A (Technologically Enhanced) Sound Education: Implementation, Experimentation and Analysis of Raymond Murray Schafer's Exercises

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Abstract: Raymond Murray Schafer is considered one of the leading experts in the field of music ecology. In one of his works, he proposed specific exercises to encourage listening awareness in young students. This paper aims to describe an experimental activity in which three exercises extracted from Schafer's work have been implemented in the form of computer-based tools, so as to be administered both in a traditional and in a technologically enhanced way. The experimentation has been conducted on 233 primary school students, showing to what extent the adoption of technology can be applied to listening attention and awareness.

1 INTRODUCTION

The adoption of technology and computer-based approaches in teaching has neither positive nor negative connotation per se; rather, technological advancements offer tools that, when profitably used, can improve the didactic experience and the learning process. Scientific literature contains many examples of technologies profitably usable in teaching, but it also reveals how their misuse may lead to negative effects (Ellis, 1973; Kay, 1996; Ribble and Bailey, 2004).

This work starts from a very general research question: is the administration of educational experiences through technology more effective than a traditional one? Needless to say, this question is hard to answer in general terms, so we restricted the investigation field to a narrow context. In particular, we tried to understand how children relate to the surrounding sound environment, and how technology may help them in acquiring soundscape awareness. To this end, we applied a quantitative methodology to the administration and evaluation of specific exercises, so as to extract objective data on the effects produced on children by both traditional methods and technological tools.

The remainder of this paper is organized as follows: Section 2 will introduce the theoretical bases that inspired our research; Section 3 will describe the state of the art about technologies that foster acoustic awareness and listening skills; Section 4 will present the experiences we administered to our control and experimental group; Section 5 will provide details about the experimental protocol; Section 6 will discuss the results we achieved; finally, Section 7 will present our conclusions.

2 A SOUND EDUCATION

Raymond Murray Schafer, born in Canada in 1933, is a multifaceted man: composer, librettist, pedagogue, writer, educator, and environmentalist. He is best known for his interest towards *acoustic ecology*, a discipline that studies the relationship between human beings and their environment mediated through sound (Wrightson, 2000). In 1966, he formed a team at Simon Fraser University, Vancouver to investigate themes related to acoustic ecology. Among his most relevant publications, it is worth mentioning (Schafer, 1977), (Schafer, 1986), and (Schafer, 1992).

The latter work, titled "A Sound Education: 100 Exercises in Listening and Soundmaking", aims to improve the listening skills of children, stimulating attention and awareness towards surrounding soundscapes. Since in his opinion the modern civilized world is becoming deaf because of the noise, the author stresses the importance of re-education to sound. In the introduction, he says: "I believe that the way to improve the world's soundscape is quite simple. We must learn how to listen."

As a possible solution, Schafer proposes a number of exercises dealing with soundmaking and listen-

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ing, gradually moving from ear cleaning (the ability to distinguish sound from noise) to the design of soundscapes. All training activities do not require previous skills, and have not been conceived to be performed systematically from start to finish, rather they are intended for casual performance as the occasion demands. In this sense, our approach – i.e. the selection of a very limited number of exercises to be proposed in a classroom environment – does not conflict with the pedagogical principles enunciated by Schafer (see Section 4).

3 STATE OF THE ART

In this section we will provide a short overview on research initiatives that make use of technology to encourage acoustic awareness and develop listening skills.

First, it is worth mentioning those initiatives collectively referred to as *ear training*, aiming to identify, solely by hearing, typical elements of music, such as pitches, intervals, melody, chords, rhythms, etc. Ear training is considered one of the components of formal musical education. An early application of technology to ear training is reported in (Hofstetter, 1975): it describes an experiment conducted with an ear-training class at the University of Delaware in order to determine the impact on student achievement in harmonic dictation.

In more recent times, McGill University developed a computer-aided system for timbral ear training. The system lets students develop their sensitivity to timbral changes and their memory for timbre through a set of specific listening tasks of increasing complexity, thus providing an objective and effective training method for the development of listening skills (Quesnel and Woszczyk, 1994).

As the use of computers became widespread, a growing number of institutions integrated ear-training computer-assisted instruction (CAI) into their music-theory programs. A comprehensive and systematic review dating back to late 90's, comparing more than 60 ear-training CAI programs, is contained in (Spangler, 1999).

Finally, it is worth mentioning those pedagogical approaches and computer-based applications that take full benefit from multi-layer music description, namely from an integrated and synchronized representation of score symbols, audio and video tracks, alternative notation, and so on. Examples include first-sight reading, collaborative music performance, score following, etc. Some case studies are reported in (Baratè and Ludovico, 2012) and (Baratè et al., 2014).

4 THE SELECTED EXERCISES

Within the corpus of exercises proposed in (Schafer, 1992), we chose three activities. The basic idea was to administer them to primary school students both in a traditional form and using technology-powered tools (e.g, a personal computer, a sound reproduction system, etc.) in order to track the differences in performance between the control group and the experimental group.

The criteria we used to select exercises included:

- Heterogeneity in the skills to be developed in children;
- The possibility to implement a suitable and easy-to-use tool to enhance the traditional administration model;
- The need to overcome a number of logistical constraints typical of a school environment (a few hours to conduct the experimentation, limited spaces, available technological devices, etc.).

Below, we provide a short description of the selected exercises and their goals within our pedagogical experimentation. Regarding the commonalities, all activities aim to develop listening and attention skills, and are proposed in a collaborative environment. Please note that the administration modes will be different from an exercise to another, as explained in Section 5.

4.1 Exercise 1

Exercise 1 aims to enhance the awareness of young listeners about the soundscape around them. Schafer describes this activity as follows: "WRITE DOWN ALL THE SOUNDS YOU HEAR. Take a few minutes to do this; then, if you are in a group, read all the lists out loud, noting differences. Everyone will have a different list, for listening is very personal; and though some lists may be longer than others, *all answers will be correct*. This simple exercise can be performed anywhere by anyone. It would be a good idea to try it several times in contrasting environments in order to get into the habit of listening." This exercise, fundamental to raise attention towards the soundscape, is actually the first one both in our experimentation and in Schafer's book.

In our experimentation, children were asked to list all the sounds they are able to detect around them, when immersed in a natural soundscape or in an artificial one.

Figure 1: Indoor and outdoor listening activities for *Exercise 1*.

As for the traditional administration, children were taken to 4 different indoor and outdoor school environments (hallway, amphitheater, courtyard, and sports field) and invited to listen carefully for 10 minutes (see Figure 1). Then, they were asked to list on a paper form all the recognized sound elements, distinguishing between sounds perceived as far and close only to keep children concentrated on their task. During the observation phase, it was noted that sounds could be clustered into 4 groups: classroom sounds (teacher and student voices, chalk on the blackboard, etc.); animal sounds (singing birds, barking dogs, buzzing flies, etc.); street traffic sounds (cars, buses, bicycles, etc.); sounds of nature (whistling of the wind, rustling of the grass, falling rain, etc.).

As for the enhanced mode, children had to fill in the same card, but they were asked to listen to 4 soundscapes coming from an amplification system. Scenarios had been previously created by editing recorded live sounds or elements from sound libraries. Audio tracks deliberately mixed stimuli that could hardly coexist in a natural acoustic environment, but supposedly familiar to students: noises out of school, animal sounds, house soundscapes, metallic sounds, water-related noises, farm sounds, and urban noises.

4.2 Exercise 2

Exercise 2 seeks to investigate the concept of *synaesthesia* between sound and color. This subject has been thoroughly investigated from different points of view – artistic, psychological, clinical, perceptive, etc. – and further information can be retrieved in (Vernon, 1930), (Zilczer, 1987), and (Neufeld et al., 2012), to cite but a few. Concerning the correlation between color, music, and emotion, it is worth citing (Palmer et al., 2013), who scientifically proved the existence of an instinctive connection, a sort of "emotional palette", between some music and colors.

The activity proposed to children corresponds to *Exercise 41* from (Schafer, 1992): "Do sounds have colours? For some people they do. Discuss what colours some of the sounds in your collection might be. Why?" Specifically, children were asked to associate a number of music themes with colors picked from a limited palette. In this case, the administration to the control group was carried out through a paper form to be colored, while the experimental group used a web interface (see Figure 2). For both groups the palette included red, blue, yellow, green, orange, fuchsia, white, and black. Such a simple palette included 3 primary, 3 secondary and 2 neutral colors, balanced in number and mixed in their order, so as not to influence children in their choices.

Concerning music, we proposed 8 themes from Sergei Prokofiev's *Peter and the Wolf*, a symphonic fairy tale for children where each character in the story is associated with a particular instrument/ensemble and a musical theme: bird (flute), duck (oboe), cat (clarinet), grandfather (bassoon), wolf (French horns), hunters (woodwinds and trumpet), gunshots (timpani and bass drum), Peter (string instruments).

4.3 Exercise 3

Exercise 3 aims to refine the ability to listen to a sound and mimic it. In (Schafer, 1992) such an activity is proposed in *Exercise 56*: "Expression is trained by imitation. Musicians know this and spend many hours imitating musical sounds. But any sound can serve as a model for imitation. Once I brought a set of bamboo chimes into a class and asked the class to come as close as possible to imitating the chimes with their voices. We listened to the original, then tried to reproduce it, listened again, tried again, until we began to comprehend all the parameters of this devious sound.

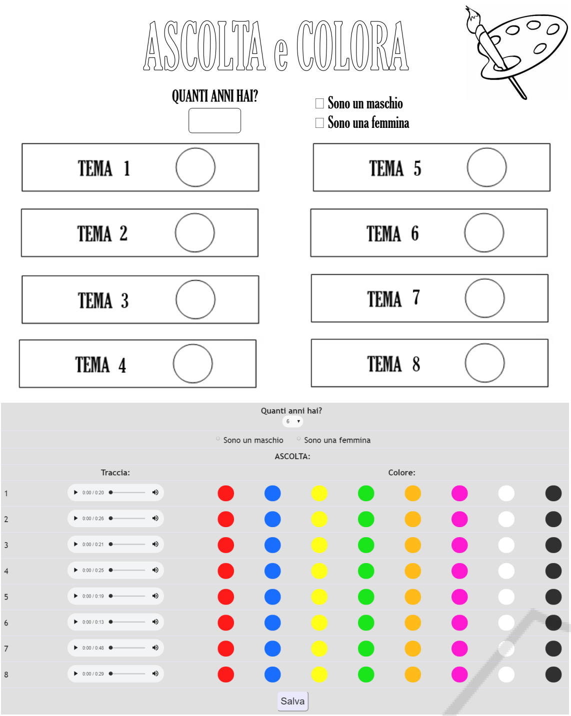

Figure 2: The paper form vs. the Web form for *Exercise 2*.

You could do the same with other sound-producers: an alarm clock, a mechanical toy, the sweeping of a broom, a child's rattle, etc. The main thing is to keep at it, listening and imitating, until you come as close as you can."

This exercise was proposed in a classroom setting by focusing on animal sounds, supposedly familiar to children but not trivial to be imitated by voice. Assignments were made by educators according to rhythmic and melodic criteria, considering the age of children: the hen for the first grade, the owl for the second, the cat for the third, the sheep for the fourth and the horse for the fifth. Children reproduced animal sounds during three sessions: a first time immediately after listening to the original sound, the second and the third time after some practice and additional listening. The exercise was administered in three ways:

1. *Traditional mode* – Children carried out the task cooperatively, in groups of 6 or 7 elements. Listening occurred via a loudspeaker. In order to record the voice imitation, each group elected a representative. There was no possibility to listen to the recorded performance, so feedback was exclusively based on schoolmates' comments;

2. *Individual enhanced mode* – Children performed the activity independently. Listening was done via headphones. Self-assessment was possible via recording playback;

3. *Cooperative enhanced mode* – Children were administered listening and training activities both individually and cooperatively. In order to record the final sound, each group elected a representative, who could improve his/her performance through playback-based training and group advice. In this case, listening occurred both via headphones and through loudspeakers.

5 EXPERIMENTAL PROTOCOL

In this section, we will provide details about the experimental protocol, focusing on the composition of the sample and the administration modes. Results will be presented and discussed in Section 6.

5.1 Sample Composition

Experimental activities involved 233 primary-school students attending the *Istituto Comprensivo "G. Puecher"*, Erba, Italy. The sample was composed by 43 children aged 6 to 7 from first grade classes, 51 aged 7 to 8 from the second grade, 43 aged 8 to 9 from the third grade, 53 aged 9 to 10 from the fourth grade, and 43 aged 10 to 11 from the fifth grade. Each grade included two classrooms, named A and B. The number of participants actually varied from a session to another due to absences.

The sample was quite heterogeneous concerning home Countries: 56 students out of 233 (about 24%) were foreigners. In detail: 6 children from Albania, 1 from Bangladesh, 2 from Benin, 1 from Brazil, 4 from Burkina Faso, 4 from China, 1 from Ecuador, 1 from Egypt, 1 from El Salvador, 1 from Philippines, 1 from Ghana, 2 from Guinea, 7 from Morocco, 1 from Moldavia, 2 from Pakistan, 1 from Peru, 4 from Romania, 1 from Rwanda, 1 from Russia, 4 from Senegal, 6 from Syria, 1 from Togo, 2 from Tunisia, and 1 from Turkey.

The sample was subdivided into two groups, on the base of the attended classroom: 119 students formed the control group (classes 1A to 5A), and 114 the experimental group (classes 1B to 5B).

5.2 Administration Modes

As mentioned before, the sample was given 3 activities based on (Schafer, 1992). Experiments were administered in two ways: the control group experienced traditional methods (e.g., natural acoustic environment, use of physical media, etc.), while the experimental group was asked to complete the same tasks

Table 1: Soundscapes and participants for *Exercise 1*. Soundscape ♯5 was administered to both the experimental and the control group.

Natural soundscapes	
Place	*Number of participants*
Backyard	112
Amphitheater	116
Entrance	111
Hallway	115
Artificial soundscapes	
Place	*Number of participants*
Soundscape ♯1	102
Soundscape ♯2	105
Soundscape ♯3	107
Soundscape ♯4	102
Soundscape ♯5 (joint)	110 + 101

by using technological devices (e.g., computers, earphones, etc.) and computer-supported tools such as web applications.

Activities were conducted from April 23 to May 25, 2018 during lesson time, and lasted 15 to 60 minutes, depending on the type of exercise. Each classroom took part in about 5 weekly sessions.

6 RESULTS

6.1 Exercise 1

The first exercise focused on the ability to perceive the soundscape and recognize its elements. Details about soundscapes and the number of participants are provided in Table 1. During listening activities, children were asked to take note of all perceived sounds. For each landscape, either natural (control group) or artificial (experimental group), the number of sounds identified by each participant was recorded and compared to the total number of elements in the soundscape.

The behavior across consecutive sessions was observed, and the cumulative score of each group was compared in a final joint session. The improvements achieved by each group were noticeable only in the first sessions. Moreover, the influence of administration modes was not relevant: during the final joint session, attended by both the control and the experimental group, their scores did not show significant differences (see Figure 3). This outcome seems to suggest that an effective auditory training can be performed by means of both traditional methodologies and technological tools.

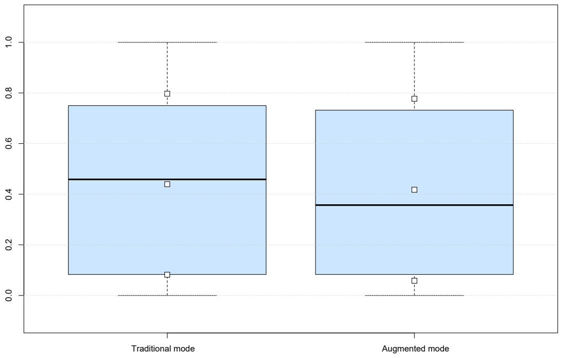

Figure 3: Results achieved by the experimental and the control group during the joint session – Soundscape ♯5 for *Exercise 1*.

Some interesting aspects emerged during the analysis of results. For instance, Soundscape ♯5 contained the sound of a metal teaspoon beating on a glass. Even if this noise should be familiar, few children were able to recognize it; rather, many of them identified it as the ringtone associated to a short message. This is an example of *schizophonia*, a term coined by Schafer to describe the splitting of an original sound and its electroacoustic reproduction. Observing the differences in listening abilities, children aged 8 to 11 obtained better scores than their younger schoolmates, and this seems to indicate an age-related increase in attentional capacity. With respect to gender, there was no substantial differences in the results of the control group, whereas in the experimental group females showed a greater ability in sound recognition (in any case, median values are very similar).

Finally, two interesting aspects emerged from the observation of the traditional administration. The first effect can be described as sound perception driven by sight: e.g., during a rainy day, many children recognized the sound of raindrops even if doors and windows were closed and that sound was not actually perceivable. The second aspect concerns self-production of sounds (e.g., coughing, sneezing, etc.) when administered sounds had already been recognized: in this way, students could take note of additional items and artificially improve their performance.

6.2 Exercise 2

Concerning this exercise, focusing on the association between music themes and colors, we have analyzed two aspects: 1. The distribution of the colors chosen by participants for each music theme; 2. The correlations between music features and the color selected by the majority of children. In particular, the features were: key, average beats per measure (BPM), register, median (B_M) and interquartile range (B_{IQR})

Figure 4: Association of colors to music themes for *Exercise 2*: traditional administration (top) vs. enhanced mode (bottom). Top percentages are shown in the corresponding colored area.

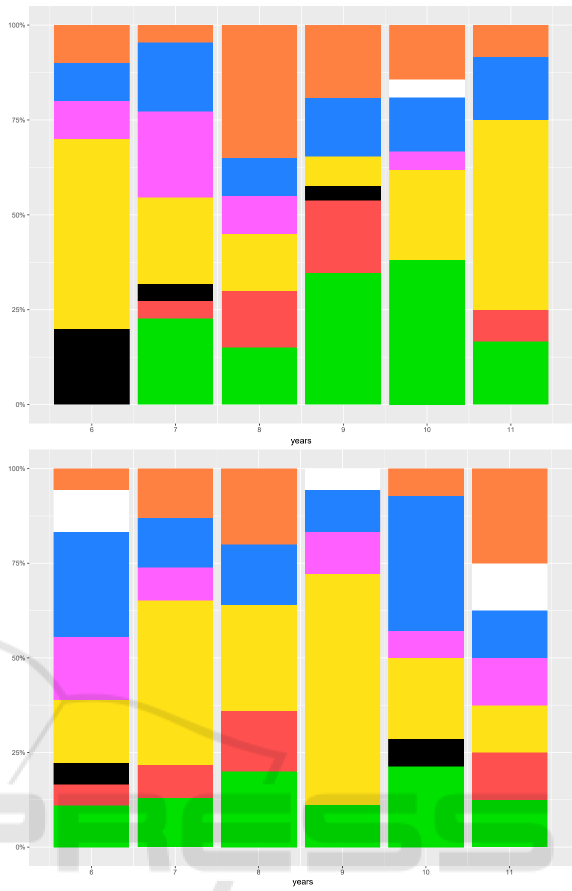

Figure 5: The choice of colors associated to the bird's theme in *Exercise 2*, organized by age (horizontal axis). The upper diagram shows results for the traditional administration, the lower one those for the enhanced mode.

of the brightness, as defined in (Presti and Mauro, 2013). Differences in age have not been evaluated, while the two administration modes have been analyzed separately. The values of the mentioned features for each music theme are the following (TM = traditional mode, EM = enhanced mode):

- Peter (string quartet) – Key: C; Average BPM: 95; Register: high; $B_M = 0.87$; $B_{IQR} = 0.57$;
- Bird (flute) – Key: C; Average BPM: 144; Register: high; $B_M = 1.25$; $B_{IQR} = 0.7$;
- Cat (clarinet) – Key: D; Average BPM: 42; Register: low; $B_M = 0.49$; $B_{IQR} = 0.34$;
- Duck (oboe) – Key: E♭; Average BPM: 84; Register: high; $B_M = 1.3$ $B_{IQR} = 0.42$;
- Grandfather (bassoon) – Key: B♭ min.; Average BPM: 83; Register: low; $B_M = 0.38$; $B_{IQR} = 0.29$;
- Wolf (French horns) – Key: C min.; Average BPM: 88; Register: low; $B_M = 0.48$; $B_{IQR} = 0.17$;
- Gunshots (timpani) – Key: C; Average BPM: 87; Register: low; $B_M = 0.33$; $B_{IQR} = 0.18$;
- Hunters (woodwinds) – Key: F min.; Average BPM: 54; Register: low; $B_M = 0.45$; $B_{IQR} = 0.35$;

The associations of colors to music themes in the two administration modes are reported in Figure 4. White is more present in enhanced experiences, probably due to the presence of the color in the palette, whereas in the traditional mode children had to intentionally leave a space uncolored.

Often the most selected color was the same for the two administration modes. But it is particularly interesting the case of the bird's theme, where yellow stimulated complementary behaviors in the two administration modes: in the traditional mode, it is the preferred choice among the lateral age groups, while in the enhanced mode it is the top choice for the central bands (see Figure 5).

Observing the outcomes of the second analysis, i.e. music features and colors, results are correlated with the data about brightness and music key. For those themes where B_M is low and the key is minor, children mainly indicated darker colors; conversely, for themes in major key and with a high value of B_M, they selected brighter colors. It is worth noting that, during the final discussion, children asked for a wider palette. This observation underlies the need to express themselves in a more complex and precise way.

6.3 Exercise 3

This exercise focused on the ability to imitate sounds. In this case, we adopted a slightly different experimental protocol, introducing 3 administration modes, as explained in Section 4.3.

Methodologically, for each age group a registration was chosen as the best instance of each mode to be compared with the other modes. In the case of collaborative modes, the sound was chosen by the class by vote, whereas in the individual mode it was the sound automatically recognized as the most similar to the original (a choice also subjectively validated by teachers).

In addition, automatic analysis was used to compare administration modes. For each recording, five tests were performed taking the original animal sound as the reference. The analytical process automatically extracted indicators about timbral, rhythmic and melodic characteristics. Specifically: timbre was investigated by calculating the Mahalanobis distance (De Maesschalck et al., 2000) between the Mel-frequency cepstral coefficients (MFCCs) of the two sounds; rhythm was analyzed by observing the distance extracted through Dynamic Time Warping (Müller, 2007) and the cross-correlation between the amplitude envelopes of the signals; melodic aspects were evaluated through the correlation between the two signals' chromagrams and, in order to exclude the effects of pitch shifting, through the highest correlation between different circular shifts of the chromagrams. For a definition of the mentioned audio features, in particular MFCCs and chromagrams, please refer to (Alías et al., 2016). Figure 6 shows the diagram obtained by computing the mentioned indicators over all the considered recordings, clustered by administration mode: Group A – traditional mode (blue), Group B – individual enhanced mode (orange), Group C – cooperative enhanced mode (yellow).

Finally, through the use of the decision method known as *Utopia point* (Martínez-Iranzo et al., 2009), we tried to understand which administration mode obtained the best results, and which participants got the maximum and minimum distance from the Utopia point, i.e. the worst and the best result respectively. Table 2 shows the mean and the standard deviation of the distances from the Utopia point registered by the three groups: Group A – traditional mode, Group B – individual enhanced mode, Group C – cooperative enhanced mode.

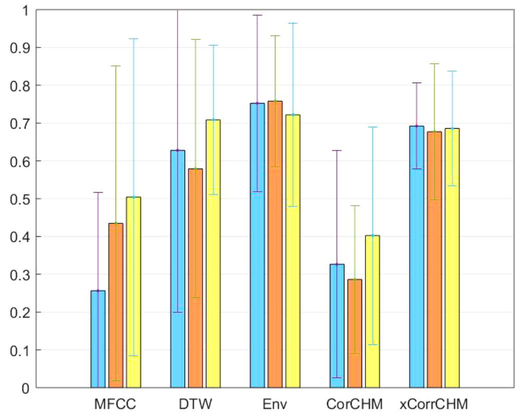

Figure 6: Aggregated indicators for *Exercise 3*. In blue Group A, in orange Group B, in yellow Group C.

Table 2: Mean and standard deviation of the distances scored by the 3 groups from the Utopia point in *Exercise 3*.

	Mean	Standard deviation
Group A	0.7341	0.3684
Group B	0.8414	0.2702
Group C	0.9164	0.2855

In the assessment phase, timbre-analysis results were similar for all the administration modes; conversely, in the melodic analysis, and specifically in pitch detection, results were very sparse, independently from the administration mode.

With respect to the Utopia point, the administration mode that best scored was the traditional one, while the other two returned similar results, not so far from the former. The top-score participant reached a distance $d = 0.128$ from the Utopia Point, working in traditional mode; conversely, the worst result ($d = 1.2385$) was obtained by a child who was administered the individual enhanced mode.

Once again, the observation highlighted some interesting aspects not directly related to sound perception. For example, during the vocal performance of sounds, many children tended to physically mimic the animal they were interpreting. When asked to explain this behavior, children revealed that it was intended to improve the imitation.

7 CONCLUSIONS

The educational activities proposed in our experimentation confirmed that technology is not positive or negative in absolute terms, at least in the context of soundscape self-consciousness: for some types of listening experiences, the adoption of technology can be more involving and effective with respect to traditional methods, whereas, in other cases, advantages are not evident, and technological aids can even cause distraction.

Even if the activities reported in this work involved more than 230 students, in order to produce meaningful and reliable results the experimentation should be extended to other primary-school classes, include additional exercises extracted from (Schafer, 1992), and propose other strategies to take benefit from technological means.

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