CHARACTERIZING SHIP ACOUSTICAL ENVIRONMENTS FOR SPEECH COMMUNICATION

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1. INTRODUCTION

This paper describes one phase of research aimed at developing improved hearing criteria for the Canadian Coast Guard (CCG) [1]. The overall objective was to propose reliable criteria specifying whether or not CCG ship personnel have adequate hearing ability to carry out their jobs proficiently. The main concerns here were speech communication and warning-signal recognition. The required abilities depend on the tasks at hand and on the acoustical environments in which the personnel are working. Thus, it was necessary to include the effects of those attributes of the work environments with the potential to affect speech understanding and warning-signal detection. These attributes include the background noise, reverberation and communications equipment. A detailed task analysis was performed [1]. Typical work environments on board Coast Guard vessels, relevant to these tasks, were characterized – this was the objective of the work reported here. The results were used to calculate SII values for ship personnel with different hearing-loss profiles, to determine the maximum hearing loss that would result in the specified minimum SII [2] and warning-signal and alarm audibility [3].

2. METHODOLOGY

Three CCG departments – Deck, Engineering, and Logistics – and the specific tasks identified for each department, as well as the common tasks identified as a requirement for all departments (i.e., Marine Emergency Duties), were considered. Ship environments in which tests were carried out included the bridge, engine room, deck and galley.

ANSI Standard S3.5-1997: Methods for Calculating Speech Intelligibility Index [4] was used as the basic reference for the work. It contains details of all calculations involved in the data analysis. Acoustical environments for speech were characterized by the Speech Transmission Index (STI) and background-noise levels.

In the present context, the background noise used to calculate SII is the total effective background noise due to the three influencing factors. As discussed in the Standard, their effects were quantified by means of STI measurements made using a speech source (SSARAH), either a regular or dummy-head (KUNOV) microphone, and the Maximum Length Sequence System Analyzer (MLSSA).

STI measurements were done in a way simulating typical ship-communication situations, using a speech source with four output levels (corresponding to four standard speech levels [4]). Ship personnel communicate verbally, both without and with the aid of communications equipment. When communications equipment was involved (non-linear system, involving coupling of a head-set with the listener's ear), a dummy-head microphone was used as the receiver; measurements were made using relevant speech levels (i.e., the source output setting appropriate to the task associated with the test) and in realistic background-noise levels. The effect of the acoustical response of the dummy-head microphone on measured results was taken into account mathematically during subsequent data reduction. When no communications equipment was involved (linear system), measurements were made with unrealistically high signal-to-noise ratios (i.e., quiet ship-operating conditions and using the highest source output setting) to improve accuracy. Background-noise levels in the more realistic operating conditions relevant to the task being considered were measured separately. Final results corresponding to more realistic speech-signal levels, background-noise levels and, thus, signal-to-noise ratios were determined mathematically.

2.1 Background-Noise and Warning-Signal Measurement

The MLSSA system was used to measure, in octave and third-octave bands and under realistic operating conditions, the spectra of the ship background noises at the positions at which STI measurements were made. In addition, the spectra of typical ship warning signals and alarms were measured at appropriate positions.

2.2 STI Measurement

Following are details of the procedures used in the cases of both direct communication and electroacoustical-device communication.

Pre-Calibration

Calibration of the measurement system was required to characterize it for use in correcting measurement data for potential system imperfections. This involved measuring the impulse response of the system in a "perfect' environment (anechoic chamber, microphone close to the source, negligible noise). STI_0 values were calculated from the impulse responses. These were converted to effective signal-to-noise ratios SN_0 and then to effective modulation-transfer-functions MTF_0.

Ship Measurement

In each test environment, source and receiver positions were chosen which were typical of the tasks carried out in those environments. For each source/receiver combination, the MLSSA system was used to measure the associated impulse response. The MLSSA system was subsequently used to determine combined speech and noise-spectrum levels (S_m) and speech-transmission indices STI_m. These were converted to effective signal-to-noise ratios SN_m which were converted to effective modulation transfer functions MTF_m. Corrected modulation transfer functions MTF_c, accounting for measurement system imperfection, were calculated using the calibration data MTF_0. The resulting MTF_c's were then converted to corrected effective signal-to-noise ratios SN_c. These and the measured combined speech and noise-spectrum levels S_m were used to calculate the corresponding equivalent speech-spectrum levels E' and equivalent noise-spectrum levels N'. These noise spectrum levels were added logarithmically to the background-noise levels measured under realistic operating conditions. The final E' and N' values were direct inputs to the SII and warning-signal-detection calculations.

4. ACKNOWLEDGEMENT

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REFERENCES

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NATIONAL CENTRE FOR AUDIOLOGY

Canadian Audiology received a boost with the recent announcement that a National Centre for Audiology (NCA) is to be created at the University of Western Ontario. This initiative will create a national resource at the front ranks of the discipline, internationally.

"The National Centre for Audiology will provide an interdisciplinary environment within which to expand knowledge of hearing function and hearing problems, the needs of people with hearing impairment, and behavioural and technological methods to assist persons with hearing loss. The Centre will assume a national leadership role in the education of Audiologists, Audio Engineers, and other highly-qualified personnel, in the communication of knowledge about human hearing, in the development of public policy relating to hearing health, and in the delivery of hearing health care services to Canadians."

The NCA is being built on the strengths of Western's present program in Audiology. Over the next few years, faculty will be added in key areas of the discipline, educational programs will be revised and expanded, existing research programs will be expanded, and new research programs added. Links between the educational, research and clinical elements of the program are being strengthened.

Funding for the National Centre will come from a variety of public and private sources. One important component -- the enhancement of the research infrastructure of the Centre -- was recently approved by the Canadian Foundation for Innovation and the Ontario Research Development Challenge Fund: together with private contributions, these agencies will contribute more than $3 million towards the purchase of equipment and space for the Centre.

Support for the development of the other components of the NCA is continuing to be sought. Erin Lawson, Community Relations Officer at Western's Faculty of Health Sciences, says that the community response to the NCA initiative has been extremely positive: "in planning Western's 125th anniversary fundraising campaign -- which is scheduled to begin shortly -- what we found was that the NCA initiative was the one that was immediately understood by everyone involved to be relevant and important. It's also been the one that has received the most encouragement from the community and the institution."

For more information on the NCA initiative, contact Lucy Kieffer, Administrative Officer, at (519) 661-3901 or by e-mail at kieffer@audio.hhcru.uwo.ca