AN ECOLOGICAL APPROACH TO ASSESS AUDITORY PERCEPTION

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1 Introduction

Improvement in auditory perception is a major objective of therapeutic interventions offered to hearing impaired children or adults. Numerous tests are proposed to guide these interventions and assess benefits. Optimally, these tests should explore complex abilities such as those encountered by hearing impaired people in daily life.

In fact, available tests are mostly designed to be administered in a controlled environment (such as a sound booth), in quiet or in a standardized speech spectrum noise issued from fixed positions, often with arbitrarily predetermined signal to noise ratios. For example, the Hearing In Noise Test is based on the repetition of sentences against a 65 dBA speech spectrum noise coming from the front, right or left side. The test has been standardized as an adaptive procedure to determine a speech reception threshold (SRT); however, in clinics and in research, it is frequently administered with predetermined signal to noise ratios (+10, +5, 0 dB). While sentences appear as a realistic daily stimulus, one can argue that a speech spectrum noise issued from fixed positions with variable or arbitrarily predetermined signal to noise ratios can be far from real life.

Yet, it is possible nowadays to recreate realistic soundscapes through multichannel audiovisual systems. This project aims to explore this avenue. Specifically, the objectives are to :

1. design a system that can virtually reproduce everyday sound experiences and offer a more realistic testing condition to assess auditory perception in hearing impaired children and adults, namely localisation abilities and speech perception;

2. specify the psychometrics of the system and define norms from normal-hearing individuals.

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2 Method

The Immersion 360 system has emerged from a pilot project on a prototype system where the feasibility and the relevance of creating virtual environments to assess auditory perception has been confirmed [1]. At this time, experiments showed that altered capacities for speech perception could be observed in a virtual environment despite an excellent performance in a standard clinical setting at a similar signal to noise ratio; more, changing the environment affected the performance, even when signal to noise ratios were kept constant. Therefore, the usual clinical condition did not seem to correctly replicate real life functioning, which is characterized by diverse soundscapes where conversation to noise ratios are in the +3 to +5 dB range in order to maintain intelligibility [2].

From this ground, the Immersion 360 system was developed to virtually reproduce common daily sound experiences in terms of noise type, incoming directions and signal to noise ratios in order to recreate a realistic testing condition to assess auditory perception of hearing impaired persons. As this system can also emulate discrete source positions, localisation capacities can also be assessed with the same equipment. The actualised version of the Immersion 360 system consists of 8 point-source speakers and 8 virtual speakers forming altogether 16 sound sources. These sources are located at equal distance on a 360^0 horizontal arc. The implementation of virtual sources increases the resolution of the system despite a limited number of actual sources, allowing more precise measures of angle errors for auditory localisation in a system based on a limited number of point-source speakers. A meticulous calibration of each source, physical and virtual, ensures an homogeneous loudness across the speaker array. Following suggestions from experienced clinical audiologists, nine common virtual environments were incorporated in the Immersion 360 system to assess speech perception in daily settings (car, garage, cafeteria, restaurant, ball game in a gymnasium, race training in a gymnasium, kindergarten, road traffic, street traffic). These environments were recorded live on locations and reproduced horizontally on 360 degrees. Any other environment needed for clinical or research use can be recorded and integrated in the system.

These two features, that is virtual speakers and integrated environments, distinguishes the Immersion 360 system from similar systems based on an array of speakers [3].

Participants

Eighty normal-hearing adults (18-30 years) were recruited in Canada and in France to assess the psychometrics of the system and define norms for normal-hearing individuals. Hearing thresholds had to be better than 20 dB HL from 250 to 8000 Hz. External and middle ears had to be free of any pathology. All participants were native French speakers.

Procedures

Sentence recognition was assessed with the French-Canadian version of the Hearing in Noise Test or the French adaptation of AzBio [4] in nine virtual environments (car, garage, cafeteria, restaurant, ball game in a gymnasium, race training in a gymnasium, kindergarten, road traffic, and street traffic). These specific environments were selected from a survey completed by clinical audiologists on the most challenging environments in real life reported by hearing impaired people. Speech and noise levels were set at the actual levels collected with a sound level meter on the recording sites. HINT/AzBio lists of 20 sentences were administered in each environment; the score was determined by the percentage of correctly identified words. Presentation order of environment and HINT/AzBio lists were randomly chosen. In order to calculate the test-retest reliability, all tests were repeated one month later with half of the cohort.

3 Results

Averages, standard deviations, and 95% confidence intervals were computed for each test of the Immersion 360 system. These metrics were used to define the normative values for the tests. An analysis of fidelity was used to verify the test-retest reliability for each test of the system and to determine the standard error.

The averages and standard deviations of the speech recognition score in all nine environments were analysed on the perspective of a progressive number of participants, that is 10, 20, 30, 40 and 50 participants. This analysis shows that the variability of these psychometrics remains under the standard error in all tests when 40 to 50 participants are included, and in 91% of the tests between 30 and 50 participants, but fall to 76% of the tests when considering 20 and 10 participants. Stabilization of performance is therefore observed from 30 participants. This confirms that the sample used in the study is sufficient to establish a normative reference.

Table 1 shows that the average performance for speech perception in each environment of the system generally lies between 98 and 100% with a very low standard deviation; the normative lower limit is over 94% (race in a gymnasium). Test-retest showed no significant difference in performance; the maximum standard error is 1%.

Table 1. Psychometrics for the Immersion 360 system

a) AzBio

	Quiet	Car	Street traffic	Garage	Gymnasium Race	Gymnasium Ball	Kinder-garten	Road traffic	Cafeteria	Restaurant
Mean	99,85	99,71	99,71	99,94	95,72	99,06	99,17	98,87	98,43	99,21
SD	0,20	1,05	1,21	1,04	2,83	1,76	0,74	0,91	0,89	0,68
95% interval	99,74	99,16	99,07	99,40	94,23	97,19	99,75	98,48	97,91	98,86
	99,96	99,26	99,34	99,49	97,20	99,07	99,56	99,25	98,94	99,56
p test-retest	0,91	0,32	0,30	0,35	0,43	0,07	0,62	0,73	0,79	0,91
SE	0,11	0,42	0,55	0,74	1,02	0,57	0,41	0,28	0,41	0,49

b) HINT

	Quiet	Car	Street traffic	Garage	Gymnasium Race	Gymnasium Ball	Kinder-garten	Road traffic	Cafeteria	Restaurant
Mean	100,00	99,66	99,61	99,38	98,51	99,88	99,45	99,95	99,76	99,76
SD	0,00	0,78	0,52	1,04	3,72	1,10	0,91	0,14	0,62	0,56
		99,44	99,06	99,01	99,31	99,87	99,33	99,94	99,50	99,59
95% interval		99,87	99,95	99,59	99,70	99,29	99,79	100,00	99,92	99,91
p test-retest		0,45	0,42	0,73	0,50	0,29	0,82	0,33	0,80	0,16
SE		0,25	0,14	0,33	0,17	0,29	0,33	0,04	0,18	0,16

4 Discussion

This study confirms the feasibility of designing a system that can virtually reproduce everyday soundscapes and thus offer realistic testing conditions to assess auditory capacities, such as localisation and speech perception. When applied to a large cohort of normal hearing participants, the Immersion 360 system rendered psychometrics for sentence recognition in the expected range for this population, that is near 100%. This psychometrics can be used as a normative reference for these tests.

The near-perfect performance observed in speech perception in all environments could be anticipated. Indeed, as reflected by the signal-to-noise ratios measured during the recording sessions of each environment, communication partners are always trying to obtain an optimal speech intelligibility regardless of the environmental noise by keeping a positive signal-to-noise ratio. This observation questions the relevance of assessing speech recognition at very low signal-to-noise ratios (0 dB and less) such as frequently done in audiological clinics and in research.

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