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A Subjective Research Regarding the Effect of Acoustic Conditions on Normal and Hearing-Impaired Students

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ABSTRACT

This study was designed to share the first subjective findings of a comprehensive study that examines the acoustical comfort in educational spaces of hearing impaired individuals.

The area of the study identified as an inclusive classroom (A) (without acoustical arrangement) and a special classroom (B) (acoustically arranged) for hearing impaired individuals. In order to comparatively reveal the subjective evaluation of the current acoustical status of the related classrooms, a questionnaire and a speech discrimination test were applied to a group of normal hearing (NH) and hearing impaired (HI) individuals.

In the results of the surveys, it was found that the class (B) is more comfortable and quieter than the class (A), as expected. According to the test results; in class (B) compared to class (A), the percentages of speech intelligibility have shown a significant increase for NH individuals, however, it did not change for HI individuals, contrary to expectations. It is concluded that the different devices used by HI individuals cause this state.

The important outcome of this part of the comprehensive study, is that the acoustical appropriateness cannot be the only design criterion for speech intelligibility in educational spaces for HI individuals.

Keywords: Hearing impaired individuals, Inclusive classroom, Acoustical design, Speech discrimination test.
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1. INTRODUCTION

Education is universally accepted as a fundamental human right. The most important factor underlying this is that education is a very important factor in the development of all aspects of human personality. Therefore, it is very important to create appropriate conditions and methods for each individual to get education without any distinction. These conditions include the training method, the process and the type of education as well as the proper physical environment of the classrooms where the education process is carried out. Because, the physical environment characteristics of classrooms have a great effect on the quality of education and have been emphasized in many researches in the literature [1-6].

In addition to basic design criteria such as designing a suitable seating arrangement, making accessible and ergonomic interior design, it is very important to provide technical equipment for visual and auditory stimulus, to create the physical environment supplying visual and acoustical comfort; while designing a classroom giving common education suitable for togetherness of individuals having special needs with normal/healthy individuals.

The acoustic comfort requirement depending on the speech intelligibility factor comes to the fore in these spaces, due to the fact that the education process is mostly based on verbal-audio communication method. Many subjects related to the speech intelligibility factor and the special needs of the hearing impaired (HI) individuals; such as the communication and education methods, the requirements for physical environment in educational spaces, the support types psychological and medical needs etc., are investigated starting from the 1900s [7-12].

Although many factors such as hearing loss type, degree of hearing loss, hearing loss cause, age, hearing aid used, hearing aid started to use are important in applications for education; the majority of HI individuals are able to obtain clear speech and go to school at a higher rate, owing to early interventions to them [13-16].

Because the hearing needs of individuals are different from each other, basically two different methods of education are implemented to HI individuals: *special education* (if the individual is not sufficient) and/or *inclusive education* (if the individual is sufficient) practices which are classified based on the sufficiency of individuals to study/educate by verbal-audio communication method.

As in the world, *inclusive education* methods also being implemented in Turkey for HI individuals, however, during the implementation, various difficulties are encountered. In addition to difficulties such as lack of curriculum and authorized staff or support services; the insufficiencies of the physical environment also influences the process and quality of *inclusive education* [18]. HI individuals having *inclusive education*, are often educated in "typical" education classrooms which do not have any improvement in terms of physical environment. Acoustically unfavorable ambient conditions such as the problem of echo (caused by the use of hard materials, parallel walls, ceiling, floor coverings), background noise (caused by unwanted sounds coming from different sources inside and outside the classroom); reduce the rate of speech intelligibility in the classrooms, and consequently adversely affect the education of HI individuals [21].

Depending on this detection, a comprehensive study has been initiated to examine the acoustic comfort conditions of the classrooms in which HI individuals have been educated with *inclusive education* method and to contribute to the related literature having some deficiencies. In this paper, the results of the questionnaire and speech discrimination (SD) tests conducted by students are presented in order to reveal the subjective evaluation of the current acoustical status of classrooms for HI individuals determined in

Eskisehir/Turkey. The questions of the survey and the words for SD tests were gathered from the literature [22-30] and they were applied in two different classrooms having different physical environments.

2. EDUCATIONAL SPACE OF HEARING IMPAIRED (HI) INDIVIDUALS AND ITS ACOUSTIC

HI students' educational space requirements may vary depending on the degree of hearing loss. As a method of communication, it is recommended that the verbal-audio method be used as a method of communication in order for HI individuals to use hearing remnants more efficiently. With this communication method, the HI individuals who are considered as having the necessary qualifications required by the educator and audiologist, can continue their education in the *special education* schools with the appropriate curriculum and methods. *Inclusive education* method is recommended for HI individuals who have the ability to study with their normal hearing (NH) peers. It is argued that this method of training also helps to reduce the difficulties of HI people in communication and the distresses they face in socialization [17-20].

HI individuals are recommended to use a hearing aid in order to improve their hearing skills and to hear sounds better. The selection and application of hearing aids are chosen to suit the type of hearing loss, configuration, communication skills and economic level of the patient [19,21]. Hearing aids are categorised as; **portable devices** (such as behind the ear, in-ear, etc. (bone path glasses type, headband type, channel in, and pocket type) devices) and **implantable devices** (such as middle ear implants, cochlear implants, etc. implanted in the bone, brainstem implants). Behind-the-ear hearing aids are mainly composed of microphone, amplifier and speaker parts. The microphone converts sound from the environment into electrical energy, the amplifier turns the electrical signal into the raised electrical signal, and the loudspeaker converts the amplified electrical energy into acoustic energy. Cochlear implant devices are electronic devices that take mechanical sound energy and convert it into electrical signals and transfer it directly to the cochlea, enabling the person to detect sounds [31,32].

The efficiency of the devices varies according to the physical environment of the spaces where they are located, especially the acoustic ambient conditions. Therefore, it is very important to provide acoustic comfort conditions for the HI individuals who continue their education with the help of hearing aids.

In the related literature researches, it is clearly emphasized that acoustic arrangements in educational spaces are necessary for both HI and NH individuals [7-9]. Furthermore, the acoustical parameters and their optimum values reverberation time (RT), background noise (dBA), signal-to-noise ratio (SNR), etc.) required to provide acoustic comfort conditions in educational spaces, have been declared via directions of various international organizations (WHO, EU etc.) and various standards, regulations, etc. (Table 1). In order to make subjective evaluations about acoustic environment, interviews, tests and questionnaires were applied to the educators and the students. Among the subjective evaluation methods, speech discrimination (SD) tests for defining speech intelligibility have been preferably applied by varying the acoustic conditions in the educational spaces. In such tests conducted on NH individuals, the results of speech intelligibility were found to be high in acoustic conditions with low background noise and adequate signal-to-noise ratio [1-12].

As it seen in Table 1, the optimum values of acoustic parameters recommended for acoustic comfort in the educational spaces for NH and HI individuals, are very close to each other. Therefore, it can be inferred that NH and HI individuals can training together in the spaces where the recommended optimum acoustic conditions are provided.

In cases where acoustic arrangements cannot be made, it is recommended to apply FM or Induction loop systems in the education spaces for HI individuals by means of devices such as microphones and amplifiers. In these systems, the sound/speech can be sent directly to the ear / hearing aid thanks to the microphone which is close to the sound source. Thus, the sound/speech can be transmitted to the HI individuals, by being less affected or not affected by the physical environment.

Table 1. *Recommended optimum values for classroom acoustics* [30,34-37]

	Reverberation Time (RT)	Signal-Noise Ratio (SNR)	Background Noise (dBA)
WHO (normal)	0.6	-	35-55
ANSI (normal)	0.6 – 0.7	-	-
BB93 (normal)	0.8	-	35
BB93 (hear imp.)	0.4	-	35
ASHA (hear imp.)	0.4	15	30-35
BATOD (hear imp.)	0.4	15 – 20	35

3. APPLIED FIELD STUDY

3.1. Identifying the study areas and the participants

In terms of physical environment and acoustic conditions, two different classrooms were identified as the study areas. One of the classrooms is the Classroom A, which has acoustic arrangements both in building design and space planning and provides *special education* to the HI individuals. The other is Classroom B, which does not have any acoustic planning and/or arrangement, and has typical classroom design where *inclusive education* is applied (Photo 1,2).

Photo 1. The schools where the study is conducted and the classrooms identifed as the study area. [38]

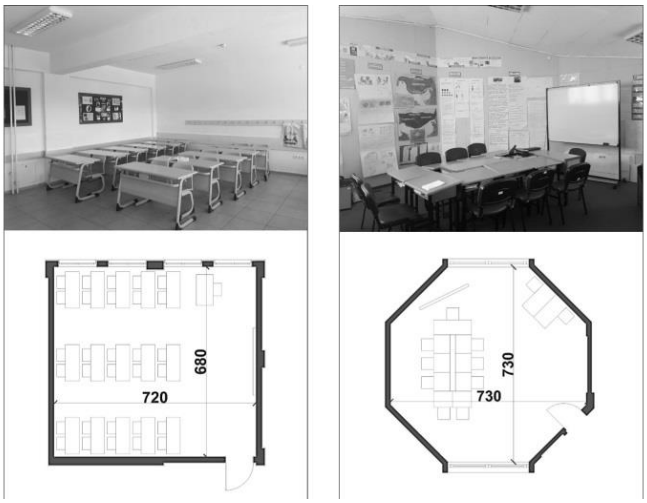


Photo 2. Visuals belonging to classrooms.
Left - Classroom A; Right – Classroom B.

The subject group consisted of 14 students in total, 7 HI individuals providing the same conditions in terms of hearing loss type, degree of hearing loss, age and corresponding to this number, 7 NH individuals without any health problems. Although the HI individuals in the subject group have common conditions for the hearing impairment, the hearing aids they use differ. 5 of HI individuals use cochlear implant and 2 of them use behind the ear hearing aid. Table 2 shows the distribution of individuals from the subject group according to genus and type of hearing aids (Table 2). The cooperated audiologist and the engineer (hearing instrument engineer) foresee that this difference has not a great importance and the HI individuals are positively or negatively affected from the environment conditions, at the same level.

Table 2. *Number of individuals in the subject group.*

	Gender			Hearing Aids		
	Female	Male	Total	Behind the Ear	Cochlear Implant	Total
NH	3	5	8	-	-	-
HI	4	2	6	2	5	7
Total	7	7	14			

3.2. Application of the Survey and Speech Discrimination Test

A questionnaire, consisting of 7 questions about how they evalute the sound environment in the classroom, what type of sounds from inside and outside of the classroom and how the sounds disturb them, how they are affected by noise, etc., was applied to subjectively evaluate the current acoustic comfort status of the classrooms where they were. In the continuation of the survey, SD test consisting of phonetic balanced (PB) monosyllabic Turkish words (Table 3) was used and the results were evaluated within the scope of the study.

Table 3. *Phonetic balanced (PB) Turkish single syllable word list example.* [33].

Kas	Küf	Göz	Muz	Borç
At	Saz	İn	Ak	Fil
Ney	Fon	Kar	Örf	Et
Öç	Yün	Laf	Çat	Hür
Bir	Beş	Diş	Az	Pes

The questionnaire and SD tests were applied to the group of subjects consisting of 14 students simultaneously as single group in Classroom A, as 2 groups consisted of 7 students in each in Classroom B. During speech discrimination test,-a female vocal read 2 sets of 25 words which were gathered in different array from PB single syllable word list, with 5 seconds intervals between each words. The students participating in the test were given a blank answer sheet, and were asked to write the word during the 5 seconds after the vocalization. The same procedure was repeated in both classromms (A and B).

3.2.1. Evaluation of Survey Data

The results of the survey were clarified by calculating the arithmetic average of the answers given by the group and they were expressed as a percentage.

For the question asked for determining the awareness of the subject group about the current acoustic status of the classroom where they are, 57% of the participants defined the acoustic environment of Classroom A as "complex" and 50% as "discomfortable"; when 50% defined the Classroom B as "comfortable", and 79% as "clear and understandable".

Both classrooms (A and B) are exposed to different noise levels due to their locations in the school buildings (Photo 1). Because of this difference, in the question of the “How do you find the noise level in the classroom”, 50% of respondents found the classroom A as "noisy", 64% of them found the Classroom B as "quiet".

In continuation of the survey, indoor and outdoor factors causing noise was listed and asked to be signed the disturbance levels of the factors through the options ”Nothing“, ”A little“, ”Medium“, ”Too“, ”Too Much“.

Due to the differences between the floor coverings of the two classrooms, "the table and chair dragging noises" were found "a little disturbing" in Classroom A at the rate of 64%, and it was found "not disturbing" in Classroom B at the rate of 71%.

86% of the students did not find the mechanical noises as uncomfortable for both classrooms (A and B) due to the lack of ventilation system, computer and electronic devices in the spaces designated as the study areas.

Because of the prediction by authors about that the geometric form, the angle and the coating material of the wall and ceiling of the classrooms affect their acoustics, the students were asked to answer the question of "How uncomfortable are the echoing sounds?". 50% of them rated the Classroom A as "Medium", and 86% rated the Classroom B as "None".

Depending on the project of the school building, the designated classrooms are exposed to different levels of noise from the corridor due to their location in the building. In the question asked for this, 48% of the subjects in the Classroom A found the noises coming from the corridor to be moderately disturbing, while 71% of subjects in the Classroom B did not find any disturbing noises.

Due to the location of the children's playgrounds in the school, different distances from on-campus roads, temporary construction areas and the ring road, classrooms are exposed to different levels of external noise. In this context, the disturbance of external

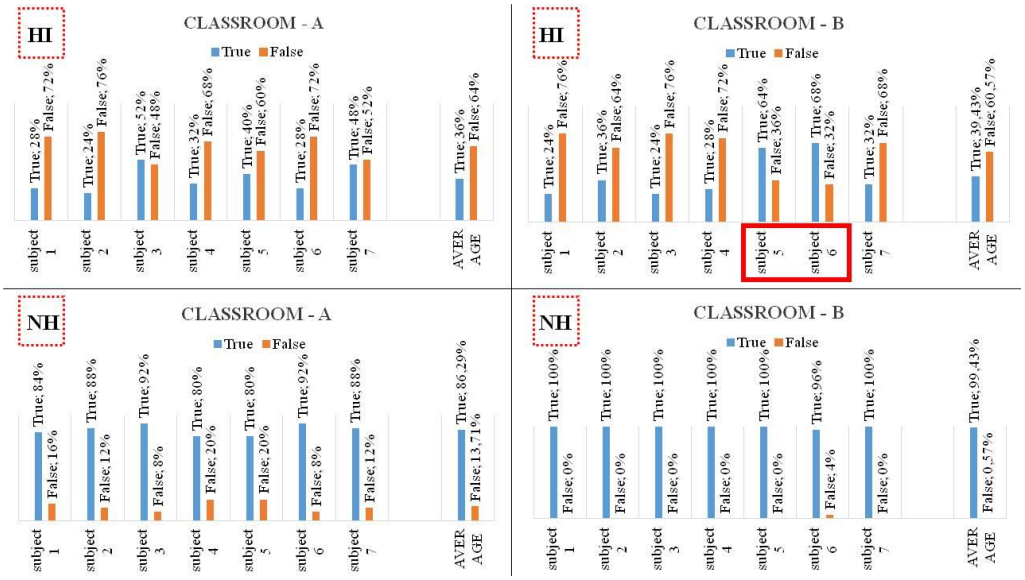
noise were evaluated by 36% of the subjects as a bit annoyed in the Classroom A and 64% as not annoyed in the Classroom B.

As can be seen from the results of the survey, the Classroom B, which has an acoustical interior layout and has been properly positioned within the building, has been evaluated favorable by the students as compared with Classroom A which has a typical classroom interior layout devoid of acoustical subjects. The students evaluated the sound environment of the Classroom B- comfortable, clear and understandable, and the degree of noise level and the degree of being influenced by internal and external factors causing noise were found low. On the other hand, they stated that Classroom A which is not acoustically arranged, were found to be acoustically complex and noisy, and they were affected by the noises from the corridor, the garden and around the school.

3.2.2.Evaluation of Speech Discrimination (SD) Test Data

In the SD tests , the answer sheets filled out by each student were checked and the speech intelligibility percentages were calculated. In these calculations, it was taken as a criterion that the student correctly perceived the word that he/she heard and wrote it on the paper. Photo 3 shows the results of the tests (Graph 1). The results were expressed as a percentage by calculating the arithmetic average of the correct and wrong words written by the subjects (separately for NH and HI group) in Classroom A (Test 1) and Classroom B (Test 2).

- Test 1, Class A, Percentage of speech intelligibility for HI subjects 36%
- Test 1, Class A, Percentage of speech intelligibility for NH subjects 86,3%
- Test 2, Class B, Percentage of speech intelligibility for HI subjects 39,4%
- Test 2, Class B, Percentage of speech intelligibility for NH subjects 99.4%



Graph 1. Results of speech discrimination tests for study areas.

Considering the results of the SD tests, it was observed that the percentage of NH subjects speech intelligibility had increased as expected. However, contrary to the expectations, it was found that the acoustic conditions of the spaces where they were, did not have a great effect for the HI individuals. According to the results, it was determined that the average of speech intelligibility percentage of HI subjects was very low compared to the results

of NH subjects. At the same time, in Classroom B which is acoustically arranged, the percentage of speech intelligibility showed an increase of 13% for NH subjects, whereas there was no significant increase for HI subjects. This shows that the difference of acoustic conditions between the two classrooms does not have a significant effect on the HI subjects' speech intelligibility. However, it was found that the percentage of speech intelligibility in some subjects (Subject 5, Subject 6) increased with a percentage more than 25% in Classroom B compared to Classroom A, when analyzed the results in detail according to HI individuals one by one (Graph 1). Therefore, this situation was discussed with experts (educator, audiologist and electronic engineer) and it was concluded that the different working principles of the hearing aids used by HI individuals may cause differences between the results obtained in the tests. Therefore, depending on the acoustic conditions in the spaces where they are, the speech intelligibility differs greatly for HI individuals using behind-the-ear digital hearing aids, whereas in cochlear implants this situation is completely uncertain. However, in order to be able to say this result certainly, it is necessary to increase the number of subjects and to compare the results of individuals with cochlear implants and individuals using behind the ear hearing aids over the ratio of speech intelligibility. In this study, the number of data is insufficient for the comparison because of the presence of 7 people, 2 of whom have behind the ear hearing aids and 5 with cochlear implants.

4. CONCLUSION / EVALUATION

Due to the hearing impairments of individuals, different needs arise in different periods of their lives. For example, a HI individual who is in education period has many requirements such as appropriate education method, physical environment etc. In order to be able to evaluate the hearing residue in a positive way, individuals who use hearing aids and continue their education by verbal-audio method, need an acoustically good educational environment. Since most NH individuals can easily acquire and use their native language, speech intelligibility rate is much better compared to HI individuals. Therefore, most NH individuals are able to continue their education in typical, general and common (in spaces that do not have any acoustic arrangement) classrooms. In contrast, HI individuals need an acoustically improved environment (without echo, low noise level, direct sound can be heard clearly etc.) because they are more affected by all noises in the environment. Since it was thought that it would benefit the subjects such as socialization and adaptation to society, it was inevitable to create a suitable educational environment for both groups on the recommendation of the education (inclusive education) of the HI individuals together with their NH peers.

In the literature, there are many studies on acoustic comfort conditions for the educational spaces of HI and NH individuals. With the results, it is emphasized that providing acoustic comfort in educational spaces positively affects the speech intelligibility and accordingly the quality of education, acoustical parameters and their optimum values are proposed and awareness is created for the people who interested on acoustic or not. However, there are not many studies on subjective evaluations for HI individuals. A comprehensive study was initiated on this finding and the results of the first part of this research were presented in this paper.

Within the scope of the study, the questionnaire and speech discrimination (SD) tests were applied to the group of subjects formed to obtain the subjective evaluation of two classrooms, which were chosen as a sample study area, in order to examine the acoustic comfort of the classrooms in which the HI and NH individuals were educated with *inclusive education* method.

According to the results of the survey, it was revealed that Classroom B with acoustic regulation, was found more comfortable and quieter than Classroom A having typical and widespread design, by the students, as supporting the expectaions of authors.

According to the test results, while the speech intelligibility percent showed a significant increase for NH individuals in Classroom B compared with Classroom A, these percentages did not change significantly for HI individuals, in contrast to expectations. Although it is foreseen that the devices used by HI individuals will not differ, the results suggest that the devices may cause this. In order to be able to say this result certainly, it is necessary to increase the number of subjects and to make more detailed and collaborative researches focused on this subject. However, if the type and working principles of hearing aids are considered to be a definite result, it will be revealed that providing only the recommended optimum acoustic parameter values for the classrooms is not sufficient for the speech intelligibility of each HI individuals. It is thought that providing these values may be positive / necessary for NH and HI individuals using behind the ear hearing aids, however, the use of FM or Induction loop systems may provide positive results for HI individuals who use cochlear implants.

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