounds; in this procedure, recording electrodes are used to detect and measure small voltages, or evoked potentials, generated by the brain in response to acoustic stimulation. This method is similar to that used to test the hearing of infants. Behavioral techniques are well-established for marine mammals; however, electrophysiological procedures require specialized instrumentation and specific knowledge of auditory physiology in the species to be tested. To develop evoked potential audiometry as a tool for rapid assessment of pinniped hearing, a testing system currently used with dolphins is being replicated and adapted for use with pinnipeds. This system will be used to obtain information necessary for the standardization and improvement of methods used to evaluate auditory sensitivity in pinnipeds and other marine mammals.

The program is being carried out by key individuals from three partner institutions: Colleen Reichmuth Kastak and David Kastak from the University of California Santa Cruz (academic partners), James Finneran and Patrick Moore from the US Navy Marine Mammal Program at SPAWAR Systems Center San Diego (government partners), and Dorian Houser from BIOMIMETICA (industry partner). These individuals form a strong cooperative research team with unique combined expertise and interdisciplinary backgrounds. In the current effort, SPAWAR and BIOMIMETICA are replicating and adapting a multi-component electrophysiological testing system currently used to conduct audiometric research and hearing diagnostics in dolphins at the Navy Marine Mammal Program. This specialized system, along with methodological and statistical approaches used to collect and evaluate data, is being shared with the UCSC partners, who are field testing and applying it with representative species of pinnipeds (California sea lions, harbor seals, and northern elephant seals) for which behavioral measures of hearing are available. All partners collaborate on problem solving during system development and in the interpretation of the data collected.

The project began in July 2004 and is scheduled to continue through July 2005. During the next seven months, we plan to use the newly developed system to complete several significant audiometric measurements with pinnipeds that have been trained to voluntarily participate in testing procedures. These include determining the optimal placement for recording electrodes by mapping response amplitude as a function of electrode position on the head, identifying the stimulus types and parameters most appropriate for use in evoked potential measurements with pinnipeds, obtaining frequency-specific hearing sensitivity measurements for multiple individuals, and comparing the electrophysiological measurements obtained for each subject to those made using traditional behavioral methods. Upon the completion of the study, the data will be directly compared to parallel research being conducted with dolphins by our partners at SPAWAR using similar research protocols.

WORK COMPLETED

During the first five months of the project, all necessary permits and permissions to conduct research with trained, captive pinnipeds have been secured (National Marine Fisheries Service Marine Mammal Permit #1072-1771-00, exp. 12/2009; Department of Defense Animal Care and Use Review/Approval; Institutional Animal Care and Use Committee Review/Approval). The electrophysiological testing system has been built and the controlling software has been modified for in-air testing of pinniped hearing. Two of three subjects involved in the study have been trained using operant conditioning and

positive reinforcement techniques to voluntarily participate in electrophysiological testing procedures (*i.e.*, enter the controlled acoustic environment of the hemi-anechoic chamber, allow subcutaneous electrodes to be inserted into the skin on the head and body, position motionlessly at a listening station, and accept exposure to the brief clicks, tone pips, and sinusoidally amplitude modulated signals that comprise the experimental stimuli). All subjects have been trained to participate in frequency-specific hearing assessment using behavioral psychophysical procedures. Research planning and collaboration in data collection amongst all partners has occurred at both the UCSC (Long Marine Laboratory) and the SPAWAR (US Navy Marine Mammal Program) research facilities. Supplementary funding has been acquired from ONR Global to expand the research partnership to include short-term participation from another specialist in marine mammal sensory physiology, Alexander Supin, from the Severtsov Institute of Ecology and Evolution in Moscow, Russia.

RESULTS

No empirical findings on evoked potential audiometry in pinnipeds have been generated at this stage of the study.

IMPACT/APPLICATIONS

Quality of Life

Development of standardized procedures and technologies for evoked potential audiometry that are suitable for marine mammals species are necessary to achieve the ultimate goals of understanding species-specific population level variations in hearing sensitivity and to move toward the ability to measure the hearing sensitivity of species for which behavioral methodologies are not applicable (e.g., baleen whales, beaked whales, Antarctic seals). Such information is essential to mitigating the effects of anthropogenic noise in the marine environment and furthering our knowledge of the role of acoustics in marine mammal biology, behavior, and ecology.

Science Education and Communication

Technical training is being provided to undergraduate and graduate students in the marine sciences and ecological and evolutionary biology programs at UCSC. These students are developing skills that can be applied to future studies and teaching activities related to the sensory physiology of marine and terrestrial vertebrates. The approach being taken in the study and the findings expected to be generated are being shared in the scientific community (*e.g.*, in peer-reviewed publications and meetings such as those organized by the *Acoustical Society of America*) as well with the general public through the public science education programs at UCSC's Seymour Marine Discovery Center.

TRANSITIONS

National Security

The technology to be developed in this study will aid the US Navy in addressing environmental compliance issues related to military noise sources in the marine environment and their effects on marine mammals.

Quality of Life

The technology to be transferred and refined in the current study will provide scientists with new research tools that can be used to help answer questions that have management implications for marine mammals. Additionally, these tools will become available to those working in the field of marine mammal medicine to improve diagnostic efforts in clinical settings and improve understanding of congential and disease processes affecting hearing.

RELATED PROJECTS

"Electrophysiological techniques for dolphin population-level audiometry"
Principal Investigator: James Finneran, US Navy Marine Mammal Program, SPAWAR Systems Center
www.spawar.navy.mil/sandiego/technology/mammals/index.html

This project is conducted by our collaborators in this NOPP partnership. The measurement techniques being shared between the programs represents one of the first substantive efforts among researchers working in the area of marine mammal hearing and noise impacts to collaborate on multi-species investigations using standardized methods to generate comparable results.