Technique, Creation, Perception and Experience in the Learning of Electroacoustic Music: Some practical proposals

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This article arises from the need to reflect upon the possibility of developing new ways of teaching electroacoustic music, based on the opportunities recently offered by technology and the theories about learning that have been developed in recent decades. After taking into consideration the limits of the current teaching methods, the article examines various theories and approaches that involve questioning the objectivity of the learning process, the concept of multiple intelligences, the concentration on the experience as the focal point of learning and so forth. On the basis of these reflections, and after evaluating various teaching experiences over the past twenty years, the authors make some practical proposals, without imagining a curriculum, but rather by outlining several possible activities within an organic teaching project. To this end, a software program is described and realised in which the learner is engaged through the use of an interactive game format that can be played by the individual or in a group, and that encourages the development of the capacities of analysis, perception, practical skill, knowledge, imagination and creativity.

1. THE LIMITATIONS OF THE CURRENT METHODOLOGIES

In recent years there has been a process of renewal in the teaching of electroacoustic music, which is also described in volume 18/2 of *Organised Sound*. For many years the resources available to teachers were mostly theory textbooks, software manuals or self-produced materials. In essence, one of the limitations of the traditional way of teaching electroacoustic music was the separation of its theoretical and practical aspects, as well as its lack of dealing with perception and creativity. There has been a particular tendency towards producing textbooks and manuals that concentrate on 'learning the tools of music technology' with very little reference to the creative, perceptual and experiential aspects. Meanwhile, in the other fields of teaching (such as language learning) giant strides have been made in both theoretical and practical areas. In the past, this has created a gap between the rapid advances of learning theories and their application in various disciplines, and the slow evolution of the teaching of electroacoustic music.

The purpose of this article is to imagine techniques and teaching methods for electroacoustic music which could possibly bring about a fusion of knowledge, practical skill, experience, perception and creativity with non-linear and non-standardised teaching processes. The second section of this paper is a self-analysis of the steps taken by the authors so far with the aim of renewing teaching modalities but also specifying the limits of their work that have yet to be overcome. This is followed by a discussion of several theories of learning that we use as a guide for the practical proposals described in the last two sections.

2. PREVIOUS EXPERIENCES OF THE AUTHORS

In the two volumes of the book *Electronic Music and Sound Design* (Cipriani and Giri 2014) we made some concrete proposals for overcoming the following limitations which we noticed were prevalent in the realm of electroacoustic music education:

- The separation between theory and practice
- The segregation between technical learning and the craft of electroacoustic music composition
- The gap between theory and perception
- The absence of the learner's active involvement in the process of learning.

2.1. The separation between theory and practice

In *Electronic Music and Sound Design* the traditional separation between theoretical and practical textbooks (or software manuals) is addressed by bringing these two domains much closer together. The whole book is laid out as a succession of chapters of theoretical material, each one followed by a chapter containing practical computer techniques. Each pair of chapters stands together as a unit. This format, which Richard Boulanger defines as 'interactive and enhanced books' (in Cipriani and Giri 2014: vii), includes sample patches, analyses, interactive sound-building exercises and reverse engineering exercises, thereby allowing experiential skills and theoretical knowledge to reinforce each other.

2.2. The segregation between technical learning and the craft of electroacoustic music composition

Another type of disparity that traditionally exists in music education is the segregation between textbooks and materials related to learning the tools of music technology and those related to learning the craft of electroacoustic music composition. In the second volume of the above-mentioned textbook there is a 'transgression' of the usual practice of separating these two areas. Technique and creation are brought together by means of a particularly extensive chapter on the art of sound organisation. This chapter includes a theoretical part, supplemented with numerous sound examples (also by well-known composers), and a practical part, in which the learner is encouraged to realise (with Max and MSP) some possible personal interpretations of the various types of sound motion described in the theoretical part. In this way, links are created between the technical aspect and the concepts and practice of the organisation of sound in time.

2.3. The gap between theory and perception

The gap between textbooks which deal with theory and the direct perceptions of the learner is addressed in Volume 1. There is an interactive example for each theoretical aspect explained in the various sections of that volume.

> Thanks to these interactive examples, the user can immediately hear the sounds being discussed, as well as understand their design, without necessarily having to spend time in programming them. In this way, the study of the theory is immediately connected to the concrete experience of sounds. (Cipriani and Giri 2010: x)

2.4. The absence of the learner's active involvement in the process of learning

The reader is encouraged to use his or her perceptions, analysis and critical thinking, in addition to his or her own experience.

Cipriani and Giri (2011) state that, in their experience, electronic music learners are often quite passive: they might understand all the patches and the theory, but they are still unable to correct their errors, adapt, invent, and use the knowledge and skills they have acquired in a personal, creative and active way. At first, novices often need to be given context-free rules that they can adhere to, in order to accomplish immediate goals and reinforce their confidence through following fixed procedures. On the other hand, we believe it is particularly important to promote context-based experience, develop critical thinking and encourage the use of individual perception and creativity while acquiring new knowledge and skills. There should not be an excessive reliance on technology, since software is always subject to development and replacement. As one commentator points out:

> There's always going to be a new technology or a new version of an existing technology to be learned. The technology itself isn't so important; it's the constant learning that counts. … The model you build in your mind, the questions you ask to build that model, and your experiences and practices built up along the way and that you use daily are far more relevant to your performance. They're the things that develop competence and expertise. Mastery of the knowledge alone isn't sufficient. (Hunt 2008: 155)

Our integrated system encourages the novice to imitate the suggested practice while learning the theory. Various practical exercises of modification, correction and expansion are immediately proposed, according to a problem-solving approach. Thus the model of an imitative and passive process is immediately challenged. We encourage the learner to find different ways to replace parts of algorithms, complete unfinished algorithms, analyse and correct algorithms with bugs, and practise reverse engineering (in which the reader listens to a sound and then tries to invent an algorithm to create a similar sound). The interaction between perception and knowledge – and the interchange between deductive, inductive and creative processes – is continuous and reflexive. There are some similarities between this kind of learning approach and learning to play a musical instrument, especially regarding the sonic feedback that musicians continuously receive in the 'search for the right sound' guided by their technique and intuition, which leads them to gradually improve their performance using perceptual data. Our method is intended as a holistic and integrated process of research and discovery.

We have put these latter concepts into practice in the sixth section, where we make a concrete proposal as to how this 'search for the right sound' can be developed, in the form of a game. But what are the limits of our work? What is still missing so that a teaching system can progress towards a greater degree of integration, in a holistic sense? Before enumerating the various problems that have to be solved, it is necessary to examine some theoretical aspects, which will be dealt with in the next section.

3. THEORIES OF LEARNING

In the twentieth century various studies on education proposed adopting multiple points of observation concerning the phenomenon of learning.

3.1. Behaviourism

The behaviourist paradigm focuses on the student's response to an external input or stimulus from the teacher. If the student's answer is in compliance with the expected behaviour, the teacher then gives positive reinforcement, and if it does not there is a negative reinforcement. Positive and negative reinforcement should not be understood as strictly meaning reward or punishment, but they are conditionings that are intended to increase or decrease the frequency of a certain behaviour. The information being taught is seen as being objective and capable of being transmitted from the teacher to the student in a process that can be conditioned and determined as a result of reinforcement strategies.

Subsequently, the studies also concentrated on the student's cognitive structures and perceptual processes, which will be discussed in the following section.

3.2. Cognitivism and Gestalt

Cognitive theory deals with, among other things, how information is assimilated and accommodated by the subject, and how this information then acquires a meaning within an internal cognitive structure. Inevitably, the idea of objective knowledge that is transmissible in a conditioned and linear process loses its centrality, because cognitive theory focuses on how this knowledge is given special meanings by students within their own cognitive structures. The final objective and aim of study thus becomes the acquisition of a skill, not the learning of concepts for their own sake. Looking through the eyes of the learner, the field of study is extended to the social and cultural context in which the subject lives, and how this is a part of the learning process.

Another theory that focuses on the subject is that of Gestalt psychology. This studies how various elements are put into relation with each other by the subject within a dynamic field of perception that can be reorganised also by intuitive processes operating by means of non-linear associations.

3.3. Constructivism

In light of these theories it is evident that teaching cannot be limited to the static and linear transmission of information, but that it must be seen as a dynamic process within an 'organic' context. In this sense, the learner is an active subject because she or he is called upon to participate in the construction of meaning. From these premises, the constructivist philosophy of education was developed. The basic concept of this current is that learning takes place through experience, as expressed by the well-known term *learning by doing*. This does not necessarily mean concentrating exclusively upon practical activities, but it is a way of moving from concrete experiences to abstract thinking. When designing learning environments it is important to take the characteristics of the learner and the context into account. In the constructivist approach, the teacher presents a problem within a concrete context and makes the materials available which will be used in order to resolve the problem, while paying special attention to the degree of preparation and the particular inclinations of the individual and the group as a whole. The teacher then supports the student or students during the exploratory process without giving any solutions a priori, encouraging the autonomous construction of an individual meaning and relevance in each student, derived from direct experience, discussion and analysis.

3.4. Multiple intelligences

Another useful theoretical formulation is Gardner's concept of multiple intelligences. Starting from the observation that intelligence is usually associated with logical-mathematical and linguistic capabilities, Gardner suggests that there are various other types of intelligence. In this approach, the types of intelligence are generally grouped into three large categories: interactive (linguistic, interpersonal, kinesthetic), analytical (musical, naturalistic, logical-mathematical) and introspective (existential, visual, intrapersonal). When designing teaching activities, one can therefore take into account the kind of intelligence towards which each student is more predisposed. This will introduce the learner to a style of learning based on the approach that is most congenial to him or her.

> Thus, an individual with a strong musical bent might best be introduced to programming by attempting to program a simple musical piece (or to master the use of a program that compose). An individual with strong spatial abilities might be initiated through some form of computer graphics and he might also be aided in the task of programming through the use of a flow chart or some other spatial diagram … Kinesthetic intelligence may play a role in working with the computer itself, facilitate skill at the terminal, and be exploited in those cases where the subject matter of a program involves use of the body programming a dance or a sequence of football plays. (Gardner 1983: 390–1)

3.5. A combination of theories: why we are proposing an interactive game

The theories that have just been presented are used together in combination with each other. We will now take a look at an example of an interactive game, a preliminary draft of which will be shown in section 6, in order to show one of the possible types of activities based on different learning theories. The interactive game software presents problems to be solved, which are organised in a concept map. As an experiential activity, the game fits into the constructivist category, but the game also contains a reward mechanism specific to behaviourism: solving an activity can also be

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rewarded with prizes that affirm the acquisition of a certain skill or ability. Routes between the various levels of the game can also be imagined in the form of an actual map where the progress of the student corresponds to an increase in the possibility of movement and manipulation within the game itself. These possibilities are another form of reward. For example, after having completed a first level which is only concerned with recognising the pitch of one sound with respect to that of another, the student could then be given the option of choosing which activity would happen next, in addition to modifying the pitch of the sounds. One possible choice, for instance, could be between recognising rhythmic figures and recognising timbre parameters. A later level could also be concerned with recognising the motions of a sound's parameters, in order to arrive at a level where actual compositional activities are proposed, though always by choice.

Interactive games are something with which the younger generation has considerable experience, at least in countries with a highly advanced degree of computerisation. This satisfies the criteria of the constructivist method, where one should begin with concrete experiences known to the student and move towards other, increasingly more complex ones, which require a greater capacity for abstraction. The learner would perform a symbolic 'hero's journey' that goes beyond simple rites of passage in order to gain an awareness of purpose – from purely practical first steps towards a deeper reflection upon the meaning of the actions involved. One could even imagine narrative paths which guide the learner through the game, taking the text *The Hero with a Thousand Faces* by Joseph Campbell (2008), scholar of myths and religions, as a point of departure. The map of the game can actually be thought out by following a narrative structure in a broad sense, highlighting some symbolic functions that can be taken by both teachers and students. In following the narrative while playing the game, another student may assume either the role of travelling companion who participates and discusses the findings just made, of teacher and mentor who informs and advises or of gatekeeper who invites the student to a test needed for passing to the next level. The student progressing through the game would realise that he or she is creating the soundtrack of the narrative. This could be the goal of the game itself, regardless of the path chosen by the learner within the map. The game can then serve as a supporting material, even as an in-class activity, with students asked to play roles, working together and with the teacher. In addition to behaviourism, cognitivism and constructivism, one could imagine also including the theory of intelligences proposed by Gardner. The intelligences identified by Gardner can be used to stimulate students by differentiating the various proposed activities. The following are some examples of possible relationships between activity and intelligence type:

- Invite the learner to record a soundscape in order to stimulate the naturalist intelligence.
- Press keys at the correct time corresponding to a moving icon which represents a sound event (this already happens in video games such as *Guitar Hero* published by Activision) to activate the kinesthetic intelligence.
- Associate the sounds of objects with their graphic representation in a virtual room to inspire the visuo-spatial intelligence and so on.

In creating the structure of the game map it is therefore necessary to consider the type of activity proposed, in order to ensure that the learner can choose the approach, based on intelligence type, which most suits him, thus allowing him to develop the others by beginning with the one where he feels the most secure.

In the next sections we will formulate practical and concrete proposals that rely on these theories, for an active learning experience in the specific context of electroacoustic music.

4. THE DESIGN OF LEARNING ENVIRONMENTS FOR ELECTROACOUSTIC MUSIC: THE EXAMPLES OF DSP AND EARS 2

The stimuli that derive from the theories, the principles of which we have just described, lead us to identify some ways in which the teaching of electroacoustic music might be developed:

- The acquisition of a skill or ability, not just of knowledge for its own sake, and the chance (as theorised by constructivist theory) of basing and designing teaching as much as possible on concrete experience, from which abstract concepts can be derived.
- The possibility of developing group educational activities also in a network.
- Making sure that the student does not learn passively and trying as much as possible to consider the different kinds of intelligence used in the development of activities, by means of an interdisciplinary and holistic approach.

At this point it is worth mentioning some learning environments that seem to comply with some of these principles.

One of the most significant advances in the field of education in the 1990s was the DSP software developed at the NOTAM Center for Technology in Music and the Arts (Norway). DSP is a multi-platform software program that is intended as an educational instrument for introducing children and young people to the basic principles of composition and audio processing. It was especially designed for students with a particular interest in music and sound, and it is now widely used in schools in Norway and all over the world. The interactive qualities of this software and the concurrent establishment of a national project of mainly electroacoustic composition for children (called *Breaking the Sound Barrier*) certainly also constituted an incentive for those involved in the teaching of electroacoustic music to adults. From the late 1990s to the present day there has been a great deal of activity and innovation in the sector of methods of learning, but this has often remained at the local level, limited to single universities or specific countries.

Perhaps the most significant current project, due to the collaboration of six important institutions from various different countries (MTI/DMU – UK, INA/GRM – France, NOTAM – Norway, ZKM – Germany, Miso Music – Portugal and EPHMEE/Ionian University – Greece) is the project Electroacoustic Resource Site 2 (EARS 2.0) 'an entire pedagogical environment introducing primarily, although not exclusively, children aged 11 to 14 to electroacoustic music in terms of its concepts, repertoire and creative practice' (Landy, Hall and Uwins 2013). This is a multilingual resource site with an extraordinarily organic design, thanks to the holistic connections between its creative and perceptive aspects, as well as those regarding knowledge and technique. In addition, the social networking and communicative elements of the site mean that this site might well become a reference point and a kind of 'Silk Road' for the sharing of ideas and practices in the field of teaching electroacoustic music among people all over the world, whether they are teachers or students.

These experiences have also had an impact on the production and design of learning environments for electroacoustic music in Italy. In this context the rewriting of the textbook *Virtual Sound* by Vincenzo Core should be mentioned (Bianchini, Cipriani and Core 2015, forthcoming). This manual of theory and practice using the program Csound was originally published in English in 2001 but it has been radically altered so as to deal with the ideas mentioned above, with a strong emphasis on interactive activities accessible via the Internet. Also, the recently published textbook *Laboratorio di tecnologie musicali* (Laboratory of Musical Technologies; Cappellani, D'Agostino, De Siena, Mudanò and Paolozzi 2014), which is dedicated to learners from 14 to 18 years old, is firmly based on technical and creative practice, in addition to activities of problem solving, from which the theoretical concepts are deduced only in a second phase. The work done on these textbooks, integrated with the Internet, needs to be followed up by the formulation and elaboration of additional practical methods and proposals that can be used in various different contexts. We will take a look at some of these proposals in the next section.

5. SOME PRACTICAL METHODS AND PROPOSALS

5.1. Examples of educational projects for a constructivistic approach

We will now formulate some specific practical proposals for problem-solving and creative activities. We might ask a learner to analyse the various sounds of the wind, and to reconstruct a simulated version using filtered noise, to realise an *étude* in which the wind changes from a breeze into violent gusts. Everyone has experienced the phenomenon of the wind, and so this sound already has a meaning in the student's cognitive structure.

The activity of analysis, reconstruction and manipulation requires various skills: the ability to use technical tools, to apply the theoretical concepts of acoustics and electroacoustics and to be able to use them in the act of creation. When they are in this mode students are active because they are stimulated to interpret the information and stimuli, and to create relationships between perception, knowledge and experience in order to solve the problem.

We have presented a single activity so let us now see how this approach can fit in with some other proposals. In this field it is not necessary for learners to have played as many 'games' as possible. It is instead important for them to be aware of the general rules of the game so that they can adapt them to the various different situations. We can therefore resubmit an activity of reverse engineering similar to the previous one, but considered from a different angle, using the same theory and the same techniques so as to obtain different sounds. We might ask the student to analyse the sound of a commercial subtractive synthesiser that can be heard in a pop song, to reconstruct its algorithm, and to create timbral variations on it. In this way it can be shown how a technique (in this case that of subtractive synthesis) can become a dynamic tool that is not limited to a single modality of use. We can then expand the same activity by analysing and recreating by means of subtractive synthesis the sounds of synthesisers in music tracks of various periods, styles and countries over the past fifty years or so. In this way we can stimulate a reflection on how the use of a given technique is modified on the basis of a certain musical context. Also in these activities it is important that the first pieces presented should be well known to the students, so that they will develop a sensibility towards timbre also in their habitual listening practices. Once these basic skills have been acquired, it is possible to tackle more complex contexts such as that of acousmatic music.

A special technique, subtractive synthesis, is represented in different contexts, and thus placed in relation to other branches of cognitive structure. Constructivism proposes a model of active learning, which not only requires performing activities increasing in difficulty, but also the ability to think about them critically. It is for this reason that there are continuously logical reversals of perspective within the examples – from the points of view of art, culture, sonic result and so on. These switches in viewpoint are designed to encourage the student's ability to represent and manipulate the problem. The stimulation of these faculties makes the subject an active participant.

We can then return to the sound of the wind, asking the student to reconstruct it with various techniques other than subtractive synthesis, such as the processing of the sampled sound of blowing into wind instruments. Compared to the previous exercises, there is a reversal of perspective, because similar sonic results can be obtained by using different techniques. In fact in this case the focus is on trying to create the same sound with the use of a new technique. The idea is that of constructing an interconnected information network in the student's cognitive structure. Within this network, students may seek solutions that are appropriate for the type of activities they will probably encounter in their professional life. The information and know-how does not consist of absolutely fixed blocks, but of bodies in movement that are open to multiple interrelationships. This kind of awareness is necessary in order to develop a skill.

5.2. Some proposals for group activities

Since students themselves are not isolated entities, it is appropriate to reflect on how to set up the activities to work in a group context. One of the advantages of group instruction is the opportunity it offers for reciprocal peer teaching, since students can share a similar language, which is often more understandable than that of the teacher.

The students can be asked to create short tutorials, also using audiovisual materials, to illustrate the operations and basic functions of a software program, under the constant supervision of the teacher. The tutorials can then be placed in a repository on the web, to be shared by all the students and teachers.

Cooperative learning can also be used for historical subjects or analytical activities. Using the jigsaw method, the students are divided into two or more 'jigsaw' groups, each of which is appointed various experts who are assigned to a certain theme or topic. For example, if the task involves learning about the history of electroacoustic music, in each jigsaw group there could be an expert on synthesisers, one on the soundscape and one on spectral music. Each jigsaw group thus has one expert for each specific topic, and also, in this case, the separation of roles should ideally respect and enhance the students' individual aptitudes. The various experts conduct research on their specific field and then meet periodically with the corresponding experts from the other jigsaw group or groups, in order to discuss their assignment and compare ideas. These groups made up of students who all have the same specialisation are called the 'expert groups'. At the end of this process of mutual interaction and research, the experts report back to their original jigsaw groups in order to instruct the other group members about their topic. Finally all of the students can be tested on what they have learned about each aspect of the entire field under investigation, as well as their understanding of subject as a whole, in this case the overall history of electroacoustic music.

This kind of learning is active because, as a result of the discussion and comparison of perspectives and perception, there is a negotiation of meaning between the students and they are also able to have the benefits of peer communication. Also, in the case of the analysis of a piece of music or sound work it is possible to appoint experts who will investigate the formal, technical or conceptual levels of a work. The learner who is particularly predisposed towards abstract thinking can thus manage his learning from a practical point of view, and vice versa, and this opens up some multiple perspectives, giving a comprehensive overview of the subject. Online discussion forums can also be created for these activities. Any work created in these group activities can be discussed in terms of its aesthetic qualities, without any divisions into different classes or levels. Group discussions represent an ideal platform for an entire community or course of studies.

5.3. An experience of a complex activity: the De Sica project

The proposals set out in the previous sections concentrated on the approach for students without specific skills in the organisation of sound. We will now take a look at an integrated teaching project realised at the School of Electronic Music of the 'L. Refice' Conservatory of Frosinone (Italy).

For the master's degree course in music and new technologies, a single macro-activity was conceived that involved both sound engineering and audiovisual composition students.

This is a group which possesses advanced skills. It is a special case in that the learners were faced with a professional-level task, which could also be proposed in the arts outside of the context of learning. The project itself was the realisation of an audiovisual piece and an audiovisual installation, both based on an Italian television series from the 1960s. In this (almost forgotten) series, actor and director Vittorio De Sica read twenty-one fairy tales by authors such as Hans Christian Andersen and Oscar Wilde. The content of the shows was simply a camera pointing at him reading a book. This theme was chosen on the occasion of the fortieth anniversary of De Sica's death, to re-discover and emphasise the contemporary relevance of the important audiovisual legacy that he left us by reciting these fairy tales. The teaching process was divided into three phases:

- planning
- coaching
- realisation.

The project involved five teachers:[1]

- a professor of aesthetics
- a sound designer for cinema
- a composer and researcher in the field of audiovisual arts
- a visual artist and researcher in the field of multi-media communication
- a sound engineer, also active in the sector of music for film and cinema.

The first two phases were carried out at the same time. The visual artist and the composer outlined the context of the activity, inviting the students to reflect on the historical, philosophical and cultural aspects of audiovisual compositions and sound installations as well as the possible ways of integrating these contemporary art forms with the fairy tales narrated by De Sica. The form and structure of the fairy tales were analysed in the light of these reflections. The students then chose four out of the twenty-one tales as the basis material for creating the final work. At the same time, some more specific training was conducted, in which the sound designer accompanied the students on the initial shooting in the chosen locations, the sound engineer coordinated the activities of recording and mixing, and the professor of aesthetics analysed the music of De Sica's neorealist films. Since this was an advanced course, the students were given a great degree of freedom for planning, and they organised meetings to discuss the work among themselves, and to collect additional audio and visual material which could be integrated with that of De Sica's television broadcast.

The materials were shared on cloud storage platforms, and a mailing list and mobile phone group messaging network were created. The work was configured in two separate forms: an audiovisual installation with three screens and surround sound, and an audiovisual composition with a single screen divided into three parts. Because it includes several disciplines, this experience demonstrates that audiovisual creation with electroacoustic music and sound design particularly favours an approach involving various different types of intelligence, so that the student can easily find a personal level of access. The latest collaborative project, which we will cover in the next section, is that of the interactive game.

[1]Francesca Agresta, Maurizio Argentieri, Alessandro Cipriani, Giulio Latini and Fabio Venturi.

6. A PRACTICAL PROPOSAL: THE SOFTWARE TAG AND THE 'SEARCH FOR THE RIGHT SOUND'

As we have already pointed out, we believe it is particularly important to promote context-based experience, develop critical thinking and encourage the use of individual perception and creativity while acquiring new knowledge and skills.

Using the principles set out in the third section as a starting point, we designed a piece of software that facilitates the learning of sound design techniques by reversing the traditional path of theory → practice.

The *Audio Game* is actually a software application that uses play to enhance the skills of listening and analysis of electroacoustic sounds, as well as the ability to imagine and reconstruct sounds, while stimulating the creativity of aspiring sound organisers. In the same way that you begin by 'playing' with phonemes and words when you learn a language, and learn to put sentences together through listening and imitation, our game starts from combinations of simple sounds and, through listening and imitation, leads the 'player' to acquire more and more complex techniques.

In parallel, just as the study of grammatical and syntactical structures in language is dealt with when the subject is already able to use them instinctively, in our game theoretical explanation takes place at later point in time. The application is connected to the Internet site theaudiogame.net, which contains all of the theoretical information and which records the games played by the users as well as their scores for these games.

The game is divided into three levels:

- ear training
- reverse engineering
- sound design.

6.1. First level: ear training

In this context we do not mean the traditional kind of ear training used for identifying the pitch of notes, but rather training of one's ability to identify the different characteristics and possible manipulations of sound.

In the first level the players are offered a series of one hundred test sounds created or processed by means of various different techniques (additive synthesis, subtractive synthesis, filtering, delay, etc.). For each sound a control panel appears through which the players can control a single characteristic of the sound and of sound processing.

The learners must identify or approximate as closely as possible the value that will permit them to reconstruct the test sound.

These test sounds are not simple pre-recorded sounds, but they are generated in real time by the application, which means that the number of possible sounds is virtually infinite.

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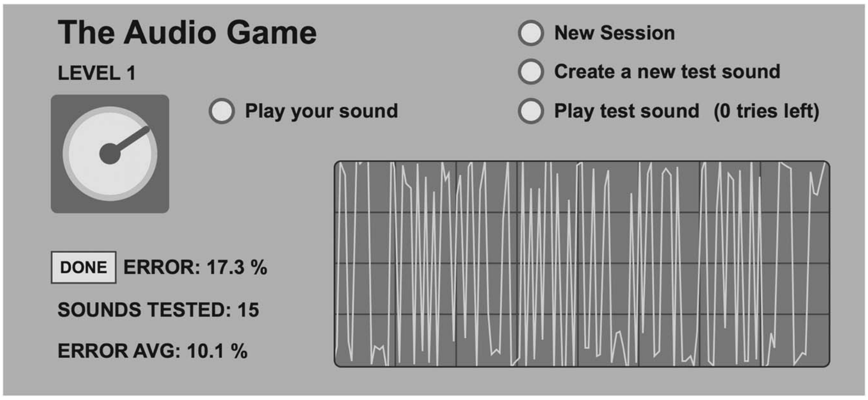

Figure 1. First level: ear training.

For example, a test sound could be the sound of a snare drum processed by a low-pass filter with a cutoff frequency of 1,000 Hz. The students can use a knob on the control panel so as to adjust the cutoff frequency of the filter, applied to the original unprocessed version of the test sound, which is defined as the 'raw sound'. The closer the players are able to approximate their own frequencies to the cutoff frequency of the test sound, the higher their score will be.

The purpose of this first step is to become familiar with the basic building blocks necessary for sound construction: the examples are very simple, the sounds have a homogeneous timbral content (i.e. there is no superimposition of different sounds) and the control carried out by the player produces very obvious effects in the final result.

Figure 1 illustrates the configuration of the game at this level:

1. The player presses a button to load a test sound (which is randomly selected by the application). This sound can be listened to only up to a maximum of three times during the exercise.
2. A second button is used to play to the raw sound to the player, which he will have to modify or filter.
3. A knob on the control panel is used to modify the cutoff frequency for the filtering of the sound. When the players feel that they have identified or sufficiently approximated the cutoff frequency of the test sound they can click on the 'Done' button.
4. A message then appears, indicating the percentage of error of the test: 0% naturally means that the parameter has been identified exactly, while 10% means that the parameter (such as a cutoff frequency) identified by the player is 10% higher or lower than the real parameter, and so on.
5. When players are able to identify the parameters of a whole series of sounds with an average error of less than 5%, they can go up to the next level (that of reverse engineering). If their results have errors of greater than 5%, the players can try with a new set of test sounds different from the previous ones.

An important point to emphasise is that all of the activities on this level are carried out before any theoretical explanations have been provided. The players can hear that by moving the knob they can change the sounds, but they do not know exactly what kind of technical processes are taking place. In fact the knob is not associated with any kind of numeric display.

The theoretical part is provided only after the player has passed the level. The explanation of the operation of a filter, for example, only comes when the player has gained a clear perception of how it modifies a sound. Once the first level has been completed, the student is directed to a page of the website theaudiogame.net, which contains a list of theoretical lessons that explain the parameters that have been used during the game and the relative techniques of synthesis and processing.

Here is a partial list of some of the characteristics of sound (or of sound processing) that the learner has the opportunity of manipulating and controlling:

- frequency
- amplitude
- waveform (for FM-generated sounds, sounds made with other non-linear techniques, or sounds derived from the mixing of two separate sounds)
- attack
- decay/release
- bandwidth (for noise generators, granular synthesis sounds, etc.)
- filter type
- cutoff frequency
- resonance factor
- sound motion with envelopes or low-frequency oscillators, such as glissandos, tremolos, vibratos, etc.
- use of effects such as flanger, chorus, delay with feedback, reverb, etc.

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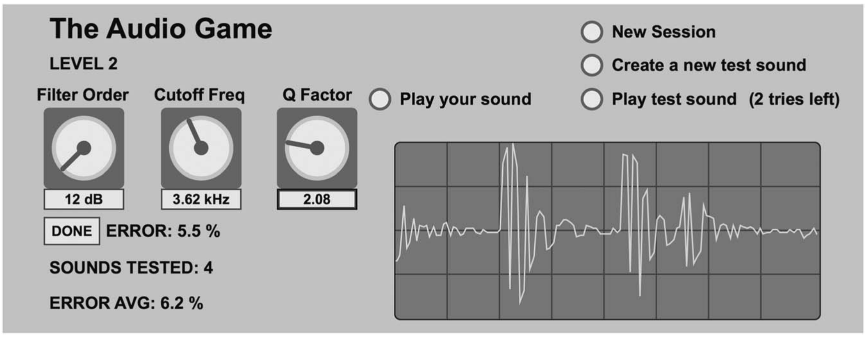

Figure 2. Second level: reverse engineering.

It should be borne in mind that at this stage the student may modify only a single parameter, such as the modulator frequency or the modulation index of an FM sound, the decay time of a reverb, the amount of feedback in a delay and so forth.

6.2. Second level: reverse engineering

In the second level, the student is presented with a series of one hundred test sounds of increasing complexity. In this level, the control panel presents all of the relevant parameters for the reproduction of a certain sound or effect. The number of parameters to be set can be anywhere from two up to ten or more.

A test sound such as the above-mentioned filtered snare drum sound would have a control panel with the following parameters (see Figure 2):

- cutoff frequency
- filter slope (between 12 and 48 dB per octave).
- Q resonance factor
- filter envelope shape.

The evaluation is calculated by means of a weighted average of the errors made on each of the various parameters.

At this stage the student already knows how each of the separate parameters work (having passed the first level), and this time the knobs are equipped with numeric displays. Thus the student learns how the various parameters interact with each other by modifying their numeric values.

Each knob has a caption indicating the name of the parameter, and clicking on the caption opens a window that reminds the user about the function of that parameter. In this way the player is able to simultaneously learn practical skills and theoretical knowledge in the form of a network of interconnected concepts, rather than in a sequential form.

At this stage, the sounds are more complex than those of the first level, and can thus be overlapped and evolve over time. The player is often asked to correctly set an envelope controlling parameters such as the amplitude and frequency of a sound, the cutoff frequency of a filter, stereo position, modulation index and so on.

Unlike in the first level, where the test sounds are presented without any predefined order, but rather with a criterion of the greatest possible variety, the sounds of the second level are presented in order of increasing difficulty (as regards the number of parameters involved), and in homogeneous groups as regards the techniques of synthesis and sound processing that have to be utilised.

When the student gets an average error of less than 5 per cent for a series of test sounds the last level (that of sound design) is 'unlocked'.

6.3. Third level: sound design

At this level, the student must first of all identify the techniques that have contributed towards generating the sound, and then set the relative parameters.

The level is divided into two sub-levels of increasing difficulty: the *guided level* and the *free level*.

In the *guided level* the sounds are generated in real time by the application (as in the previous levels). This time the control panel has the same configuration for each sound: a group of six menus, each of which contains a list of techniques of sound synthesis and sound processing. It is not always necessary to use all six menus.

When a particular technique in the menu is selected a window opens that contains the relative parameters. The processed sound passes from the algorithm of one menu to the next menu in series.

The above-mentioned example of a filtered snare drum sound can be resolved in this level by selecting a sampler in the first menu, from which the right snare drum sound can then be chosen, and in the second menu a filter can be chosen (it should be noted that the menu does not only contain filters, but all of the main techniques of sound processing). In this case the other menus are not used.

Once the first sub-level has been successfully completed the player can move on to the second sub-level, the free level.

In this last phase the test sounds are not generated by the application, but they are retrieved from a database that contains a library of pre-recorded sounds (some of which are excerpts from well-known music tracks) realised with various different techniques and methods of synthesis.

The cycle of training in the martial arts known as Shu Ha Ri dictates that at first the student must copy the techniques exactly as he or she is taught. In the next stage the student assimilates and deepens his or her theoretical and experiential knowledge. In the final stage the practitioner innovates and offer his or her own original interpretations and thoughts. In some ways the structure of this game resembles this kind of route, and the free level is provided to stimulate the learner's capacity for problem-solving and invention.

In the *free level* the control panel is an empty window into which the student can put (by choosing them from a menu) a series of graphic icons that represent various algorithms of synthesis and sound processing, and he or she can freely connect the various different modules in the attempt to reconstruct a sound that is as similar as possible to the sound presented.

The patches thus created are shared on the theaudiogame.net site between the students of one or more classes, and the students themselves vote to assess the patches (which are submitted anonymously) and thus to decide who will be the 'winner' of the game. By solving each activity the users collect prizes, which consist of increased knowledge and the freedom to practise the knowhow and skills that have been acquired. In this way students attain a satisfactory and concrete understanding of their progress, as well as its wider acknowledgement by the community of players, who discuss it and evaluate it.

7. IDEAS FOR THE FUTURE

In the future, the *Audio Game* could be expanded and developed into a more advanced form.

Once the user has gone past the initial levels (which need to be solved in the right order because this is necessary in order to acquire the basic skills), it would be possible to move on to a reticular map, which would allow the user to freely decide which activity to do, out of a choice of various exercises dealing with the same theme or with a similar degree of complexity, so as to then progress to the next group of exercises. There could be tasks involving the identification of the various sounds that can be heard in connection with visual elements in a music video, or having to press sequences of buttons at the right time, completing unfinished concept maps or correct fixing incorrect concept maps, so as to stimulate the learner's capacities for invention and problem-solving skills.

With so many varied activities available to them the designers of these tasks can assist and encourage learners to bring into play their various different types of intelligences, continually developing them and causing them to interact in a wide range of diverse modalities.

By moving between the different levels of the game, the student will in fact be passing through a concept map. In addition there will be the opportunity for online group tasks and activities in multiplayer mode, involving the creation of short collective compositions or proficiency challenges between the learners. An interactive platform in the form of a collective game would allow students to undertake an active journey of discovery. The three macro-areas of learning (understanding, listening and making) can thus be explored simultaneously within the same interdisciplinary activity, instead of being divided into separate activities to be performed at different times. In this scenario, the teacher is no longer simply a provider of information, but rather an active coordinator of individual or group experiences and a point of reference for various journeys and pathways that lead ahead or for resolving the doubts and perplexities that arise along the way. In this case, his or her ability to listen and provide useful feedback will be even more important than in the past.

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