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AAL: Intelligible City for All

Evaluation of Ecological Intelligibility Test for Normal Hearing and Hearing Impaired

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The project I'CityForAll aims at enhancing the sense of safety and self-confidence of presbyacusic persons whose hearing impairment increases with age. For elderly, this impairment impacts on the intelligibility of vocal messages and the localization of alarm sounds as well as the perception of their alarming power.

Two mobility situations are considered: in public confined spaces and in urban spaces. In public confined spaces, the ICT solutions consist in smart loudspeakers for better intelligibility of vocal announcementments. In urban mobility situations, I'CityForAll partners are developing an embedded system in vehicles for a better perception and localization of alarms. For the intelligibility assessment of public address systems in confined spaces, an in-lab ecologically-oriented protocol was developed, which is derived from the standard Hearing In Noise Test (HINT) used by audiologists. The modifications we introduced to the HINT test concern two aspects. The first one consists in taking into account the reverberation in intelligibility evaluation, coupled to background noise. The second idea is to place the test-subjects in the realistic context of a railway station by using railway station noise and vocal announcements as test conditions.

The proposed eco-test has been carried out at CERTA with a population of 23 subjects including normal hearing and hearing impaired persons. The statistical analysis of the results shows that:

- We obtain different intelligibility score distributions for different test-conditions but having the same equivalent SNR: test condition with noise and reverberation and test-condition with noise only. Hence, the effect of reverberation on intelligibility is different from that of additive noise.
- When the test-subjects have been told they are supposed to be in a railway station at the beginning of the ecological test (reverberation + railway station noise + vocal announcement), the distribution of the intelligibility scores are different from those obtained during the standard tests under the same test conditions but with HINT sentences.

Motivation: highlight the interest of an ecological intelligibility test

Effect of Reverberation Distortion on Intelligibility Measure

Hypothesis

We suppose that the reverberation is a background noise generated by the acoustic reflection of the sound, and that it affects the speech similarly to an additive noise.

Experience

1. We compute an equivalent signal to noise ratio that takes into account noise and reverberation

$$SNR_{eq} = 10 \times log 10 \frac{P_{signal}}{P_{noise} + P_{rev}} \frac{P_{signal}}{P_{noise}} Clean speech power$$

$$P_{noise} Noise power$$

$$P_{rev} Reverberated sound power$$

We obtain HINT sentences with same SNReq but with different SNR and TR60 conditions (Fig.2).

2. We use the Mood's Median Test to compare the distribution of the intelligibility scores obtained with HINT sentences with the same SNReq.

Results

- At the same SNReq, the distribution of the intelligibility scores varies depending on the level of noise and reverberation distortion.
- The effect of noise on intelligibility is higher than that of reverberation.
- Reverberation seems to improve speech intelligibility in noise for some cases.

Conclusion

- Noise and reverberation distort differently the speech: reverberation distortion can not be modeled by an additive noise.
- **Reverberation distortion should be included** audiometric hearing tests



Fig.2: Intelligibility score distributions obtained with test sentences having an equivalent SNR equal to -4dB and -6dB. The distributions were estimated by a "Gaussian kernel estimator" and compared using Mood's Median Test with threshold α =5%^(*) Green: same distribution, Red and Blue: same SNR distortion



(*) Corder, G.W., Foreman, D.I. (2009). Nonparametric Statistics for Non-Statisticians: A Step-by-Step Approach Wiley, ISBN 978-0-470-45461-9



Procedure of Ecological Intelligibility Measure

Purpose of the ecological test :

The proposed ecological intelligibility test aims to stick to the reality and help the patient to be aware of his deficiency. It includes:

1. Hearing In Noise Test (HINT) with reverberation and railway station noise

HINT database: (L1-L5) is composed of 5 lists of 20 sentences each. The duration of a list is 2 minutes. Every list is phonetically balanced. The five lists are segmented in two sub-lists with 10 sentences each (L1-1,L1-2,...,L5-1,L5-2). The first 8 sub-lists (4 lists) are distorted according to one test-condition per sentence (SNR + TR60). The last two sub-lists are distorted according to **one test-condition per sub-list**.

This yields 82 different test-conditions for the HINT test. All test-conditions are summarized in the Table.

2. Vocal announcement test

Test material for railway station situation: 3 vocal announcements (VA1-VA3) of 3s-6s duration will be distorted with three different test-conditions as summarized in the Table. The audiologist asks the test-subject to imagine himself in a railway station.

The test order: HINT test first. Vocal announcement test second

Test procedure: the reverberated speech is played on the front loudspeaker at a fixed level. The noise is broadcasted on the right-left loudspeakers at the given levels to obtain the test-condition SNR (Fig.1).

- The test-subject is asked to repeat the heard sentences.
- The audiologist writes down the responses of the test-subjects
- The whole test-session for each test-person is recorded on a digital device for later processing.
- Inform the test-person when HINT test is finished and Vocal announcements test begins "we are now done with the first test category, we will begin another type of test, so please imagine you are waiting in a railway station ... ' or something like that.

Time required for an entire test session (for one test-person): if we suppose that one list can be played in 2 min, than the test session does not exceed 30 min per person.

Intelligibility score : percent of correct recognized words in sentence.

Classical HINT: phonetically balanced list of sentences distorted with babble noise.

Ecological intelligibility test : phonetically balanced list of sentences and vocal announcements (real sentences) distorted with railway station noise and reverberation.

Effect of a priori Knowledge of the Situational Context on Intelligibility

Hypothesis

We suppose that a priori knowledge about the situational context would improve the intelligibility.

Experience

We compare the intelligibility scores obtained with (Fig.3):

-HINT test with one sentence (test condition SNR = -2dB and TR60 = 4.5 s)

-Five sentences extracted from the same railway vocal announcement (VA2, same test condition as above, duration 2.5s) where before the beginning of the test, the subject was asked to imagine himself in a railway station.

Results

- A priori knowledge about the situational context of the test does not improve the intelligibility for hearing impaired subjects. The lowest scores are obtained for presbycusic persons without hearing aids.
- An intelligibility improvement is observed for normal hearing persons.
- The intelligibility score depends on the content of the test sentence for both normal hearing and hearing impaired.

Conclusion

- The effect of a priori knowledge of the situational context of the test varies according to the category of the test subject (normal hearing, presbycusic...)
- The choice of keywords is important in such ecological tests.
- Vocal announcement test should be included in audiometric tests.

In-lab reverberated sentences Noise level adjusted during the tests 🕁 Right front **P**Left

Fig.1: Intelligibility test procedure

Combination of different sentences distortion

	L1-1	L1-2	L2-1	L2-2	L3-1	L3-2	L4-1	L4-2	L5-1	L5-2	VA1	VA2	VA3
TR60	0	1.5	2.5	3.5	4.5	5.5	6	7	4.5	3.5	2.5	4.5	6
-6	х	х	х	х	х	х	х	х			х		
-4	х	х	х	х	х	х	х	х					
-2	х	х	х	х	х	х	х	х				х	
0	х	x	x	х	х	х	х	х	х				x
2	х	х	х	х	х	х	х	х					
5	х	х	х	х	х	х	х	х		х			
10	х	х	х	х	х	х	х	х					
0	х	х	х	х	х	х	х	х					
2	х	х	х	х	х	х	х	х					
5	х	х	х	х	х	х	х	х					
	HINT Test							•	Vocal Announcements Test				



Fig.3: Intelligibility score distributions obtained with test HINT and vocal announcements sentences with same T60=4.5s and SNR=-2dB conditions. The distributions were estimated by a "Gaussian kernel estimator" and compared using mood's median test with threshold α =5%

HINT sentence : "*La marmotte creuse un trou*"

Announcement1: *"Vous êtes arrivés à Paris-Montparnasse"*

- **Announcement2:** *"Assurez-vous de n'avoir rien oublié dans le train"*
- **Announcement3:** *"Vous pouvez disposer dans cette gare d'un buffet"*
- **Announcement4:** *"D'un service de location de voitures situé voie 22"*

Announcement5: "Et d'une station de taxis situées à Montparnasse 2 Pasteur"

Population composition

- The considered population consists of 23 persons including men and women
- The **age** of the test subjects varies between 28-91



The test-subjects are classified according to their audiometric profiles:

- 7 normal hearing persons
- 9 presbyacusic persons with hearing aids.
- 7 presbyacusic persons without hearing aids

The selection of the population and the audiometric test was conducted by the CENTICH^{*} in France and the same ecological intelligibility test is being conducted by ESCOOP^{**} in Italy.

* Centre d'Expertise National des Technologies de l'Information et de la Communication pour l'autonomie, France. ****** The European Social Cooperative, Italy.

- specialists to better diagnose the impairment of the patient.

- Use realistic ambient noise.
- Use realistic test sentences such as vocal announcements.

Perspectives

- as alarming sounds.
- by the patient.



Description of the Test Population



Average audiogram of the population categories

Conclusion

• Reverberation and additive noise are differently perceived and do not distort speech with the same way. In fact, for the same equivalent SNR including different levels of noise and reverberation, different intelligibility scores are obtained.

• A priori knowledge about the situational context of the test sentence improves the intelligibility for normal hearing persons but seems to degrade the intelligibility for presbycusic persons, especially those without hearing aids.

• On one side, ecological tests may help the patient to be aware of his deficiency, on the other side, it may help audiologists and ENT

◆ Modifications of the classical audiometric test should be discussed with audiologists and acousticians:

• Include reverberation distortion in addition to noise distortion.

• The ecological audiometric test should also include localization tests to evaluate the ability of the patient to localize specific sounds such

• Specific questions should be added to the ecological audiometric test to better understand the deficiencies and difficulties experienced

• Further tests must be carried out with a larger sentences database and different distortions, including reverberation, to better understand the effect of a priori knowledge about the situational context.









