THE COMPUTERIZED DIAGNOSTIC RHYME TEST AS A DESIGN TOOL FOR ARMORED VEHICLE INTERCOMMUNICATIONS SYSTEMS

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ABSTRACT

The speech intelligibility of an intercom system (ICS) operated under realistic noise environment conditions is an extremely important parameter in determining the combat effectiveness of the armored vehicle crewman. Almost no evaluation of the intelligibility of the ICS is undertaken during its development phase. This may be due to naivete on the part of the government in requesting such work or on the contractor not wishing to spend the time and money necessary to perform a complete evaluation of system performance. Some testing is usually performed, but it is limited by lack of understanding of the armored vehicle noise environment and in some cases by the lack of the expensive facilities required to simulate the vehicle noise environment. The ASA standard speech intelligibility tests, such as ANSI S3.2-1960 (R1971) are cumbersome and very expensive to run. We wrote a fully automated, computerized Diagnostic Rhyme Test (DRT) to eliminate these problems. The DRT is performed in our Armored Vehicle Noise Environment Simulator, which can simulate all common armored vehicle noise environments in the U.S. Army inventory.

Initial testing of the DRT and simulator began in January 1985 with the evaluation of the currently fielded AN/VIC-1 and three Vehicular Intercommunication System (VIS) Non-Developed Item (NDI) candidate ICS systems. The test system proved to be a valuable tool in the evaluation of these intercommunication systems under normal combat noise environment conditions.

INTRODUCTION

Hearing Damage Risk

The hearing damage risk to the soldier has been known and investigated over the last 15 years. In 1971, a study was completed by the US Army Medical Research and Development Command, which dealt with hearing loss throughout the Army. It reported, that the Veterans Administration estimated, that 52 million dollars was spent in 1970 for hearing loss incurred while on active duty in the Armed Forces. The study goes on to say that it has been conservatively estimated that from 30 to 50 percent of all active duty Army personnel develop some degree of noise induced hearing loss during their military careers.

The Armored Vehicle Crewman must effectively perform his mission in the high noise environment of his vehicle. To accomplish this task he must wear a communications helmet which provides some measure of hearing protection, while at the same time, providing him with intelligible communications.

The communications systems available today in the field provide for marginal protection and barely adequate communications intelligibility. With the introduction of new more powerful, and noisier vehicles, current vehicular intercommunication systems are not adequate. The Surgeon General, for example, requires that all personnel onboard the Bradley Fighting Vehicle wear earplugs in addition to the noise-attenuating helmets they currently wear.

Speech Intelligibility

The speech intelligibility of an intercommunications system (ICS) operated under realistic noise environment conditions is an extremely important parameter in determining the combat effectiveness of the armored vehicle crewman. Almost no evaluation of the intelligibility of the ICS is undertaken during its development phase. This may be due to naivete on the part of the government in requesting such work, or on the contractor not wishing to invest the time and funds necessary to perform a complete evaluation of system performance. Some testing is usually performed, but it is limited by lack of understanding of the armored vehicle noise environment and, in some cases, by the lack of the extensive facilities required to simulate the vehicle noise environment. The ASA standard speech intelligibility tests, such as ANSI S3.2-1960 (R1971), are cumbersome and very expensive to administer.

We obtained the Diagnostic Rhyme Test (DRT) word lists developed by the Dynastat Corporation of Austin, Texas (which is under contract to several government agencies to perform the DRT) and wrote a fully automated, computerized DRT. The DRT is performed in our Armored Vehicle Noise Environment Simulator, which has an accuracy of +/- 1 dB from 31 Hz to 10 kHz, for all common armored vehicle noise environments in the U.S. Army inventory.

It is the intent of this paper to discuss an improved, more realistic, test and evaluation method to be used, as a design tool, by the system developer and the contractor. This is necessary, in the development of new communications systems and audio components, to meet the challenge of these new combat vehicle systems, and the increased requirements for more sophisticated "man-machine" interfacing.

THE SIMULATED NOISE ENVIRONMENT

Justification

In order to properly and completely understand the capabilities of a communications system in an armored vehicle it is necessary to operate this system in the actual vehicle, under operating conditions. This is logistically a serious problem because of the vehicle's location and the time required to operate it to obtain the necessary data. This does not even consider the availability of the vehicle, its crew, a suitable location to drive it, or the formalities and clearances required to get to the vehicle itself. Another serious flaw to this method of testing, is the ability to perform a meaningful speech intelligibility test while being tossed around inside an armored vehicle. The best solution to these problems is the development of an accurate noise environment simulator to provide the evaluator with the noise environment of the vehicle in his laboratory, allowing him the ability to control many of the test parameters. All then that would be required, would be the communication system and the properly trained talkers and listeners to perform the test. This is where additional problems can occur. It is not easy, nor is it inexpensive to build an accurate noise environment simulator. Some testing labs just record the talker reading the word list on the actual vehicle and play back his "speech-plus-noise" signal into the headsets of listeners, who are inside a quiet room in a laboratory. They are not even wearing the same headgear, nor are they connected to the same military communications system as the talker. In many cases, they are connected to commercial communications equipment, which adds another inconsistency to their results. The speech intelligibility test scores achieved by this method are artificially high and causes equipment to be considered "acceptable" when in reality, it is no better, and in some cases, worse than the existing equipment in the field.

One very important reason for simulation is the ability of the investigator to insure uniformity of test conditions and the repeatability of his results. If the test cannot be repeated at any time and obtain the same results, then any results obtained are suspect.

In this paper, the effects on the speech intelligibility of several military communications systems, when they are tested in the quiet, with the talker in the noise, and with both the talker and the listener in the noise, will be shown. All the systems tested that had acceptable DRT scores in the quiet, and with the "talker-only" in the noise, failed dramatically when both the talker and listener operated together in the noise.

The Armored Vehicle Noise Environment Simulator

It is essential that a very accurate simulation be developed, otherwise the test results obtained would be suspect and therefore meaningless. Any failure on the experimenter's part, in assuring that all steps taken to make and generate the simulated noise environment were correct, will result in an improper simulation. This may lead to inaccurate conclusions as to the effectiveness of the communications system to perform in its intended environment.

The first step in creating an accurate laboratory simulation is to make the on-board vehicle noise recording with properly National Bureau of Standards (NBS) traceable, calibrated recording equipment. Calibration tones must be created at the beginning of each recording tape. (Surprisingly enough, this is rarely done properly, if at all.) The recording equipment must have the capability to record the noise environment without introducing clipping or other forms of distortion. The recording equipment must also have the proper dynamic range to cover all the variances in the noise spectrum. One very important factor, often overlooked, is the physical ruggedness of the recorder and associated test equipment, to withstand the shock and vibration which results when driving in a vehicle, such as an M-60 tank. In addition to the recording equipment, an alternate form of measurement, such as a precision sound level meter, with 1/3 octave and narrow-band filters, should be used to assure the experimenter that his recording is accurate.

Once the recording is made, the next critical step is creating the simulation itself. A reverberant chamber is required to attempt to physically re-create the inside of the armored vehicle, while at the same time, to protect the rest of the laboratory personnel from the very high sound pressure levels, which will be generated inside the simulator. No chamber made can accurately reproduce a high noise environment directly from a tape recording and a power amplifier/speaker system. The output of the playback recorder must go through, as a minimum, a 1/3 octave filter to allow the experimenter to adjust for the effects of the loudspeakers and room (chamber) acoustics. Once this is achieved, a method to measure, evaluate, and compare this simulation to the actual noise environment must be made and documented. (We currently have the M-60 tank, M-113 armored personnel carrier, and the M-2 Bradley Fighting Vehicle accurately simulated in our laboratory.)

THE DRT COMPUTER PROGRAM

The DRT computer program was written in BASIC for an IBM PC-XT computer. It was written to be "user friendly" with an easy-to-follow operator's manual. It contains interactive questions, presented to the operator, to help him run through the many experimental setup procedures and options available to him.

The program consists of five subprograms, which were designed to provide the main program with answers to all the variables necessary to perform the DRT. These five subprograms are as follows:

WORDLIST - This program generates up to ten randomized word lists from the basic word list. The randomizing function randomly moves each word pair around in position on the list as well as randomly deciding which of the words in each pair will be considered the correct response. Another part of this program assures the user that each

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randomized word pair appears twice in each list. If for some reason this does not occur, the program informs the user of this problem and rejects that particular word list.

LISTGEN - This program creates a list of test subjects (listeners) and talkers which can be used for later documentation of the test results.

EQUIPGEN - This program creates a list of vehicles (noise environments) and audio equipment (system to be evaluated for speech intelligibility) which are parameters required to obtain proper graphical results.

ANSWERS - This program shows the correct word of each word-pair to the screen of the talker's computer terminal (located in the simulator), at any selected time interval, from one to ten seconds between words. (The time interval we have chosen is two seconds.) The talker's voice is processed by the communication system under evaluation, and is then recorded onto an audio tape recorder, creating the "talker tape". This talker tape can be made with the talker in the quiet or in any noise environment required to simulate the actual noise environment conditions.

TESTPROG - This program actually runs the DRT Test. One or two "listeners" sit in front of their respective computer terminals in the quiet, or in any selected noise environment, while wearing standard or developmental hearing protective devices and communications equipment. They see one word-pair, at a time, on their screens and are requested to press a "," or ".", depending on whether they thought they heard the left or the right word of the pair over their communications system. The computer scores their responses according to equation 1, which corrects for the effects of chance or guessing:

$$Pc = R - W / T * 100 \qquad (1)$$

(Pc is "adjusted percent correct", R is the number of "right" answers, W is the number of "wrong" answers, and T is the "total" number of word-pairs in a particular test session.) The results are stored in a file for future use. At the end of the test session, the computer automatically transfers the "result file" to a "Lotus 123" program for tabulating, statistical averaging, and graphing.

PRACTICAL USE OF THE DRT IN THE NOISE SIMULATOR

Background

In January 1985, we were required to perform a market investigation of VIS NDI candidates. In addition to standard electrical measurements of frequency response, sensitivity, and distortion; each candidate system had to undergo the DRT under three different environmental conditions. The first condition was with the talker and the listener in the quiet room, the second with the talker in the simulated M-113 noise environment and the listener in the quiet, and the third condition of both the talker and the listener in the M-113 noise environment. Each of the three systems tested were compared to a standard AN/VIC-1 intercommunications system, which was used as a benchmark. There were two important questions that had to be answered; what is the effect of the noise environment for both the talker and the listener in the results of the DRT scores and, for this experiment in particular, were there any off-the-shelf intercommunication systems that improved the speech intelligibility of the armored vehicle crewman, over the existing AN/VIC-1 system. The AN/VIC-1 is unacceptable with new combat vehicles, such as the Abrams Tank and the Bradley Fighting Vehicles, due to their higher noise levels than those on existing vehicles. Future requirements for Speech Recognition and Response Systems, Voice Warning Devices, and other state-of-the-art concepts, are totally beyond the capabilities of the AN/VIC-1, because it was designed over 20 years ago; long before any of these concepts were conceived.

Test Results

Figures 1, 2, and 3 show the comparisons of the three prototype intercom systems versus the standard AN/VIC-1 (labeled as STD) when both the talker and listener were in a quiet environment. The candidate systems scored 76%, 82% and 85% as compared to the STD system score of 84%. This test showed that two of the three candidate systems were equivalent to the STD system. All four systems achieved acceptable DRT intelligibility scores. (A score of 75% or better is considered acceptable.) Since these systems are never operated under this condition, these scores are totally meaningless, as shall be seen later.

Figures 4, 5, and 6 show the comparisons of the three candidate intercom systems when the talker was in the noise environment of the M-113 armored personnel carrier and the listener was in a quiet room listening to the "speech-plus-noise" of the talker over a loudspeaker. The volume of the speaker was adjusted to a comfortable listening level. (This test condition is the most widely used by testing labs and therefore it is very important to closely compare these results with those taken with both the talker and listener in the noise environment.) The candidate systems scores 59%, 74%, and 73% respectively. The STD system scored 74%. These results closely parallel the results of the first test environment, showing system 2 and 3 statistically the same as the STD system. These three systems all still exhibit acceptable DRT scores. The first candidate system is now considered unacceptable. Based on these scores, the STD system and two of the three candidate systems would achieve acceptable speech intelligibility. Since it is a known fact that our current system performs marginally in the high noise environment of the armored vehicle, these test results still do not reflect "real world" conditions.

Figures 7, 8, and 9 show the comparison of the three candidate systems when both the talker and the listener were subjected to the noise environment of the M-113 armored personnel carrier. The scores now dropped to 49%, 39%, and 56% compared to the STD system score of 57%. Now none of the four systems had acceptable intelligibility scores. Systems 1 and 2 scores dropped measurably below the scores of system 3 and the STD system. (System 2 for the first time dropping

10% below the score of system 1.)

Conclusions

The two questions raised earlier can now be answered. As the noise environment is added to the test; first with the talker only, and then with the talker and the listener, the scores lower dramatically. If it is required that a communication system operate in any high noise environment, then it is imperative that intelligibility testing be conducted in as close to a realistic noise environment as can be accomplished. Anything less than this, will cause unrealistically high scores to mask the true capability of a communication system to function in its intended environment. If this is not accomplished, the research needed to design systems to properly function in these severe noise environments will not be considered necessary and the armored crewman will continue to suffer along with poor communications systems, increasing his risk of hearing damage. The physical fatigue of working in a high noise environment and straining to understand what is being said to him will definitely impact adversely on the combat effectiveness of the armored vehicle crewman, as well as other military personnel who must operate in high noise environments.

The second question, raised earlier, was whether an off-the-shelf intercommunication system was an improvement over the existing STD system. By looking at figures 1-6, the answer would have been that two of these systems just about equaled the STD system, however, figures 7-9 showed that only one of the systems equaled the STD system and that none of the candidate intercom systems were better than the currently fielded system. This means that more research and development is required into audio transducer design, as well as active speech processing and noise cancellation, before there is an acceptable improvement in speech intelligibility in high noise environments.

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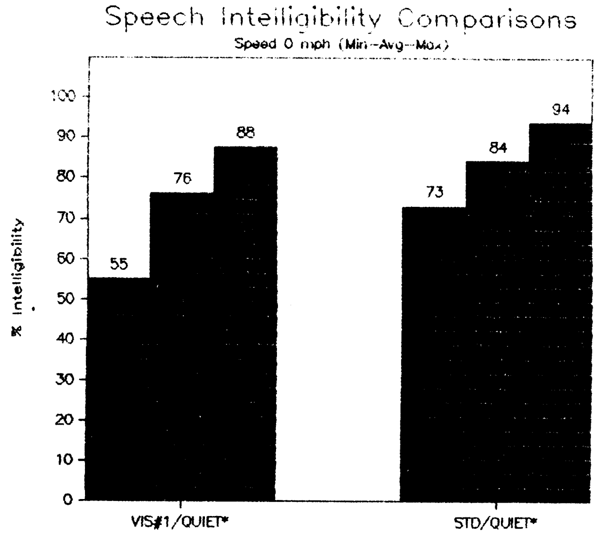

FIGURE 1 All Talkers to All Listeners

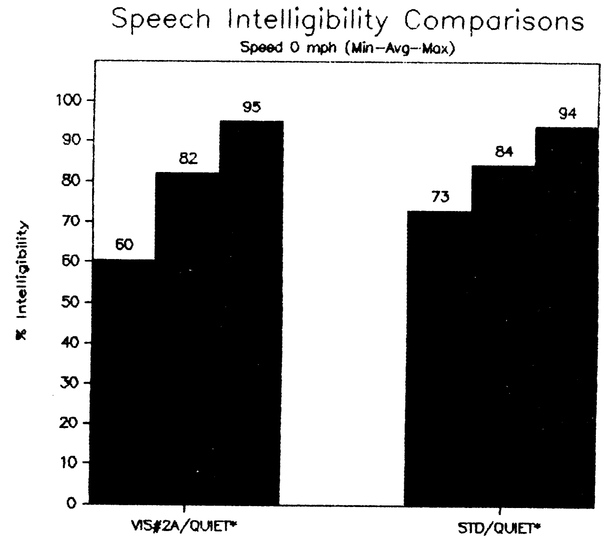

FIGURE 2 All Talkers to All Listeners

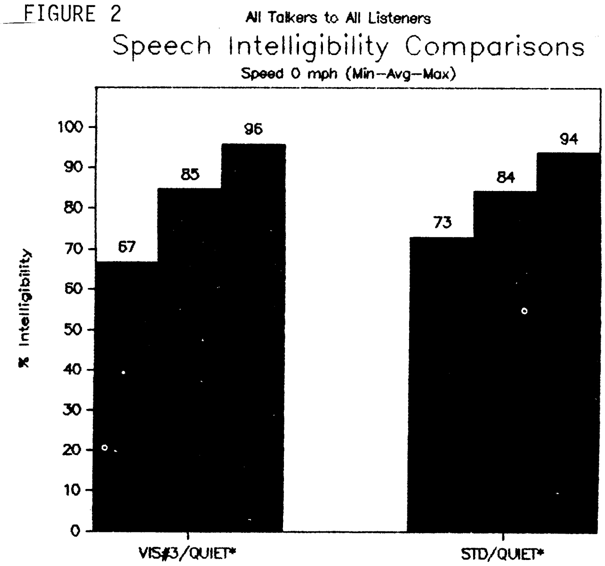

FIGURE 3 All Talkers to All Listeners

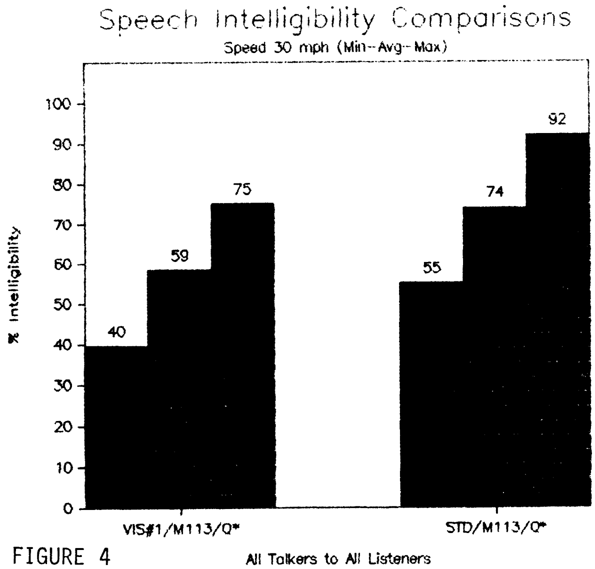

FIGURE 4

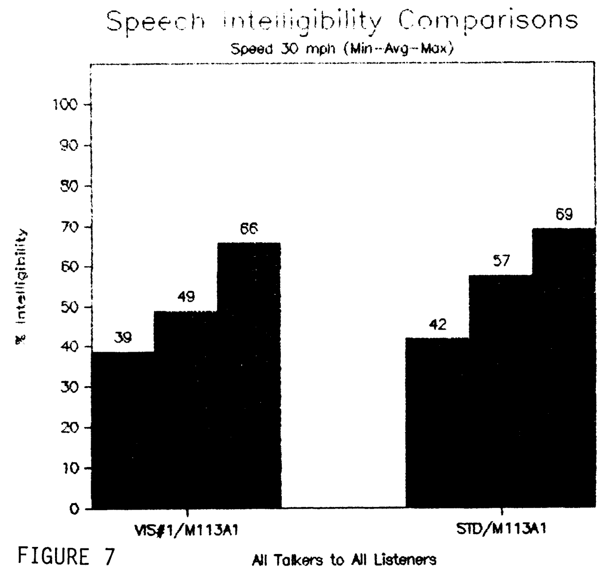

FIGURE 7

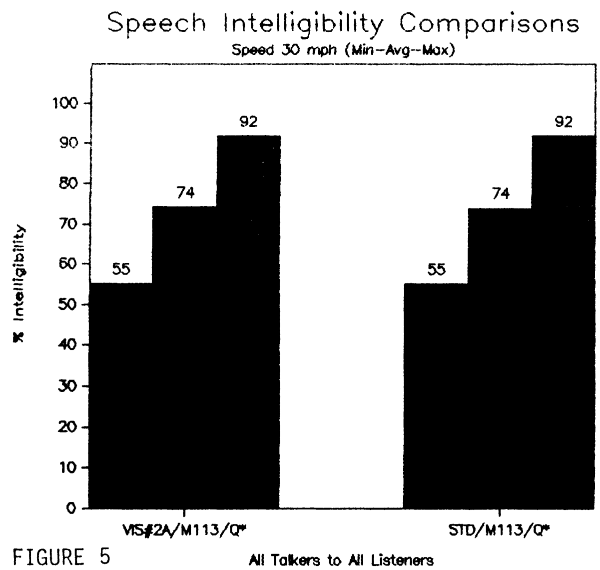

FIGURE 5

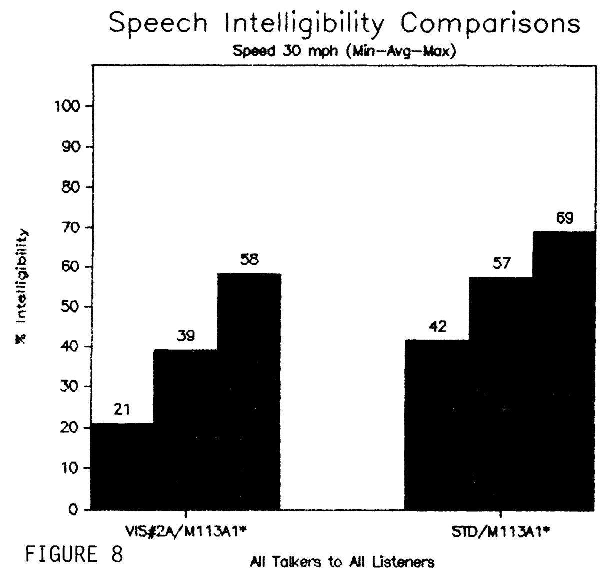

FIGURE 8

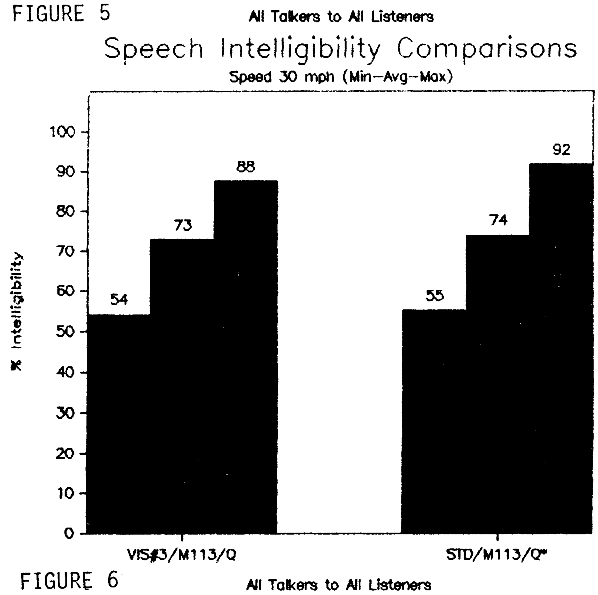

FIGURE 6

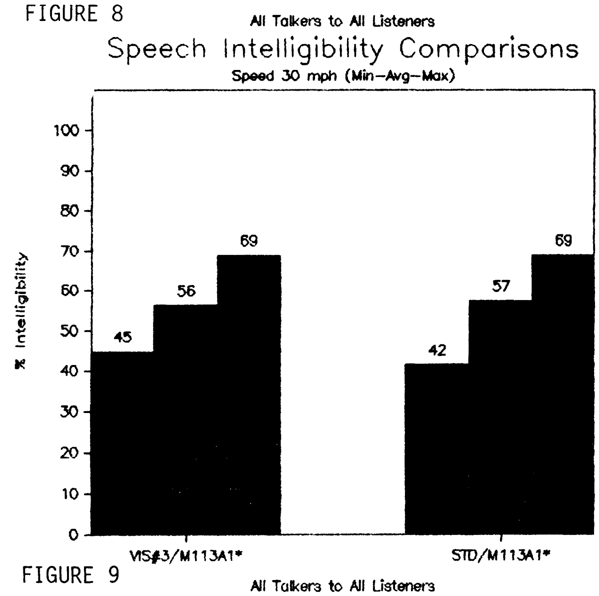

FIGURE 9

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