DIY-MAKING OUR OWN MUSICAL INSTRUMENTS

Digital teaching material for Primary and Secondary Education Teachers

Authors
Aris Droukopoulos, Thalia Ioannidou,
Yannis Kotsonis, Gelina Palla

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inter faces

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ONASSIS STEGI

Onassis Stegi (www.onassis.org) is a cultural venue in Athens, which hosts events and activities across the entire artistic spectrum, from theatre, dance, music and film to visual arts, poetry and literature. It emphasizes contemporary artistic expression, and supports Greek artists, alongside developing international collaborations and offering education opportunities for people of all ages, through continuing education programs. Every year, the Onassis Stegi organizes and coordinates international tour and exchange programs for its own productions, and promotes awareness and synergies across science, innovation and the arts. Stegi is a department of the Onassis Foundation and was officially established in December 2010.

EDUCATION PROGRAMS

Onassis Stegi Education Programs are addressed to school groups, families, teens, adults; educators, artists, people with disabilities, adults 18-40 years old, people over 65 years. Their main goal is to bring contemporary art closer to people’s everyday lives. Each year our education programs revolve around a different theme. They cover all the fields that are included in the Onassis Stegi program, such as theater, dance, music, visual arts, and new media, and many of them are interdisciplinary. They are associated with the Onassis Stegi artistic program and draw connections with other units of the Education Pillar (Onassis Library, Special Education, Cavafy Archive).

INTERFACES

Interfaces (www.interfacesnetwork.eu) is an international interdisciplinary project which seeks to introduce new music to a wide range of new audiences. Interfaces is an Onassis Stegi initiative, supported by the Creative Europe programme of the European Union. It brings together nine partner organizations from eight European countries, all of whom have a broad spectrum of experience in fields such as performing, multi-media exhibitions, new media, acoustic and electroacoustic research and education. This trans- sectoral approach is the key to opening up new perspectives on both the creative dimension of the project and the central objective, which is to engage new audiences of all ages and those potential audience segments which, for a variety of demographic or cultural reasons have not yet been exposed to the music of our time.

FROM JUNE 2016 TO AUGUST 2020, THE INTERFACES NETWORK REALISED A VERY WIDE RANGE OF ACTIONS, INCLUDING:

- New performance formats in new innovative spaces and across artistic disciplines using new media for creation and dissemination
- Educational activities including physical outreach and innovative online applications
- Research & conferences
- Artist residencies

Interfaces network is coordinated by Onassis Stegi in partnership with the following organisations: De Montfort University (United Kingdom), European University Cyprus | EUC (Cyprus), IRCAM (France), ZKM | Centre for Art & Media (Germany), CREMAC (Romania), Q-O2 (Belgium), Ictus (Belgium), Klangforum Wien (Austria).

The project is co-funded through the Creative Europe programme of the European Union.

DIY-MAKING OUR OWN MUSICAL INSTRUMENTS

Digital teaching materials for Primary and Secondary Education Teachers

Where others only see cables, chips, tin cans and foil, you will enter a vision of classroom music experiments.

TARGET AUDIENCE

Primary and Secondary Education teachers

The teacher kit will be available on onassis.org in December 2020.
Teachers and students are not required to have prior knowledge in music or electronics.

The teaching & learning material "DIY-Making our own musical instruments" is a practical guide with detailed instructions, examples and exercises, for teachers who want to experiment with DIY constructions and diverse ways of hands-on creative music-making in the classroom.

With the audiovisual material provided as their compass, teachers and pupils can work together to construct odd and wonderful musical instruments using materials such as rubber bands, tin cans and foil, along with electronic chips, cables and resistors. In this kit, alongside clear guidelines on how to build DIY instruments, you will also find background theory on physics, sounds and electricity to help you better understand how the instruments work, as well as guidelines on how to set up games and improvisations, and suggestions for creating your own little sonic compositions. Prepare for an unusual journey into the fascinating world of sounds and music, through art and science.

AUTHORS & WORKSHOP LEADERS

Aris Droukopoulos, Audio technician, loudspeaker and electronic audio equipment designer
Thalia Ioannidou, Musician, sound artist
Yannis Kotsonis, Musician, sound artist
Gelina Palla, Musician, sound & visual artist, educator

The authors would like to acknowledge the contribution of Stratos Bichakis (composer/sound artist), also a member of the workshop leaders' group in 2018-19.

DIY-MAKING OUR OWN MUSICAL INSTRUMENTS

"Music is the entire universe sounding. We are all at once audience, performers and composers of a worldwide symphony."
R. Murray Schafer

Figure 0.01. Snapshot from a workshop at the 21st Primary School of Athens "Lela Karagianni" (2018-19). Children are experimenting with improvised musical instruments they have just built themselves.

When we refer to music, what usually comes to mind is a musical piece performed by musical instruments, with or without vocal accompaniment. There are several styles and genres of music, and they multiply and change continuously, following changes and developments in human life. Older styles of music also continue to live on through musicians and listeners, alongside newer music. However, music is not just that…

The great changes that occurred during the 19th and 20th centuries triggered the creation of entirely new musical worlds. The intensification of machine use after the industrial revolution, the widespread use of electricity, and later on, the development of electronic technologies and computing contributed to a conceptual shift in the way we consider sound and music. New media created free space for music to develop towards multiple new directions. Gradually new instruments with new technologies, new capacities and new sounds were developed. At the same time, a new music evolved out of research and experimentation in various fields, by important composers such as Luigi Russolo, John Cage, Pierre Schaeffer, Karlheinz Stockhausen, Edgard Varèse, Iannis Xenakis, Reed Ghazala, Peter Vogel and many more. Through inquiries into the nature of sound and the sonic qualities of spaces and materials, through the recording of environments, the exploration of electrical sound, and the exploration of new technologies and audiovisuality, music expanded. Along with new musical instruments and new objects, new musical forms also emerged: electroacoustic music[1], sound art[2], soundscape[3], sound installation[4], sound sculpture[5] etc.

Today, many artists across the world continue to explore sound, making use of new technologies and scientific research for musical experimentation, combining electronic circuits with recycled materials, into the making of improvised instruments and sound objects. In this type of artistic practice, that associates with the DIY[6], DIWO[7] and Maker culture[8] movements, either it is an individual art project, or an artistic collaboration, or an educational group activity, sound frequently co-exists with elements drawn from the visual and performing arts. This is the context where we encountered the work of John Richards[9], which was our starting point for this teacher's kit on "DIY-Making our own musical instruments".

This was also the basis on which we designed and realised the two educational programmes for "DIY-Making our own musical instruments" at Onassis Stegi. The workshops took place over a two- month period each in eight public schools in Athens, in the period 2018-2020.

The teaching & learning material contained in the kit aims at initiating children in the fascinating world of sounds and experimental music through art and technology, without requiring any previous knowledge of music and musical instruments. Children are invited to actively partake in discussions, experiential activities for the understanding of new concepts, DIY instrument design and building, and spontaneous or structured improvisation and sonic composition. Through this experience, children will have the opportunity to acquire, enrich or actively employ knowledge in cognate subjects such as Physics (sound, electricity, electronics), Music (frequencies, rhythm, improvisation etc.), Art (form elements, drawing, designing, building etc.) and Technology (circuits, sensors, connections etc.). The programme seeks to develop active experimentation, improvisation, an understanding of the multiple possibilities entailed in combining art and technology, and the empowerment of children through achievable goals, with an unpredictable but remarkable result. Reflection and active

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[1] A type of contemporary music which was developed after the mid-20th century. Electroacoustic composers use electricity and technology to process and modify the timbre of sounds made by instruments and other sound objects.
[2] A type of experimental music which uses sound as its main medium.
[3] In music, soundscape may be a recording or a sonic performance that creates the sense of a particular sonic environment for the listener.
[4] See Section 3
[5] See Section 3
[6] Acronym for Do It Yourself
[7] Acronym for Do It with Others
[8] Contemporary maker movement which is a continuation of DIY in the digital age, and which makes use of new design technologies, such as robotics, 3D printing, laser cutting, etc.
[9] John Richards is a musician and professor at De Montfort University, Leicester (U.K.); he also directs the Dirty Electronics project.

listening, active feedback through significant music examples, and the fostering of critical skills and combinatory knowledge also played an important role in this programme. The activities proposed here induce collaboration and adoption of individual roles and responsibilities within a group, and most of all, provide children with a sense of enjoyment through artistic practice.

The workshops were developed over seven 3-hour meetings in schools, and concluded in the form of a final public showcase. However, the teaching & learning material collected in this kit is varied and wide, and is thus conducive to several different approaches. The material can easily be related to other school subjects (Physics, Music, Technology, Arts), and encourages environmental awareness (recycling, upcycling, acoustic ecology). Its content can be employed in part, through a selection of individual constructions or activities in the context of a specific course or programme, or developed in its entirety, over a longer duration, even during an entire school year.

The educational programme was realised in late primary and early secondary (junior high) school classrooms, but could easily be of interest to older children. Teens may safely and responsibly handle all the tools and materials, and may try out the more demanding constructions described in the handbook. As they are expected to have more skills and prior knowledge, they may imagine their own variations and extensions to the proposed constructions, and develop even further the recommended playing techniques & improvisations with the DIY instruments.

Figure 0.02. Photo of students from the 21st Primary School of Athens "Lela Karagianni" at the final showcase presentation in Onassis Stegi (May 2019), alongside the improvised musical instruments they built during the workshop.

THE TEACHING & LEARNING MATERIAL

This kit consists of six sections. Sections 1 to 5 contain introductory theory and guidelines for constructing simple and more complex improvised musical instruments, alongside exercises and activities. The final section (Section 6) is entirely dedicated to the possibilities offered by improvised musical instruments and to potential ways of playing. It includes recommendations on how to try them out and perform with them, as well as ideas for potential presentations in school concerts, events and showcases.

Each section (1-6) of the kit for «DIY-Making our own musical instruments» contains a variety of material organized in different categories – subsections. For easier access, these have been codified according the following symbols:

KNOWING AND UNDERSTANDING: Key theoretical knowledge for the section, to be combined with suggestions for discussion and concept-understanding activities.

COMPREHENSION ACTIVITIES: Exercises and games for the comprehension of theoretical concepts

DISCUSSIONS: Questions for open classroom discussions on the section's subjects. Children comment on the issues raised, talk about their own experiences and share their opinions.

MAKING: Detailed instructions, materials and examples for instrument-building, combining electronic components and circuits with objects from the recycling tray.

LISTENING AND WATCHING: Audio and video examples relating to the topic of the section. These can be listened to or watched in classroom and form the basis of pupil-teacher discussions. They comprise a representative selection of works and musical experiments by important artists and composers of the 20th and 21st centuries, in order to develop an aesthetic understanding of the multiple possible uses of the instruments. Some of these examples are original material developed by the handbook authors, as well as examples from the programme's implementation in schools.

PLAYING: Suggestions for experimentation, individual and group play with the improvised instruments and improvisation exercises with detailed instructions.

COMMENTS: Specialised commentary and supplementary remarks on the section.

MATERIALS: Detailed list of all the materials needed to build the instruments described in the section.

REQUIRED EQUIPMENT AND TOOLS

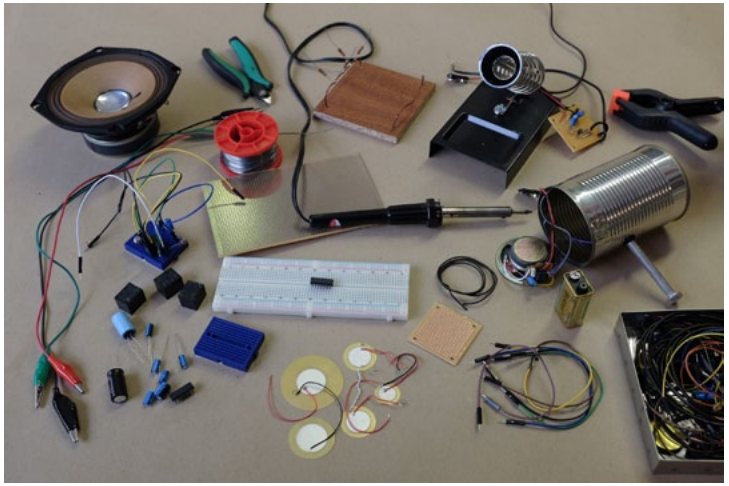


Figure 0.03. Required tools and equipment for the workshop "DIY – Making our own musical instruments".

To convene these workshops, preparation is required. This includes gathering tools and recycled materials, searching for specialist electronics stores (physical or online) and buying the necessary electronic components for circuit-building. Ideally, you will need to find a dedicated room with enough free space to host workshop activities and provide safe storage for the constructions, as some of them are quite sensitive. It is also important to have a computer with a relatively big screen, or a projector / interactive board, and a pair of good quality speakers, to ensure all the details in the sound examples are audible. The materials required for each section are presented in the *Materials* chapter of each section, right before the building instructions.

General classroom equipment:

- Bench desks or worktables
- Whiteboard or other type of board (for writing notes)
- Power socket and power strips
- Personal computer with big monitor or screen with projector or interactive board Computer speakers or other PA, as well as small active (self-powered) speakers with jack or mini-jack input
- Portable mp3 recorder, mobile phone or tablet (for audio recording)
- Portable camera, mobile phone or tablet (for video recording)
- Storage space (closet, library shelves or boxes)
- Tools and materials like a soldering iron with base, solder, pliers, cable cutters (and optionally, a cable stripper), hammer, multimeter, hot silicone glue gun, universal cutter, insulating tape, and stationery (pencils, pens, markers, A4 papers).

Before running the workshop, it will be useful to have gathered various kinds of leftover packaging from home, like tin cans, plastic yoghurt tubs, disposable cups, cardboard cylinders (e.g. from kitchen paper rolls), jar lids, empty containers made from various materials (cardboard, metal, wood) in as many shapes and sizes as possible.

TABLE OF CONTENTS

1. SOUND AND MUSICAL INSTRUMENTS

In our first workshop, we will understand sound and its features. We will talk about music and the logic behind musical instruments.

Figure 1.01. Various materials from the recycling bin and easy-to-play musical instruments: vibra-tone, tambourine, drums, kalimba.

WORKSHOP MATERIALS

- A4 paper, pencils and coloured markers
- Boxes (in handheld size, relatively rigid) from packaging or gift wrapping. Rubber bands in various sizes
- Bamboo skewers (with the sharp tip cut off first, so they are not dangerous!) Round jar lids
- Plastic cups
- Legumes, rice, coarse salt
- Metal discs, glass jars or surfaces made out of any material, that can be used for making sounds
- Very simple musical instruments like vibratone, kalimba, drums, maracas, tambourine, triangle or any other similar instrument available

INTRODUCTORY ACTIVITIES[10]

1.1. Name and sound

Every child says their name and makes a sound they like, in whatever way they want, e.g. with their mouth, body, or with an object. We then ask children to draw their sound on paper.

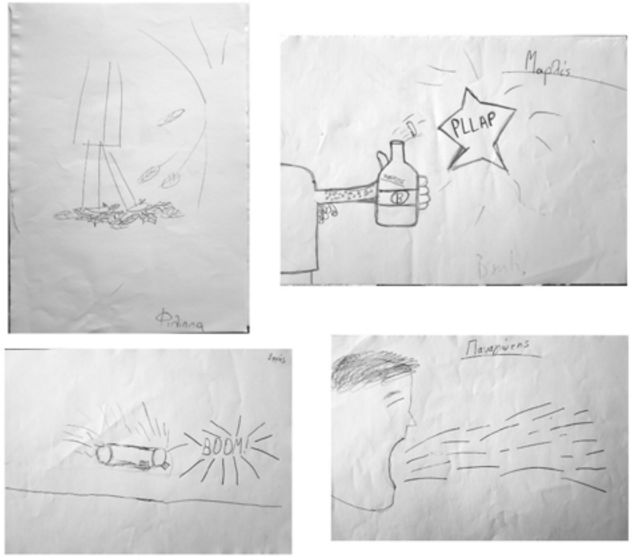


Figure 1.02. Examples of drawings representing children's sounds from the game "Name and sound" (3rd Primary School of Galatsi, Athens, February 2020).

DISCUSSION

We look together at how each child captured her/his sound on paper, and talk about the way each sound was depicted. Do we see the sound's source in the drawing? Can we think of any other activity that has a similar sound to ours? Did we use any particular symbol or colour in the depiction?

1.2. Sound and lines

We draw out each sound again, this time only using lines, shapes and/or colours, i.e. more abstractly than before. Each child draws a sound on the classroom board.

[10] See notes an the end of Section 1.

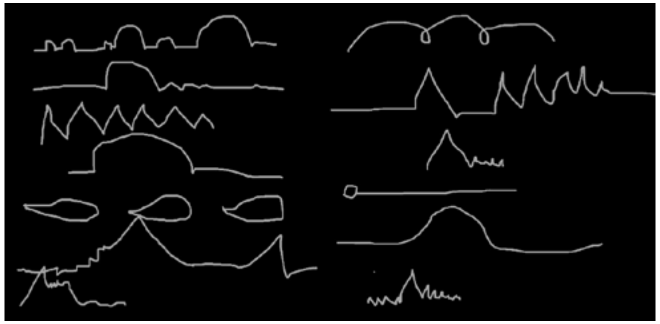


Figure 1.03. Examples of lines representing children's sounds during the exercise (3rd Primary School of Galatsi, February 2020).

DISCUSSION

We can discuss the impressions left by every sound and the features we discern or assign to it (e.g. if the sound was sudden, brief, sustained, soft or loud, stable or fluctuating, melodious, deep or high, but also if it was cold or hot, full, emotive, scary, creepy etc). As specific lines, shapes or colours have been deployed, we may also discuss the children's choices and their reasons for depicting each sound in specific ways. Why did we choose this type of line over another?

1.3. Lines and sound

The last part of this activity involves "singing" the lines we drew! One by one, children interpret one of the lines on the table with their voices. After each child has interpreted a line on their own, we can encourage them to sing a line, or a group of lines, all together, by giving them a signal to start with – for instance a rhythmic "3-2-1-oooooooo".

2. ALTERNATIVE INTRODUCTORY ACTIVITY: THE NAME (R. MURRAY SCHAFER)

We introduce ourselves to the class, by repeating our name in several different ways. We ask students to imitate how the instructor's name is pronounced every time. We then ask students to introduce themselves in a similar way. This can happen either individually with students taking turns, or by breaking down the class into smaller groups and designating a leader for each group. The leader can pronounce their own name in different ways, while others imitate the ways (then the group leaders can change in rotation). The pronunciation of the name can also be accompanied by arm or leg gestures, with or without sound.

3. ALTERNATIVE INTRODUCTORY ACTIVITY: THE DRAWINGS

We draw a few lines or symbols on the board (or we have already drawn them on cards in advance). We ask pupils to “perform” them, either by using their voice, or by making another type of sound. We then ask them to explain why they interpreted them in this way. We comment on the relationship between a sound and its visual representation, and we begin discussing different features of sounds, which will be analysed below: duration, volume and pitch.

Figure 1.04. Examples of lines that children can represent through sounds.

LISTENING AND WATCHING

We listen to *Pithoprakta* by Iannis Xenakis, while looking at the work’s score. This graphic score for 50 interpreters is easy to read, and children can follow it with interest. We remark how the visualisation of sound relates to the sound itself. At the same time, we experience orchestral music through a more abstract kind of repertoire, and allow for a first contact with the “strange” music of the 20th century.

DISCUSSION

What kinds of music do children listen to? Do they play any instruments? Have they been to live concerts? What kinds of concerts? With what kinds of instruments? Classical, traditional, electronic, acoustic, electrically amplified?

Can they think about different, more abstract sounds that they would neither call “music”, nor expect to find as “real” sounds in their environment? Can they recall where they may have heard such sounds being used (e.g. film, animation, commercials, electronic games)? What are these sounds and what is their meaning?

KNOWING AND UNDERSTANDING

What is sound?

Sound is a phenomenon that accompanies almost every human activity. In nature, sounds are produced all the time. Humans and animals make sounds even when completely still or asleep; our cultures, especially in the cities, constantly produce sounds. Our own body never ceases to make sounds; even if we were in a completely silent space, we would still hear them. For sound to exist, at least in the way we perceive it, there needs to be a sound source, a transmission medium, and a receiver.

A. How is sound produced and spread?

As a natural phenomenon, sound manifests itself in the form of soundwaves. Bodies that emit sounds are called sound sources. Sound is produced through the vibration of these bodies; the vibration may be caused by impact or friction. Vibration is a repetitive (periodic) motion of a body around an equilibrium position. When an object vibrates in the air, it causes a corresponding motion in the air molecules. The air molecules interact with each other, causing a wave.

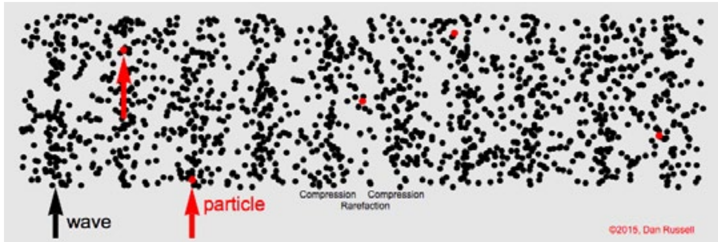


Figure 1.05. A representation of how air molecules move in soundwaves.

A familiar image which demonstrates how soundwaves move in relation to their source, is that of ripples on a pond’s surface when we throw a pebble in the water.

Figure 1.06. Wave motion (ripples) on water surface.

Soundwaves are not visible with bare eyes – we may see them forming on a water surface or capture them with electrical and electronic recording media. They have specific material properties, like all mechanical waves: frequency, period, wavelength, amplitude, time (duration) and waveform.

Sound is not only transferred through the air, but also through liquids and solids. Unlike what happens when we (humans) travel, sound travels faster through liquids than through air. It also travels even faster through solids than through liquids! However, sound cannot be transmitted in a void, e.g. in outer space, because there are no air molecules to form waves during vibration.

Humans cannot perceive all soundwaves, only the ones whose frequencies lie between 20-20.000 Hz. Sounds higher than this range are called “ultrasounds”; sounds that are lower than this range are called “infrasounds”. Dogs, bats, rodents and various other animals have a different hearing frequency range and can actually hear ultrasounds.

COMPREHENSION / OBSERVATION ACTIVITY

Each child chooses a partner from their group of classmates. One child places their ear firmly on one side of the bench desk; the other taps the desk surface from the opposite side. They listen to the tapping sound from this position; then they listen to it normally, without their ear on the desk. They are asked to observe & remark on how the tapping sounds in each case.

Have they seen old Western movies, where someone places their ear on the railway tracks, to check if a train is approaching? This is because railway tracks are solids, and sound travels faster through solids than through air. Thanks to this, the heroes in the Western have more time to plan ahead and sabotage the train!

B. How do we perceive sound?

Sound is perceived through hearing, i.e. through our ears. We need both ears; their combination is what gives us a sense of space and allows us to understand where sounds are coming from.

Soundwaves are picked up from our ear flap, and are transferred to the eardrum, causing it to vibrate. The eardrum vibrations are converted to electrical signals (also known as electric pulses). Through our auditory nerve, these are then transferred to the brain, where they are “translated” into specific sound impressions.

C. Key features of sound

There are certain features that allow us to distinguish between different sounds, and to talk about these differences. These are pitch, volume, duration and sound colour (otherwise known as timbre).
Pitch depends on frequency, i.e. the number of vibrations per second. The higher the frequency (i.e. the more the vibrating motions), the “higher” or “sharper” the sound; the lower the frequency, the “lower”, “deeper” or “bassier” the sound.

Volume relates to how loud a sound is heard.

Duration is the total time during which a sound is audible. A sound may appear to last for a long time, but may actually consist of a very short sound that repeats itself, e.g. the sound of a ticking clock.

Sound colour or timbre is what allows us to distinguish between two different sounds that may have the same pitch, volume and timbre. For example, the same musical note sounds different when played by a violin, piano or other instrument. This is also how we can distinguish the voices of two different people. The term itself (sound colour) may help us understand this concept better, if we consider how many different colours and hues of green, red or blue there are in a painting.

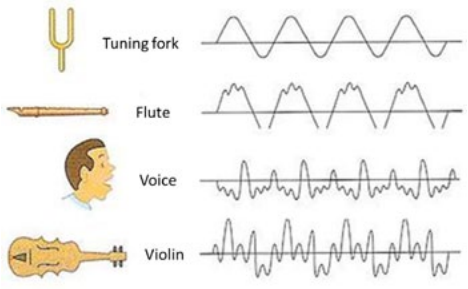


Figure 1.07. Soundwaves from sounds of different timbres.

Sound also has certain *properties*: it can be transmitted, diffused, absorbed or reflected.

When a surface is “hit” by a soundwave, a portion of the sound’s energy is reflected, another portion is absorbed by the surface material, and yet another is transmitted through this material. Below we will see some useful practical examples of these properties in action!

DISCUSSION

We consider which sound is higher or lower, comparing between: a big dog barking and a bird singing; a passing truck and a motorbike; a squeaky door and a thunder; the teacher’s voice when (s)he calmly explains something or when (s)he shouts at us to be quiet.

KNOWING AND UNDERSTANDING

A. Music - Instruments

Music is the art of combining sounds. Since antiquity, humans have been "harnessing" the power of sound, creating musical instruments and music. During all this time, music has served many purposes: enjoyment, entertainment, devotion, evocation, contemplation, labour and even torture. Various different styles and genres of music have been developed, in correspondence with the different purposes fulfilled by music, the instruments being used, the rules and properties assigned to it by different cultures, etc. As mentioned in the introduction, our conception of what music composition entails, and even what music is in the first place, changed drastically during the previous century and is still undergoing changes and developments. Musical developments have been particularly influenced by technological innovation and the invention of new, different musical instruments, many of which make use of electricity.

Musical instruments are devices that make musical sounds. A human voice is also a musical instrument. Humans make sounds in all kinds of different ways and for all kinds of different reasons, either using their mouths (e.g. by talking, singing, shouting, whispering, whistling, blowing), or by beating / striking something with their bodies. There are many different instruments that have specifically been designed for playing music, but in fact any object that allows us to make sounds and can be used to make music, can be called a musical instrument.

LISTENING AND WATCHING

1. We watch a video with musical sounds from objects found in a recycling bin.

2. We watch a video with the notes produced by a crystal glass when rubbed with a bow. Notice how, when the water moves, the sound's frequency (i.e. pitch) changes.

B. The resonator

How would a guitar or violin string sound, without the body of a classical guitar or the violin? It would be almost inaudible!

We mentioned the properties of sound above, and how sound is reflected and transmitted through the surfaces that receive the soundwaves. For musical instruments, these surfaces are incredibly significant. Thanks to them, a sound that would otherwise be very low in volume, is amplified so we can hear it.

We remarked that soundwaves behave like the ripples forming on a calm pond when we throw in a pebble. Imagine, however, what happens with these waves if we throw the pebble into a natural lake surrounded by rocks. Or if we throw in one more pebble, and another, and yet another. Similarly, soundwaves are influenced very much by the space in which they move. The materials, the size and the shape of the space actively participate in the sonic phenomenon. They multiply or absorb sound, change its timbre etc. The same sound source will sound completely different in a small room, deep inside a cave, or atop a mountain. If we scream inside the shower, in front of a hilltop, in a club with really loud music on, our voice will sound completely different each time.

When soundwaves hit a surface they are not just reflected, but they also transfer some of their energy to this surface. They "force" the surface to vibrate and "reproduce" them. The soundwaves are also altered, according to the surface's shape, mass and material. The combination of these phenomena determines the end result, the sound that reaches our ears.
This is why, for instance, all acoustic *string instruments* have a whole "body" which is actually hollow, very near the strings, which are the initial sound source. This body is their resonator, otherwise known as the instrument's sound

board. The design and construction of classical instruments usually involves very detailed work, so that the path that takes soundwaves from the strings, across the soundboard and other instrumental parts, all the way to our ears, can amplify and colour the sounds as needed. Through this resonant body, soundwaves are reflected and multiplied, while the body itself is *set into vibrational motion*, thus contributing to the sound we finally hear.

Figure 1.08. Tuning fork with wooden resonator, for the amplification of its sound.

COMPREHENSION ACTIVITIES

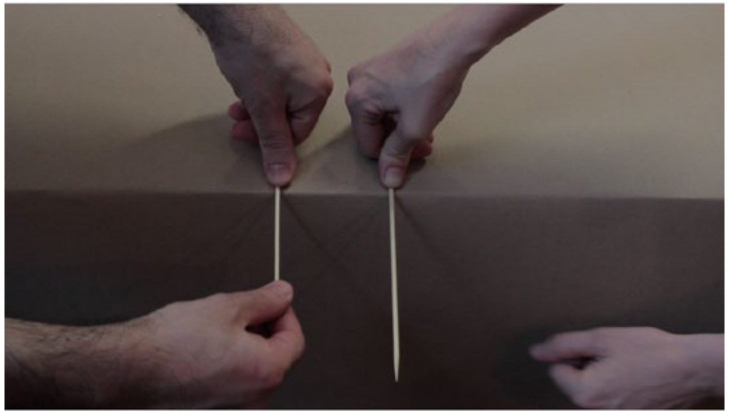
1. Listening and trying out simple musical instruments

We spend some time with the simple musical instruments we have in class. We play with them and make remarks on how they work (based on the comments above). What material are they made of? How are their sounds produced? What are their features? What is their musical role? Where is their resonator? And any other kind of question / observation we can think of!

2. Bamboo skewers: Vibration, pitch, timbre

To better understand the features of frequency and volume, and to relate them to the concepts of vibration and wave, we use bamboo skewers or sticks as instruments, observe how they produce different notes, and listen to how sound travels through solids.

Who can make a sound with this one skewer alone, i.e. without hitting it with another object?



We listen to the sound and observe the vibration. We then put our ear on the table to listen to the sound through the wood, and compare. With the bamboo skewers as a starting point, we can talk about frequency and pitch. We explain the concept of frequency, i.e. “the number of times in a given timeframe”. We observe this through the skewer’s motion. We demonstrate the point at which the skewer lies still (i.e. its position of equilibrium), and observe the vibration over and under this position. We notice how, when the skewer is longer, the distance around the equilibrium position widens, and therefore each vibration takes longer. Therefore, a longer skewer will vibrate fewer times (lower frequency), while a shorter skewer will have the opposite effect (higher frequency).

We also remark that:

Longer skewer (lower frequency) = deep / bassy sound

Shorter skewer (higher frequency) = high / sharper sound

We can consider how sound travels further when a soundwave is greater, whereas this does not happen with a shorter wave. We mention the example of an ocean wave: a big wave can go over the rocks, whereas a smaller wave will hit the rocks and stop there, turn back or break into smaller waves and change direction.

We can also observe that the sound will differ if we try to play with the skewers on different surfaces, e.g. on the desk, the chair, a marble step or a metal surface. This is because the surface with which the skewer comes in contact also vibrates; it therefore contributes to the timbre or colour of our sound differently, depending on its material, size and other features.

PLAYING

1. Skewers

We distribute bamboo skewers (with any sharp tips cut off!) to the children, so they can experiment with this "instrument".

A. Once they have split into different groups, each child finds a "note" they like on the skewer, by changing the skewer's length (see skewer video). Each group then makes a musical phrase, a melody, from these different notes. Children may even create a few "chords", i.e. play the sounds of different skewers in their group at the same time, after having tried them out to see which combination of notes-frequencies they like best.

B. Children form a circle with their chairs or desks. They will use those to amplify the sound from their skewer. They can also use a metal or plastic box to fix the skewer, so they can achieve a different timbre if they want. Once they have picked their preferred tone, one of the children or the educator signals them to start and they begin playing in circle, one-by-one, clockwise or counter-clockwise. It is best if children play continuously, one after the other, so they can create a soundwave!

2. Identifying the materials / Timbre

Children are asked to find objects in the classroom that are made of different materials, such as paper, cardboard, plastic, wood, metal, glass, leather, cloth etc. (they can also be asked to bring them from home in advance). Once they have gathered the objects, they place them inside a box or cupboard, so they are not visible. They sit in a circle facing outwards, with their eyes closed. On the inside of a circle, a child walks around in turns, having chosen an object from inside the box. As the child walks the circle, (s)he hits the object with his/her hand or with a pencil. Once the child has walked around everyone in the circle, the children who[11] are sitting down try to guess what material the object is made of, what is its size, and what the object is.

3. Can all objects be musical instruments?

Children search inside their classroom or schoolbag, for objects that can make sounds. They try them out to determine if these objects could be used to make music, and in what way. For instance, if I take a plastic bag, what sound does it make when I keep crumpling it with my hands? What sound comes out if I shake it violently in the air? If I straighten it out on one side and blow hard over the stretched plastic? What sound does a paper make, if I crease it? If I tear it? If I hold it on one side and shake it hard? If I put a few grains of rice in a cup and shake it rhythmically? What will change if I put the rice in a metal or plastic box and do the same? Children improvise with whatever they find in front of them and present their sounds in class!

[11] A similar exercise can be found R. Murray Schafer, *Hearsing: 75 Exercises in Listening and Creating Music*, Arcana, 2005.

MAKING

1. Boxes with rubber band strings: small improvised instrument

We will need various relatively sturdy, rectangular or square boxes (like various items used for packaging, or collected for recycling). They can be metal, wooden, plastic or cardboard.

Once we have chosen a box, we take rubber bands of different sizes and wrap them tight along the sides of the box. The rubber bands will be our strings, and the box will be the soundboard / resonator of our improvised guitar!

Playing on the rubber bands, we notice how sound is amplified through a resonator, just like we learned in the section on sound reflection. We can also make similar remarks on frequency (pitch) and volume, and use this construction as an instrument.

If we let the rubber band vibrate without a box, while stretching it with our hands, can we hear its sound? How low is it in terms of volume? How can we make it louder, i.e. amplify it? We use the box just like in the video. Why does the sound become louder when we use the box?

We also notice that, when the rubber band is stretched more, it emits a different tone. Why does this happen? Because the rubber band gets harder, and therefore makes a smaller (tighter) vibration; therefore the frequency is greater, and the pitch sounds higher. This is how all the well-known string instruments work in music.

Extension

We add more rubber bands, bigger and smaller, to the box and make a nice string instrument. If we want, we can draw on the box's surface, to customize it and turn it into a unique object!

DISCUSSION

We can talk about string, wind and percussion instruments; we can make remarks on how their sound relates to their size or their material, and whether they are amplified through a soundboard. The frequency of wind instruments in particular relates to a rather different phenomenon, but still results from vibration (of the player's lips, of a reed, etc.)

<u>2. The lids: small improvised instrument</u>
We will require metal lids from various jars (from honey, jam etc.) of different sizes. We choose lids whose centre can move up and down when pressed with our thumbs (this is not the case with all lids). We hold the lid with both hands and press our thumbs up and down over its centre, to produce a "clicking" sound. We bring the lid closer to our open mouth and keep clicking. If we start opening and closing our mouth while we play, the sound will start changing. We notice how our mouth works like a resonator, amplifying the sound. Besides, this is exactly what it does with the sound of our vocal chords!
See relevant video:

LISTENING AND WATCHING

We listen to *Opera with Objects* by Alvin Lucier, performed by Tim Feeney. There is a steady rhythm, which repeats for the whole duration of the piece, while the performer uses different materials to produce sounds. The steady rhythm allows us to perceive the change in timbre. Children can listen to the piece with eyes closed or without looking at the video, and try to identify the material (plastic, wood etc.) used by the musician in each repetition. As soon as the sound changes, or when they have guessed what the material is, they can open their eyes and/or the teacher can reveal the instrument's material, by showing a little clip from the video.

PLAYING

<u>Improvisation in groups</u>
We can come up with an idea on which to play. For example, I play the music that would accompany me on my way to school, or during the break. Or even, I play the sounds of a tropical forest. We can also make up a little story from scratch, and accompany this story with our sounds (we will not tell the story out loud while playing, but we can reveal it after we have finished playing). We use either a combination of improvised and conventional instruments, or just improvised ones.

See detailed instructions in the improvisation exercises, Section 6 ("Sound Story").

CLOSING DISCUSSION FOR THIS SECTION / PREPARATION FOR THE NEXT ONE

We look at a classical and an electric guitar (Figure 1.09) and talk about their differences. One has a hollow body that functions as a soundboard, in the way outlined above. How is the other rendered audible? How does it make sounds? This discussion leads the way for the next section, on sound and electricity.

Figure 1.09. Classical and electric guitar.

COMMENTS

Topics & aims of the introductory activity:

- To introduce concepts that characterize sounds, such as: continuous, intermittent, sustained, brief, momentary, loud, explosive, quiet, soft, etc.

- To realise how sound develops in time.

- To look at different ways of representing sounds, on the basis of their features or meanings.

- If the activity is carried out in its entirety, it will act as an initial coordination exercise, as we will have to find a way for children to coordinate around a signal. Since it is the first exercise of this type, the role of the "conductor" can be taken up by the teacher.

2. SOUND AND ELECTRICITY

We learn about the relationship between sound and electricity, trying out a few elementary connections. We experiment using a speaker as an instrument.

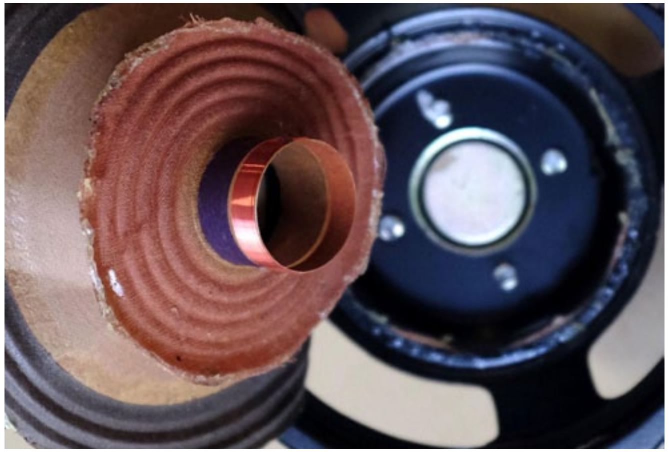


Figure 2.01. Inside a speaker, we can see a coil, a membrane, a suspension, and right at the back, the circular hole where the coil sits on the magnet.

WORKSHOP MATERIALS

- Single core cables, thin walled, or the ones who have little grips (so-called "alligator clips") on both ends.
- Batteries, preferably 4,5V (lantern), but 9V will also do.
- Speakers of various different dimensions. Ideal size 5-6,5´´, i.e. 12,7 to 16,5 cm.
- Tin foil and aluminum tape.
- Various small metal objects, e.g. screws, bolts, metal can tabs, light coins (1-2 cents) etc.
- Coarse sea salt, rice, lentils etc.
- Small and large containers (plastic, metal or wooden)
- Self-powered speakers

KNOWING AND UNDERSTANDING

1. What is an electric current?

An electric current is a coordinated motion of electrons (electrical charge) inside a conductor. There are good and bad conductors of electricity. "Good conductors" are materials who allow the flow of electricity to pass through them; "bad conductors" are materials that do not allow it, and therefore insulate it instead. Metals, water, and even our own body are good conductors, as we shall see below (and this is why we ought to be very careful). Bad conductors, otherwise known as electrical insulators, include plastic, wood and glass. Both of these categories will be useful below: Good conductors (cables) will allow us to connect our materials, so that current can flow through them; insulators (the cables' plastic coating) will help us handle our equipment and avoid short-circuits.

The flow of electric current is invisible. We only see its products (e.g. a lamp switching on), and this is why sometimes it is difficult to understand what it is. To make it easier to grasp, we can imagine electric current like a water current. Imagine a reservoir full of water and a pipe attached to it on one end, and going into the ground, on the other end. The water will flow into the pipe, ending into the ground. How far it will run depends on the size and cross-section of the pipe, but also on whether this pipe contains any other materials that obstruct the flow. Water pressure is similar to electric current voltage (V), and water flow is similar to amperage (A). If we were to fill our water pipe with sand, so that it would obstruct the flow of water, the effect would be comparable to electric current resistance (R). The lower the resistance, the faster the water will run out and our reservoir will empty — and vice versa.

There are two types of electric current: alternating and direct. Direct current is just like the example of water flowing out of the reservoir. It only flows towards one direction inside the pipe, ending up into the ground. Alternating current alternates between different directions and thus forms a wave, a vibration, just like a soundwave.

In our reservoir example, this would mean that the water would circulate back and forth inside the pipe before ending into the ground. Alternating current is the type of current that is available through our home sockets. Most electrical equipment (including sound equipment), however, needs to be powered through direct current in order to work. Current is therefore either converted inside each appliance, or released through batteries.

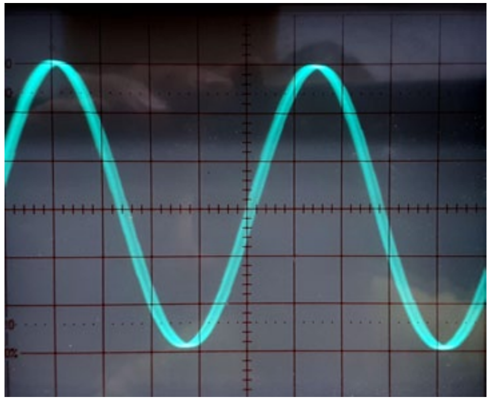


Figure 2.02. Visualisation of alternating current on an oscilloscope.

2. The battery

A battery is a chemical source of direct current, capable of storing electrical charge and, when necessary, releasing it. It has two poles: a positive and a negative one. We can join two or more batteries together, in two ways: in parallel or in series. A parallel connection occurs by pairing a positive pole with another positive, and a negative with another negative. The result is a battery with the same voltage, but a bigger amperage. For example, if we join two 4,5V batteries in parallel, the voltage will remain the same, but the amperage at which a battery can give out power, is doubled. In other words, if a lamp burns for a whole day while connected to our original battery, it can now burn for two days in a row, and be just as bright.

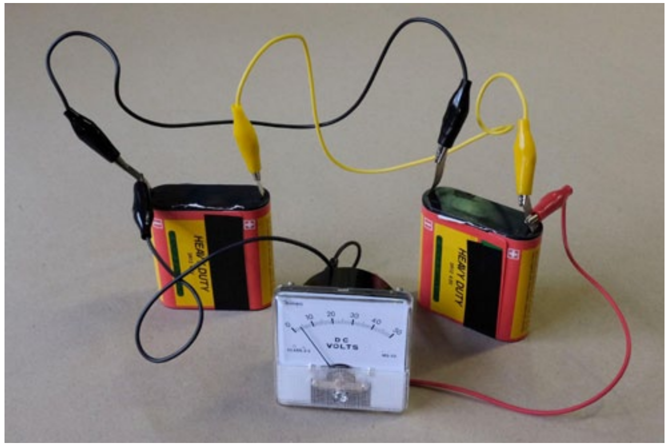


Figure 2.03. Batteries joined in parallel.

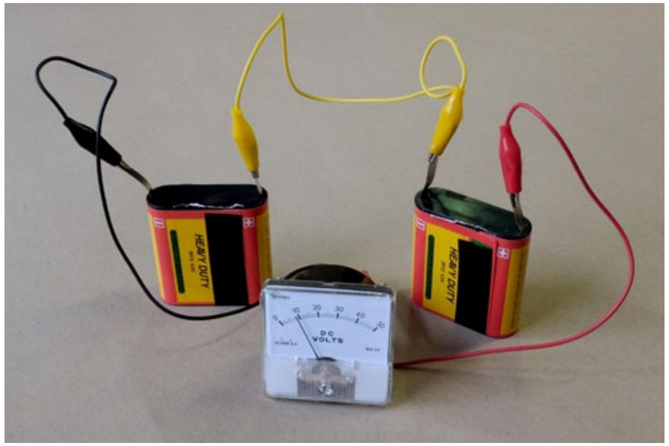


Figure 2.04. Batteries joined in a series.

Connection in a series happens when we join the positive pole of one battery to the negative pole of the other. Through this connection we can achieve twice the voltage, while retaining the same amperage. In other words, our lamp can still last for one day only, but it will burn twice as bright. When we insert this electrical component (the lamp) between the two poles and connect it to the poles with two cables, the current will flow from one pole to the other through the lamp, which has a certain resistance (R).The lamp turns on precisely because the current encounters this resistance.

3. Circuits (and short circuits!)

An electric circuit is the path followed by a current inside conductor that consist of various electrical components. In other words, the connection described above between the battery, the cables and the lamp, is an electric circuit.

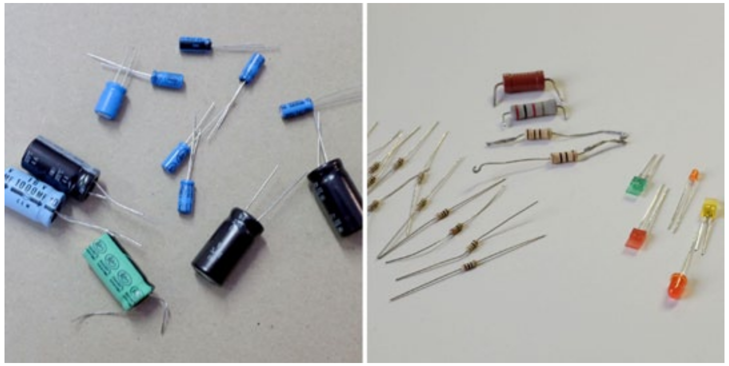


Figure 2.05. A few electrical components: capacitors, resistors, and photoconductive diodes (led lamps).

A circuit may be open or closed. When a circuit is open, the path of electricity is interrupted, and the current can no longer flow inside the conductors. We open the circuit when we turn off the light through a switch. Conversely, the circuit opens when we turn on the light and the current can flow through the lamp, switching it on.

Let us now look at what a short circuit is. This circuit is called short because the current flows from one pole to the other, with virtually no resistance. This lack of resistance means that the current flows much quicker, as its path is shorter, and therefore most of the times is dangerous and destructive. A short circuit, for instance, is what happens if we connect the negative and positive pole of a battery with a cable, without inserting any other electric component between them, or if we connect two batteries by directly joining one's negative pole with the other's positive one. This is something we should never attempt (not even to see what happens).
We should also be very careful when handling electric circuits, to ensure this doesn't accidentally happen! When we are building a circuit with cables extending towards various directions, it is highly probable that a cable may accidentally touch the wrong component at some point. If this happens, the battery may overheat or even erupt, and we might injure ourselves. Something else we should always keep in mind: in our workshop, we handle only objects and instruments that are battery-powered, but never – ever (!) – use the wall socket as a power source!

COMPREHENSION ACTIVITIES

1. Alligators and connections

We can use the alligator clips to make a simple connection with our speaker, and check when it works, i.e. when the speaker is a good conductor and when not. We notice that both our battery and our speaker have two poles, a positive one marked + and a negative one marked -. We take an alligator clip[12] and connect its one end to the battery's negative pole and the other to the speaker's negative terminal. We then connect another alligator clip to the battery's positive pole and momentarily allow its other end to touch the speaker's positive terminal. The speaker membrane will move and we will hear a "click". We notice that the metal clip needs to be in direct contact with the speaker terminal. If it falls a little on the left or right of the terminal, or if we touch the terminal with the plastic-coated part of the alligator instead of the metal clips, nothing will happen.

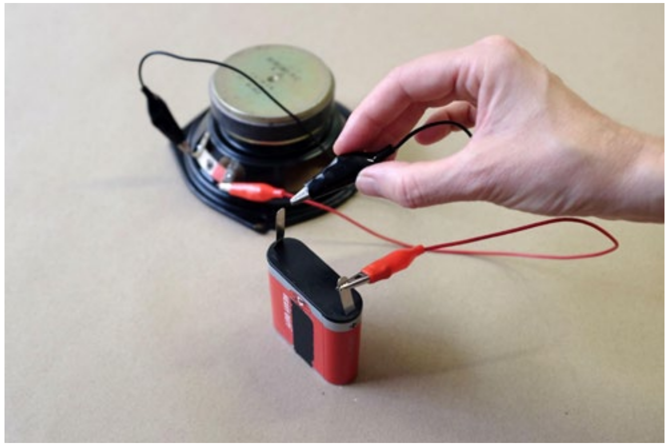


Figure 2.06. Speaker and battery.

[12] We commonly use red alligator clips / cables to connect to a positive pole / terminator and black ones to connect to a negative one.

2. Batteries in a series and in parallel

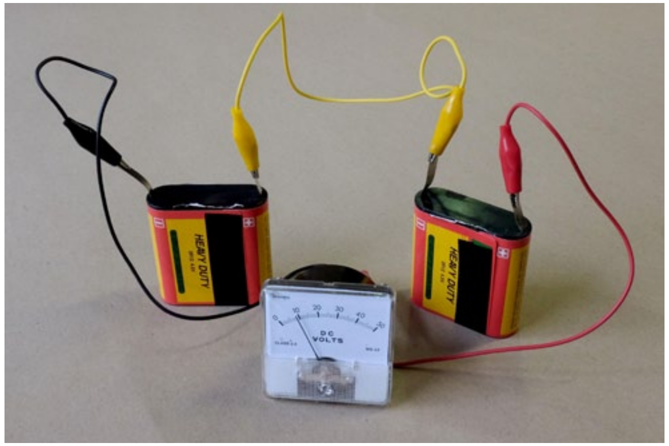


Figure 2.07. Batteries in series.

We connect two batteries, as shown in Figure 2.07. This is the series connection. We have therefore made a battery with twice the voltage, and as seen on the picture, our voltmeter shows a voltage of 9V. We then connect the alligator clips to the speaker (where the voltmeter stands in the picture), using one battery’s + and the other’s - terminals. This way, our speaker will produce a louder sound and we will see its membrane covering a bigger path when moving. The parallel connection, in this case, will not cause any such change, so we can leave it out, or test it, just to compare and check that there will be no visible / audible results.

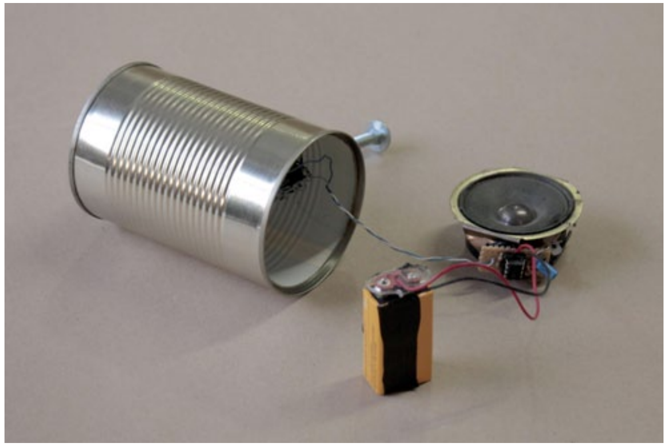


Figure 2.08. The Sudophone: metal can with insulated screw, speaker & battery circuit.

3. The circuit: Sudophone example

We can also build a more demanding construction, the Sudophone. More details on the device can be found here (Music for DIY Electronics, Music of Touch, 5. Sudophone). A good example for understanding circuits is to ask children in class to form a circle and join hands. We insert the Sudophone in this circle: we ask a child to hold its base (the can) and the next child in line to touch the screw. As hands are joined with bare skin, everyone in the circle is in direct touch with the people next to them. This means that the circuit will close and the Sudophone will sound. If the hand holding the screw touches it more firmly, the sound will change, because the conductor surface will increase, changing the current flow. Through this activity, we can understand how insulators work, as well as what a short circuit is. If we touch the clothes of the person standing next to us instead of touching their hand/skin, nothing will be heard; this is because clothes act as insulators. If we connect an alligator clip from the screw to the can while the sound is audible, we will instantly bypass the circuit we just created through our bodies. The current will take the shorter path (now available through the cable we inserted), causing a remarkable change in the sound. We will no longer be able to affect the sound by touching the screw; we will have short-circuited our circuit.

LISTENING AND WATCHING

Let us now look at an example of making a circuit and playing with a Sudophone:

Playing with the Sudophone.

KNOWING AND UNDERSTANDING: SOUND AND ELECTRICITY

1. Electromagnetism

Electromagnetism is a phenomenon that directly connects electricity with sound. When a current flows inside a conductor, a magnetic field is formed around it. If the conductor is coil-shaped, i.e. wrapped like a spring, then electromagnetic phenomena are more intense. If we place a magnet inside this coil or around it, then we have an electromagnet. If we apply voltage on the coil tips, e.g. by using a battery, then this coil will move vertically in relation to the magnetic field. And vice versa: if we move the magnet with our hand, then electric voltage will be generated on the coil tips. These two phenomena are directly related to sound. But how?

2. The microphone

The microphone[13] is a device through which we can convert soundwaves (e.g. from a voice) to electricity. In a way, the microphone works like our ear. It consists of a membrane, a coil and a magnet.

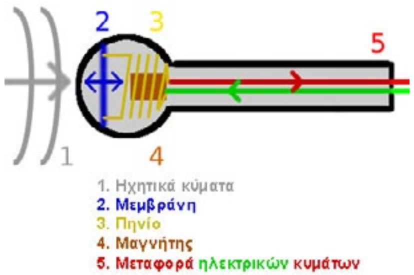


Figure 2.09. How a microphone works.

When the airwaves reach the membrane where the coil is also attached, they will cause both the membrane and the coil to move in and out. The undulation of the air causes the membrane to vibrate, just as our eardrum does. Therefore, according to electromagnetic principles, as the coil moves inside the magnet's field, voltage will be generated on the coil tips. This voltage will be proportional to the vibration (the soundwave) caused by our voice. In this way, we have "copied" the sound, and converted it to an electric current.

It is sometimes difficult to understand this phenomenon, precisely because we cannot see it. The phenomena of vibration and electricity would be much easier to understand if they were rendered visible! We can, however, use a device to help us out. This device is called an oscilloscope, and it does just that: when connected to our circuit, its screen demonstrates the electrical voltage generated by the microphone's vibrating

[13] For more details, see Section 4, "Knowing and Understanding: What is a microphone".

membrane. We can also see the battery's constant voltage. If a microphone is not available, we can use a speaker in its place, by modifying its operation.[14]

Actual oscilloscopes are not so easy to find. In their place, however, we can use easily available computer applications, like these two:

1. Soundcard Oscilloscope
2. Winscope

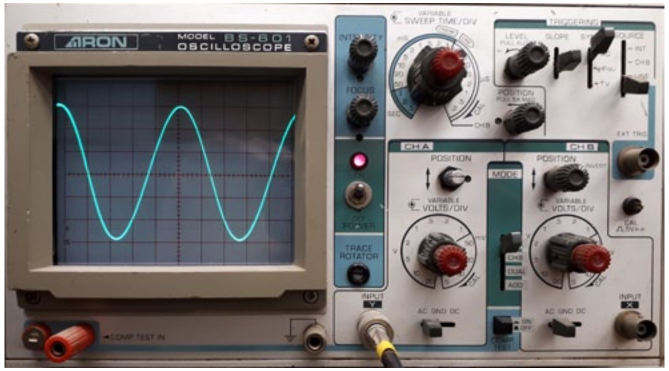


Figure 2.10. Visualising a soundwave (vibration) on an oscilloscope.

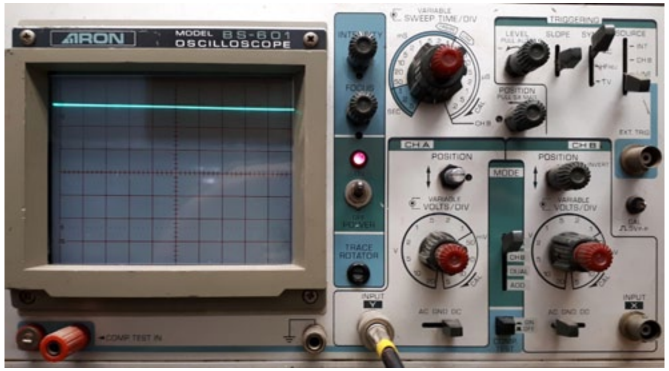


Figure 2.11. Visualising a constant current on an oscilloscope.

The only extra requirement for this is a mini jack cable, which will be inserted in the computer's microphone input. On the other end of the mini jack we will attach two alligator clips: one on the top part of the jack and one at the bottom (Figure 2.12). On the other end of the clips, we will connect the

[14] For more details on how to do that, see Comprehension Activity "The speaker as a microphone".

microphone terminals (or the battery terminals, if we want to check its current).

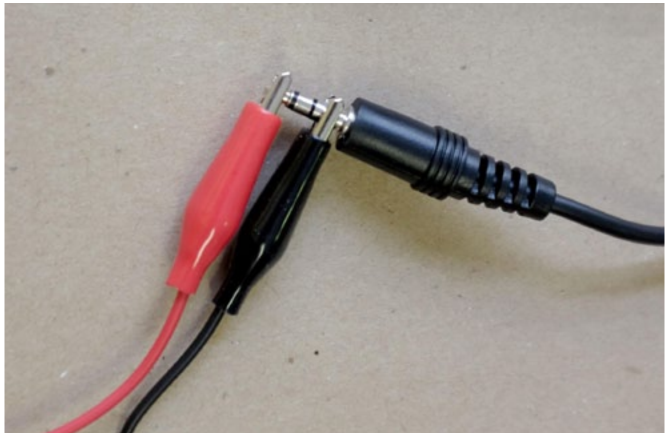


Figure 2.12. Connecting a mini jack plug to the alligator clips.

The alligator clips that are now connected to our computer (and the oscilloscope application) through the mini jack can be used to help us see our battery's current, or the vibration of current inside the speaker, which we will use as a microphone. If we move the speaker membrane with our hand or scream loudly towards it, we will see a corresponding current on the computer-oscilloscope.

This conversion of sound to electric current allows us to do many things. This is actually how we can amplify, store and process sound.

3. The loudspeaker

The device which reproduces sound is the loudspeaker. It is essentially the same as a microphone, but it has different features, which allow for better sound reproduction, rather than recording. The loudspeaker consists of a membrane, a coil and a magnet, but they are considerably larger in size than those of the microphone. The microphone components are small because they have to be easily moved by airwaves, whereas the speaker's components are bigger, because they need to move more air, in order to create a soundwave. However, we can still use a loudspeaker as a microphone, and the other way around. This will in fact help our understanding of the phenomena described here. Deconstructing a loudspeaker will reveal all of its inner components and will allow us to understand how it works (see Comprehension Activity «The deconstructed loudspeaker»). Sound is reproduced when the loudspeaker's membrane vibrates in and out, depending on the current it receives. A bass sound will carry higher voltage and therefore will show as a bigger membrane movement, whereas a higher-pitched sound will have lower voltage and the membrane movement will be smaller.

4. Sound amplification

A loudspeaker alone is not enough to receive the microphone's small current directly. It requires an amplifier, which will increase the microphone's low voltage and raise it to a level sufficient for moving the membrane enough for us to hear the sound. This amplification concerns the electric current that will be received by the loudspeaker, and is essential for the loudspeaker's operation.[15] There is, however, also a natural type of amplification, i.e. the loudspeaker's resonator, which acts as a natural instrument's resonator. The soundboard of a violin, and even the inside of our mouth act as resonators, i.e. hollow containers with vibrating elements. As seen in Section 1, when a string or membrane vibrates it produces sound on its own, but this sound is not very loud in terms of volume. A soundwave is reflected on the resonator's walls, and makes the walls themselves vibrate. The attunement of these waves, i.e. the addition of reflected waves to direct waves is what raises the sound's volume (Figure 2.13). Different materials in the resonator walls, a different resonator size, and any openings this may have, impart very different qualities on the sound, both in terms of volume and in terms of timbre.

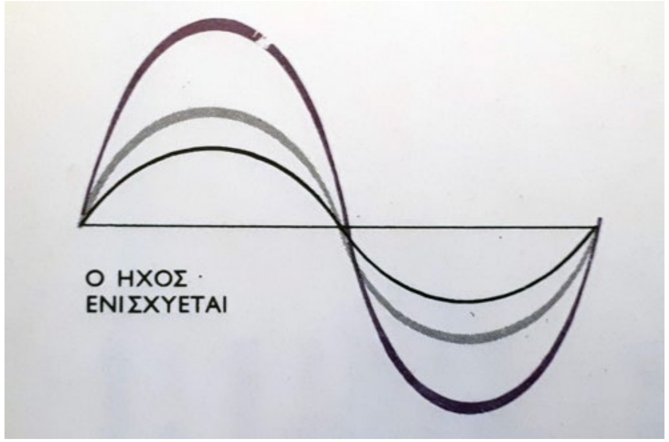


Figure 2.13. Two waves (black and grey) are added to create a higher volume wave (brown).

[15] For more information see Section 4, "Knowing and Understanding: Recording and Amplification".

COMPREHENSION ACTIVITIES

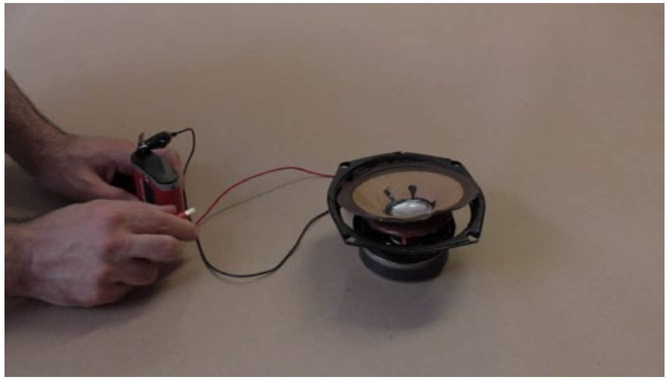
1. The deconstructed loudspeaker

Figure 2.14. A deconstructed loudspeaker. Its shiny orange coil is now visible.

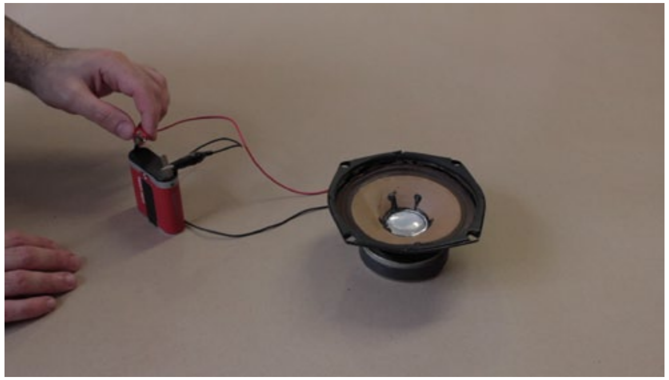
A nice experiment for further comprehending the speaker's manner of operation is to take a universal cutter and cut an old speaker's top and bottom suspension off. This is exactly where the membrane connects with the speaker's metal "skeleton" or basket. This way, we can clearly see its interior: the coil, which is wound around the membrane and glued on it, as well as the little slot inside the magnet, where the coil fits. Once we have cut the suspension off, if we put the coil back in place inside the magnet and power it through our battery's corresponding + and - poles, we will see the membrane popping outwards! As it is now no longer inside a magnetic field, it will make no further motion. We will have to act as its suspension, and place the coil back inside the magnet. If we connect our battery the other way around, by joining the + pole to the speaker's - terminal and vice versa, we will see the membrane moving downwards, towards the magnet!

LISTENING AND WATCHING

In the two ensuing videos, we can see both types of connections between the battery and the deconstructed loudspeaker:



Loudspeaker and battery, + to + connection.



Loudspeaker and battery, + to - connection.

2. The loudspeaker as a microphone

To better understand the mutual relationship between electromagnetism and sound, we can make the following experiment: use the loudspeaker as a microphone. As previously explained, the mechanism is the same: "If we apply voltage on a coil placed inside a magnet, the coil will move and generate a current". Thus, if we connect our loudspeaker to the input of a small self-powered speaker (through a mini jack, as seen in Figure 2.12) and shout loudly in front of its membrane, putting our hands around it to prevent the sound from escaping, we will hear our voice coming through the small speaker!

3. Motors

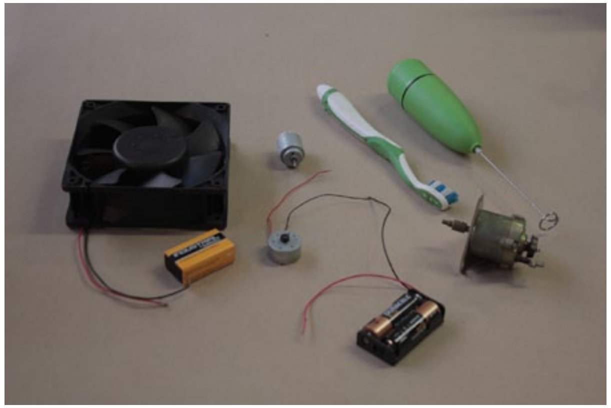
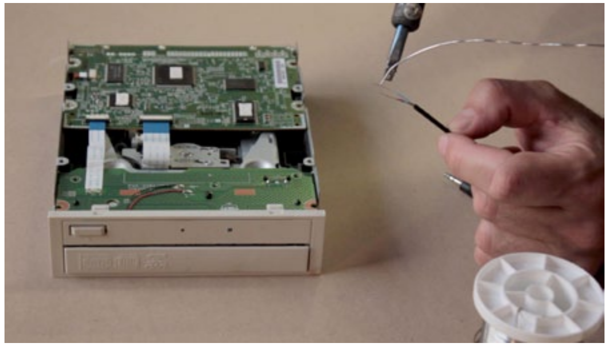


Figure 2.15. Plain motors and some common devices including motors: fan, electric toothbrush, coffee mixer.

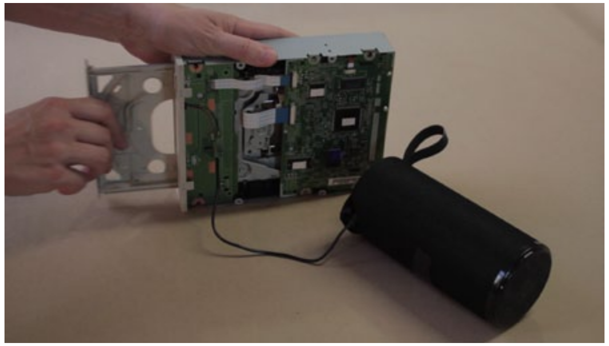
If we find any old, small motors (e.g. from a Walkman, a hand mixer or an old computer cd/dvd-rom drive), connect them to our speaker and spin their wheel then we will hear the power being generated! We can also experiment with rubber bands, which we can place on the motor wheel like straps, so that the motion will be bigger and the sound more intense. The sound coming out of the motors may differ considerably, depending on the motor we end up using; it may be high-pitched or low-pitched. In any case, however, we will need to amplify it, through our small self-powered speaker, by connecting the motor's terminals to the speaker's mini jack, using two alligator clips. Here it does not matter which cable is joined at the positive or negative terminal.

LISTENING AND WATCHING

In the two ensuing videos we can see how to connect cables to the motor terminals of an old DVD drive, using a solder and soldering iron, and how the motor-generated power current sounds through the self-powered speaker!



DVD cable soldering.



DVD performance.

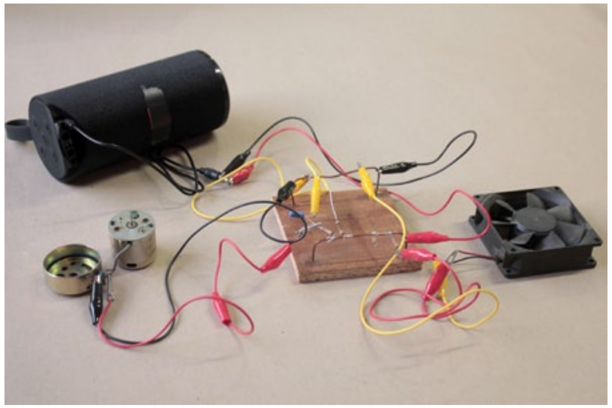


Figure 2.16. Connecting two motors to the speaker through a DIY mixer.[16]

[16] You can learn about the making of DIY mixer in more detail in Section 6, "Making: DIY mixer".

LISTENING

Two good examples to listen to music made with electric and electronic means are *Rainforest* (1968) by David Tudor and *Flux* (1967) by Dick Raaijmakers. Try listening to them with eyes closed!

DISCUSSION

After listening to the pieces, there can be a discussion about what everyone has thought about / imagined while listening to this music, and about whether there are any recognizable sounds in what we heard. What do these sounds remind us of? What do we think?

MAKING: LOUDSPEAKER

An idea for making a small electric instrument is to build a loudspeaker. Here, however, we will not explore its expected use, which is for reproducing sound. Instead, we will use it to make sounds from scratch. We will require a loudspeaker, which we can find from an old speaker or from an electronics store, a battery (ideally 4,5V as it is easier to use) and two alligator clips or just two plain cables. As we connect and disconnect the battery to the loudspeaker terminals, either through the alligators or by placing it directly on the terminals, the loudspeaker emits an intermittent "click-clack" sound. We can experiment by placing our loudspeaker on different surfaces (wood, metal, plastic), but also by creating a small speaker, using a small plastic container, cardboard box, paper cylinder etc as a resonator. We notice how the sound's timbre and volume are changing. We can also gather all kinds of different materials and place them on the loudspeaker's membrane.

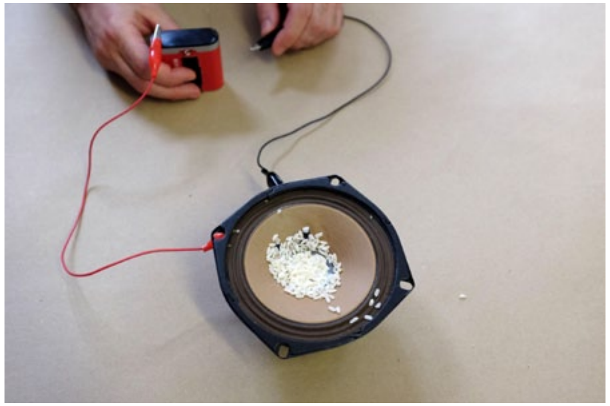


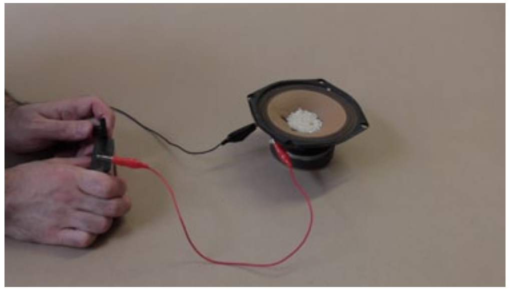
Figure 2.17. Loudspeaker with rice.

Some ideas: salt, sugar, rice, bolts, coins (1-2 cents) and more generally, all kinds of small objects. This way, the sound's timbre changes quite dramatically, and it reminds us of various percussion instruments. Moreover, by connecting two batteries in a series (Figure 2.07) with one or more loudspeakers, we can listen to these sounds in greater volume – if we look quite closely, we may notice the loudspeaker membrane cover a greater movement path as it goes up and down. If we have added salt, sugar, rice etc. it is possible that we might make a little mess!

LISTENING AND WATCHING

In the ensuing videos we can see how to connect a loudspeaker with a battery. Listening to the sounds that a loudspeaker makes on its own or with rice added to its membrane, but also how the sound changes if we experiment with a box as a resonator.

Loudspeaker with battery.



Loudspeaker with rice.

Loudspeaker with box.

PLAYING

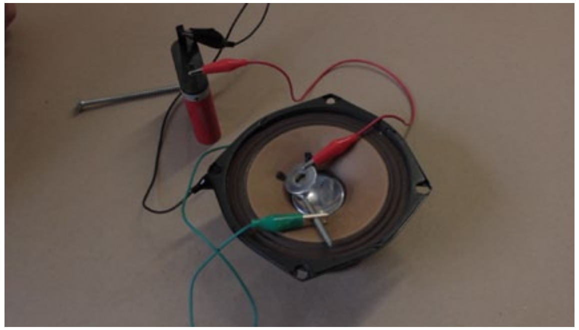
Each child plays solo, or children can form pairs. We experiment with loudspeakers and batteries and try out all the different ways of playing different sounds. We can initially experiment with the way the alligator clip touches the battery. If we merely touch it, it makes a “clack” sound. If however we drag it across the metal terminal it makes a longer sound (dzzzsss). We use materials on the membrane: rice, coarse salt, lentils, small coins. We can also put the rice, salt etc. inside a light plastic container (e.g. an empty yogurt tub) or a lid – the sound will be different! We try out different resonators (metal, plastic or wooden boxes) touching or covering the loudspeaker completely with them. In the end, children can present a small improvised piece in class, using the sounds they liked the most. They can do this either alone or in pairs with another classmate. The piece does not need to be over 1 minute long!

Extension 1: Victoria (Victorian Synthesizer)[17]

As we have learned in the previous section, sound is a vibration, a wave. With our battery, which renders generates a direct current of power, we managed to make our loudspeaker membrane vibrate towards a specific direction, resulting in a very simple sound – a beat, or “clack”. To be able to vibrate the loudspeaker membrane in different ways, we have to find ways that can convert direct current to alternating current, to create a wave, and at the same time, a tone. If we could touch our battery in such a way as to open and close the circuit extremely fast, we could achieve this. However, this could only be accomplished by a robot, not a human hand. We therefore have to figure out a way to make this happen. The simplest way is feedback, which we can apply to our loudspeaker, by making an assistant that we will refer to as “Victoria”. Victoria’s simplest form consists of a loudspeaker, a battery, three alligator clips and two light metal objects, e.g. two soda can tabs.

LISTENING AND WATCHING

In the ensuing video we see how Victoria works:



Simple Victoria

[17] The Victorian Synthesizer is an idea by Nicolas Collins.

We begin by connecting the battery’s negative pole to the loudspeaker’s negative terminal, and the battery’s positive pole to one of the two metal tabs. We place the other metal tab on the loudspeaker’s membrane and connect it to the loudspeaker’s positive terminal. We are now ready to begin! By holding the first tab and letting it drop onto the second, which is lying on the loudspeaker, we are essentially closing our circuit. This way, the loudspeaker membrane will move forward, throwing both metal tabs on the air. When these fall back on the membrane, they will touch each other again, and therefore the same thing will happen; it will keep happening, again and again, until our battery runs out!

What we have built is a very simple automated musical system based on feedback. In other words, our output (the upward moving membrane) is feeding back into our input (the loudspeaker’s positive terminal). We can experiment by placing other metal objects (coins, screws etc.), on the loudspeaker and listening to each object’s unique sound while watching it “dance”. We can also try out something more controlled, by touching the first metal tab with our hand and placing it on the second one while making delicate in-out and up-down gestures so that the two can touch – stop touching depending on our hand gestures. This way we can control the feedback and therefore, build a musical instrument.

Extension 2: Victoria mk2[18]

We can also make something even more interesting, which will allow us to have even greater control. Meet «Victoria mk2»!

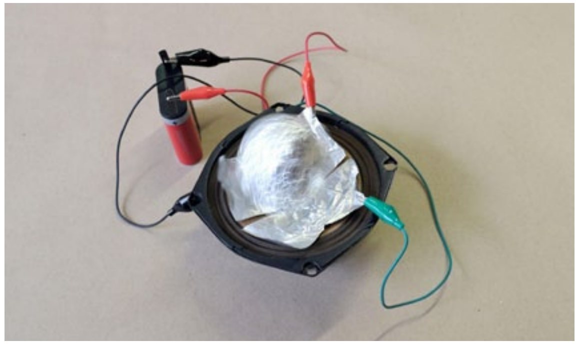


Figure 2.18. Victoria mk2.

Aside from the materials used above, we will also need tin foil, alumium tape and, ideally, a Styrofoam ball. We cut two pieces of aluminium tape and stick them on the loudspeaker membrane, making sure they do not touch each other. We also take care not to stick them on the loudspeaker’s suspension too, because we want it to be moveable.

[17] This second version of the Victorian Synthesizer has been designed by John Richards.

LISTENING AND WATCHING

We look at the different stages of making a Victoria mk2 in Figure 2.19, then enjoy the device in action in the ensuing video!

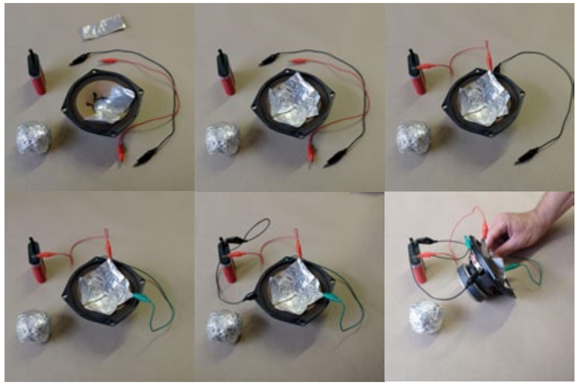


Figure 2.19. Stages of making a "Victoria mk2".

Victoria mk2.

The aluminum tape will be used just like the metal tabs in the basic version of Victoria. We connect one of the tape pieces to the battery's positive pole and the other piece to the loudspeaker's positive terminal. The negative pole, as before, goes to the negative terminal. We wrap the Styrofoam ball with tin foil; the ball can also be made of newspaper or a plastic bag – the lighter, the better. We let the our conductive ball drop on the loudspeaker; this way the gap between the two aluminum foil pieces is bridged, and the circuit closes, moving our membrane upwards! Putting our hand over the ball, we can control the speed with which it will drop again, and therefore control the tone that will be produced. Our gestures should be small and delicate, trying out different levels of pressure on the ball. Instead of our hand, we can also use a piece of elastic fabric, a balloon or a plastic bag, to apply more flexible pressure. We should take care not to connect the loudspeaker terminals the wrong way around, because then the membrane will move down instead of up, and we will not get the desired result: the membrane and ball will only move downwards once, and then stop moving.

COMMENTS

Safe practices

We should never (ever!) short-circuit batteries, i.e. connect their opposite poles, neither directly, nor with an alligator clip or other metal object. In other words, we should never touch one battery's + with the other's -, and one's - with another's +. This can easily happen by mistake, especially with 9V batteries, which can fit into each other's opposite poles. We should also be very careful when storing batteries: for instance, we should never store them in a metal box, as they may be short-circuited. If we store many batteries in the same container, we should attach some insulating tape on one of their poles, or make sure they are kept at a sufficient distance so that the poles cannot touch each other. If we do not, there is a great risk of them exploding or catching fire!

Moreover, for anything made and used at the workshop, batteries are the only sources of electricity allowed. We never use anything that is powered through the wall socket!

Batteries have a small electric charge which, even when correctly used, may generate a spark or electrify us very slightly. This is not dangerous, but in any case we ought to be careful, in case there are flammable materials anywhere near our work surface.

3. TIME AND RHYTHM: ELECTRO-CRICKET WITH RELAY

We discuss time and rhythm, duration and repetition. We build Electro-Crickets, i.e. rhythmic instruments using relay.

Figure 3.01. Electro-Cricket with the necessary materials for building and playing.

WORKSHOP MATERIALS

- A4 paper, pencil, pen and markers.
- 5V[19] or 9V relay.
- 4,5V or 9V batteries.
- Set of 5 alligator-clip cables in different colours
- Different capacitors (100µF, 470µF, 1000µF).
- 5-6.5´´ Loudspeakers (12,7 to 16,5 cm).
- Insulating tape or other type of sticky tape.
- Hot glue silicone gun and replacement silicone sticks.
- Metal, wooden or cardboard boxes.
- Plastic[20] or paper cups, or metal containers / cans, or paper / plastic boxes from the recycling tray.

[19] We use relay and batteries of the same voltage.
[20] Expanded polystyrene (EPS) like the one found in Styrofoam cups or containers, has very good sonic results.

DISCUSSION: TIME AND RHYTHM

Figure 3.02. Devices for measuring time: the hourglass (left) the Greenwich clock[21] (centre) and the metronome (right) a device used for measuring rhythm in music.

What is time and why do we measure it? What are its subdivisions? What does time have to do with music? What could its uses be for music? What do we know about rhythm? Can we think of an example of rhythm in nature, in the human body, in the city?[22]

KNOWING AND UNDERSTANDING: SOUND AND ELECTRICITY

Time, rhythm and repetition

The nature of time and questions such as whether time really exists, or whether it can really be measured, have captured human imagination and science since antiquity.

Humans measure time through chronometers, such as clocks and watches, to organize their lives and coordinate themselves with other people. Within the vastness of time, certain smaller or bigger events (movements or activities) are repeated regularly; these include the rotation of the earth around the sun, our footsteps or our heartbeats. This regular phenomenon which is repeated, naturally or artificially, is what constitutes a rhythm.

Time and rhythm are very important elements in music, because time, and the different patterns that a rhythm can take, forms the basis for structuring sounds and creating musical works.

A very simple rhythm can be made by repeating even just one sound alone, e.g. when we stomp our foot on the floor. Most of the times, however, we use at least two different sounds, a “deep” low-frequency sound and a “high” (high-frequency) sound.

[21] In Greenwich, England, with a longitude of 0, there is an observatory for the precise measurement of time. Many countries consider the Greenwhich time (GMT) as a standard, and use it to determine time in their own country.
[22] Examples: pneumatic drill, motorbike, washing machine, heart, breath, walking, owl, woodpecker, wave, rain.

These sounds can develop and transform in many different ways through time.

Of course there can also be music without evident rhythm, i.e. music which develops very slowly in time and uses different sounds, rests, and changes in sound density to create a sonic narrative or image; This is the kind of atmospheric music we call *ambient*.

COMPREHENSION ACTIVITIES (1)

1. *Play a rhythm* that you remember or a rhythm that you like, tapping one hand against the other or on your bench desk, or on your legs – or you can use a pencil on your desk. This activity can happen individually, in small groups, or with the whole class as one big group.

2. *Counting the seconds*.[23] Two children stand with their backs turned against each other, separated by a distance of approximately 2 metres. The first child starts clapping every five seconds, silently counting the seconds. Once the child has played for a little while and has stabilized a pulse, the second child starts playing. They try to synchronize so that they clap together, without seeing each other. You can also change the rhythm and the clapping may occur every two or seven seconds.

3. *Football*.[24] Children are divided into two teams, with the teacher acting as a referee. A draw determines which group will start first. Instead of a ball, there is a rhythm, which is taken up by each team whose turn it is to play, in agreement with the teacher. The team leader begins by clapping the rhythm and tries to "pass" the rhythm to a member of their team. That member plays the rhythm once and then passes it to another teammate, until the rhythm has been played by all members of the team. In the meantime, the opponents' team can make as much noise as they want, play another rhythm, talk or laugh, with the aim of confusing their opponents. If someone from the rhythm-bearing team is confused by the noise or even by accident, then the "ball" is passed on to the other team, who starts the process again, with the same rhythm or another one. If a team manages to pass the rhythm correctly between all its members, it wins the game.

LISTENING AND WATCHING

Everything is rhythm! Wherever there is life, there is rhythm.

Watch FOLI (Rhythm), a short documentary on rhythm in Guinea (West Africa), by Thomas Roebers και Floris Leeuwenberg.

[23] «Counting the rhythm», a rhythmic game developed by R. Murray Schafer.
[24] «Football », adaptation of a sound game developed by R. Murray Schafer.

COMPREHENSION ACTIVITIES (2)

Children can listen to:

1. Musical pieces like the following:

   - Steve Reich, *Clapping music*, performed by Octoplus music ensemble
   - Autechre, *Eggshell*

   Childern try to follow the rhythm by clapping or tapping their foot on the floor.

   They can also listen to other rhythmic pieces they like in class, and try to follow the rhythm.

2. An excerpt from *Reflection* by Brian Eno. This work develops in time rather differently, and its rhythm is not so evident. It belongs to the more atmospheric type of music called ambient.

3. The work *Imaginary Landscape 1* by John Cage, where rhythmic parts and repetition co-exist with ambient elements. In this recording, the work is performed by Michael Barnes, Zach Webb, Jacob Dike and Xinyi Zheng.

DISCUSSION

Can we identify some sounds in the pieces we listened to? What instruments or objects are being used? How are they used? We notice the importance of rests (pauses). What words can we use to describe the different rhythms we heard? What feelings does each piece evoke? Did any images form in our minds?

ACTIVITY[25]

We listen again to *Reflection* by Brian Eno or to *Imaginary Landscape 1* by John Cage. Inspired by the music, we write a story (which may also include images, in the style of comic strips or graphic novel). Alternatively, we draw a picture. The assignment can be carried out individually or in groups.

[25] This activity requires more time. It can take place in class or at home. It can also be combined with a visual arts class (comics) or a language & literature class (writing prose or poetry). If the activity takes place at home, enough time should be available in the next class meeting, for the whole group to see the works, go through them and discuss them.

KNOWING AND UNDERSTANDING

The duration of sound: Rhythmic value and rest

Each sound may have a different duration in time. It may be a short duration, like a momentary tap of our finger on the table or the clock ticking a second of time. Or it may be longer, like the blowing wind, or the prolonged beeping of an angry car driver.

The temporal duration of a sound is called rhythmic value. Another very important component of life, as well as music, is silence, otherwise known as rest or pause. This can also have different durations, just like sound. Intense and loud activity, is usually followed by a period of silence. After a pause, there is usually something important, something new or different than what was going on before. An example from nature is a storm, with strong winds and a lot of noise, which eventually is followed by good weather and silence. In everyday life, when we want to emphasize something, we are quiet around it; if we run for a long time, we then want to calm down and rest.

Musicians and sound artists can come up with endless combinations in the way they combine sounds and pauses, when they make their pieces.

In Section 1 we designed and sang lines[26] making sounds that we considered fitting as interpretations for these lines. The duration of these sounds was not specified. However, sometimes in music there needs to be precision in how time is allocated and distributed, so that musicians can coordinate and achieve different combinations of sounds and rhythms; this can help make a musical piece more complex and interesting. Another reason why we need to be precise is so that a work can be recorded or notated, and then replayed / performed again by many different musicians, again and again.

Every culture has developed different ways for dividing time, with distinct rhythms and discrete written symbols to mark duration.

DISCUSSION

In what kinds of everyday situations do we need to stop talking or making absolutely any noise? What has happened right before? What follows the silence? What can we think about the significance and use of silence?

[26] See Section 1, "Introductory Activity"

COMPREHENSION ACTIVITY

My own notation for sound duration

Let us invent our own system of symbols, an improvised written language for notating our sounds' durations.

We start by thinking a few different durations. For instance: sound for five handclaps, sound for one handclap, long pause for five handclaps, etc. We then make our own symbols or lines on the board (see Figure 3.03 for examples) to notate these sounds, and try to "read". We can do this all together or split into groups.

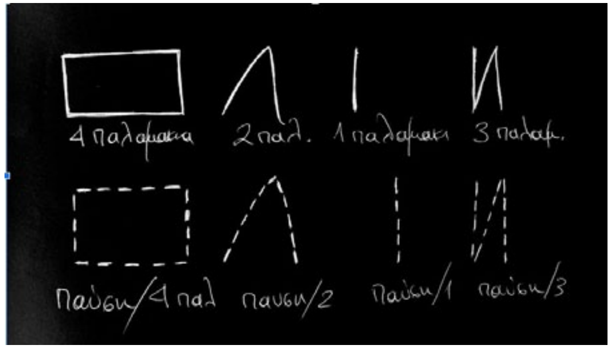


Figure 3.03. Examples of rhythmic values for sounds and rests (pauses), using improvised notation: rectangle = duration of 4 handclaps, angled line = duration of 2 handclaps, vertical line = duration of 1 handclap, crooked line = duration of 3 handclaps. In the second line, the same shapes are notated as dotted lines, to denote the corresponding durations of rests.

KNOWING AND UNDERSTANDING: REPETITION AND VARIATION

Figure 3.04. The sea waves are a natural phenomenon with repetition and variation: waves repeat in rhythm, but no two waves are the same.

Sounds may repeat, fast like raindrops, or slow like seawaves. Repetition, otherwise known as circularity or periodicity, is an important dimension in music too. A single sound, or a whole set of sounds, like a melody or pattern, may be repeated. By using repetition, a composer may decide that listeners should hear a sound or pattern exactly like the one they just heard, in order to highlight an important element. (S)he may also decide to repeat the sound or pattern with a few small or bigger changes; in that case, the composer introduces a variation. Repetition is a phenomenon that happens all the time in everyday life and in nature. For instance, seasons (spring, summer, autumn, winter) recur every year, but they are never exactly the same – they always carry different elements. Every day the sun rises and sets, but no day is exactly the same as the previous or next one. Similarly, in a work of music or sound art, there may be repetition and variation. The sonic features that may vary are not only sound colour (timbre), volume, pitch and duration, but also other, secondary features, such as the clarity of a sound.

LISTENING AND WATCHING

Steve Reich *Drumming* - Portland Percussion Group

DISCUSSION

We comment on the piece. What is happening? How is the rhythm changing? Did we notice it being simple in the beginning, then becoming more complex? How can this happen? Did we notice the repetitions?

COMPREHENSION ACTIVITY: IMPROVISED RHYTHM PIECE

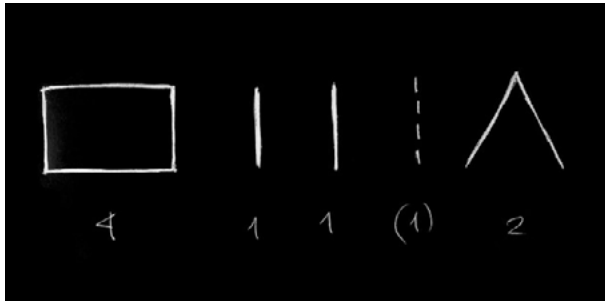


Figure 3.05. Example of small rhythmic piece with improvised symbols from Figure 3.03

We split into groups and devise our own simple rhythm pieces, writing down different combinations of rhythmic values and rests on paper or on the board (see Figure 3.05 for example). We draw the rhythmic values with our own symbols,[27] then play the pieces we devised, working all together or in smaller groups. We can "read" our rhythm piece using handclaps, or try out different sounds.

We can also try the following: one group can sing the longer sound durations with a vowel (aaaaa… etc), another can tap the shorter sound durations with their palms on their legs, and a third group can tap the momentary sounds with a pencil on the desk.

The rhythm pieces can also be played with different sound combinations, using the instruments presented in Sections 1 to 5.

KNOWING AND UNDERSTANDING

Relays, capacitors and the colour code[28]

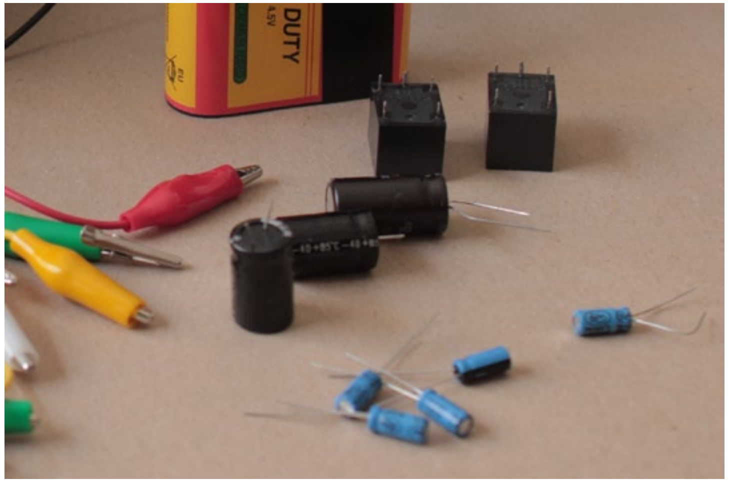


Figure 3.06. Relays, capacitors of various different values, alligator clips and battery.

A relay is an electric switch. When the relay switches off for some reason, the circuit opens[29] and the current no longer flows. In most homes, a relay of this kind is used in the main fusebox as a safety switch, which turns the power off when

[28] The teacher can write down the words on the board and draw the corresponding parts, or present the different components as pictures on the projector while explaining their function.

[29] An electric circuit occurs when we have an electric power source (e.g. battery) to which we have connected a cable or other conductive material, and electrical appliances (see also Section 2, "Knowing and Understanding: Circuit").

there is a short circuit[30] in the home's electrical installation or inside an appliance. This protects us from electrocution, fires and other disasters. The relay we will use has five pins. On its inside, the pins are connected to other components (electromagnet and switch). The relay's inside is, in fact, an entire circuit in miniature form.

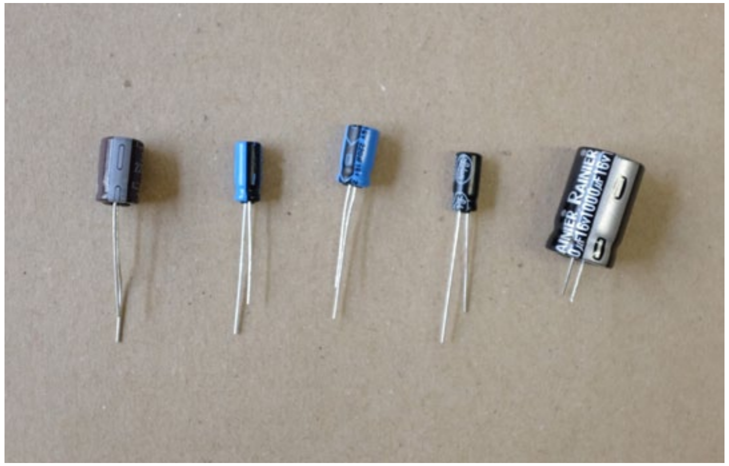


Figure 3.07. Capacitors of different values. The black or grey tapes mark the direction of the negative pole. On the same side of the capacitors, you can find the capacitor's shortest pin.

A capacitor is an electric element with two conductors (poles) and insulating material between them. It is built so that it can instantly store the electrical charge that reaches it. This way, when it is placed in a particular position inside a circuit, it will empty its charge over a duration that is relative to its storage capacity. In our case, this will delay the switch's on and off times. The storage capacity ("capacitance") of a capacitor is calculated through a unit called a Farad (F). Because 1F is a very large unit, for small capacitors we use subdivisions, like the microfarad (μF), nanofarad (nF) and picofarad (pF). The capacitors we use for the Electro-Cricket have a positive and negative pole. The negative is shorter than the positive. There is also another way to find it: on the capacitor's cylinder, there is a grey or black tape on the side of the negative pole (see Figure 3.07).

<u>Colour coding for cables:</u> In electric and electronic connections, we commonly use red or other warm-coloured cables (yellow, orange etc.) to connect a cable to a positive pole. When we want to connect cables to a negative pole or to ground

[30] A short circuit happens when a zero-resistance path is available inside a circuit, either by accident (e.g. a malfunction) or in controlled circumstances (see also <u>Section 2, "Knowing and Understanding: Short Circuit"</u>).

connection, we use black, or other dark colours (blue, green, purple).

MAKING: ELECTRO-CRICKET

To *Electro-Cricket* is a low-volume rhythmic instrument, inspired by John Richards (Dirty Electronics). It emits a continuous, repetitive sound, just like a cricket in the summer. We can manipulate its sound and change its repetition rhythm by using different capacitors.

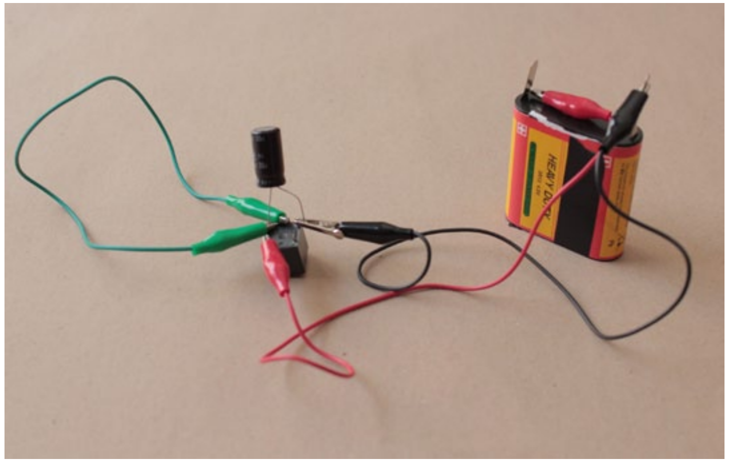


Figure 3.08. The Electro-Cricket.

We will need paper, pencil, pen and markers, to draw a wiring diagram for our circuit[31] and to take notes.

For building an Electro-Cricket we need a relay, a battery, five alligator-clip cables and at least two capacitors of different capacitance.

The teacher draws the circuit on the board, or we all look at the diagram on Figure 3.09 or a similar diagram. We draw the relay and its connections to the alligator clips, the battery and the capacitors on paper. Gradually, as we draw, we make the same connections on our relays.

[31] This diagram helps a lot in understanding the connections and is also very useful as a reference point between meetings, especially for remembering the circuit and where each component fits. Moreover, if children have their own personal diagrams, they can make their own cross-checks for possible mistakes in the connections, if something is not working.

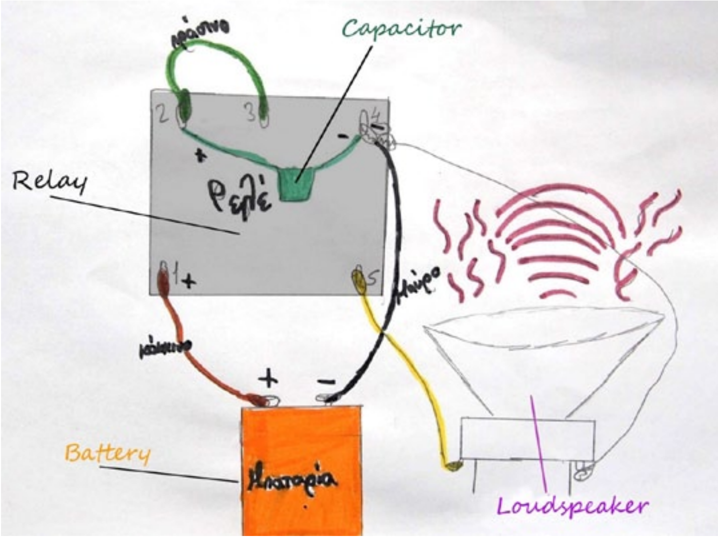


Figure 3.09. A circuit diagram for the Electro-Cricket drawn by L., a 4th-grade primary school pupil (DIY workshop 2018-2019, 21st Primary School of Athens “Lela Karagianni”).

To begin, we place the relay on the bench desk in front of us, so that the three-legged (or three-pinned) side is on top, and the two-pinned side is facing downwards. We draw the capacitor as a square with five pins on our paper. We number the pins on our drawing, from 1 to 5: pin 1 is at the bottom left, 2 at the top left, 3 at the centre top, 4 at the top right, and 5 at the bottom right (see Image 3.09). We connect pin 2 to pin 3 using a green alligator clip. We then use a red[32] alligator clip to connect pin 1 to the battery’s positive pole. With a black clip we connect pin 4 to the battery’s negative pole. In our drawing, we use coloured markers or pens for marking the connections according to the corresponding cable colour.

The Electro-Cricket should now be audible. The connection between pins 2 and 3 creates a kind of short circuit, so the relay keeps going on and off. The sound is generated through this constant switch process. We can try to jam the capacitor’s negative pole inside the alligator clip of pin 4, and the positive pole inside the alligator clip of pin 2. The sound changes! We can also try the same using different capacitors, and notice the changes in sound and rhythm.

[32] Remember Colour Coding for Cables!

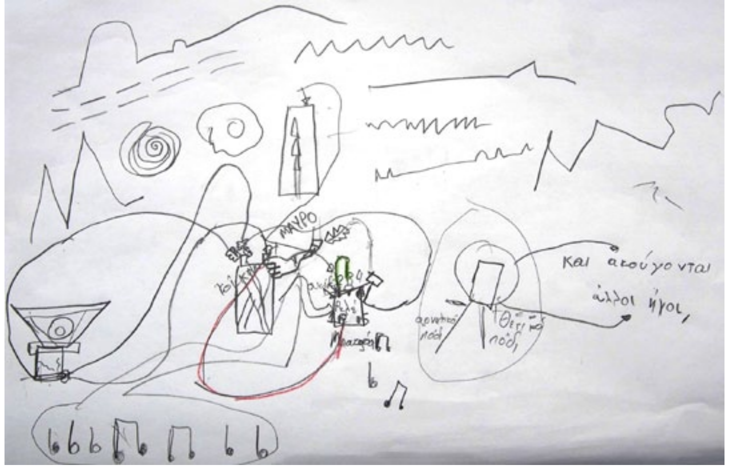


Figure 3.10. Notes on the Electro-Cricket relay, including connections and sounds, by G., a 4th-grade primary school pupil (21st Primary School of Athens “Lela Karagianni”, DIY workshop 2018.

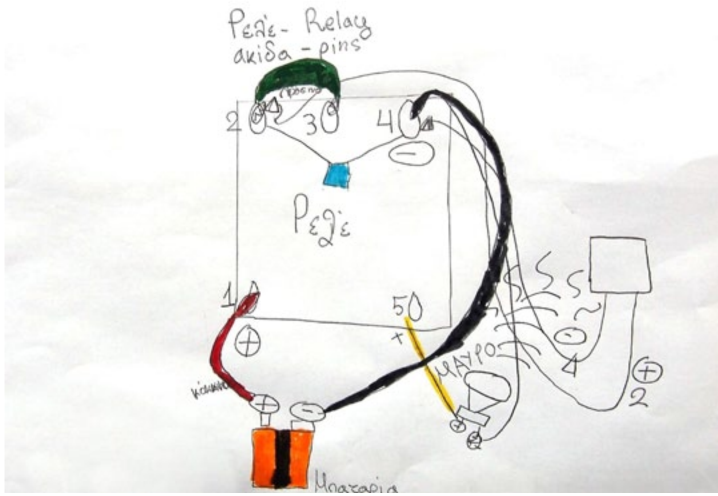


Figure 3.11. Drawing of the Electro-Cricket circuit by A., a 4th-grade primary school pupil (DIY workshop 2018-19, 21st Primary School of Athens, “Lela Karagianni”)

How does it work? The more the μF in the capacitor, the greater the delay in the electric current flow inside the relay circuit. In this case, the switch turns on and off more slowly, and therefore we can hear the on/off process more sparsely and clearly. This sound may remind us of a cricket, or even a clock. When the capacitor is “small”, i.e. it has a smaller capacitance in μF, the current flows faster, the switch turns on and off more quickly, and the sound is emitted almost continuously, like a gurgle or an insect buzz.

We can place the Electro-Cricket on resonators / boxes of different sizes or materials to amplify it. Another idea is to cover and uncover the set-up with a box, to alter its sound. We can also play with its sound by interrupting the supply of power or connecting and disconnecting the capacitor poles. Finally, we can connect it to a loudspeaker and have both sounds simultaneously.

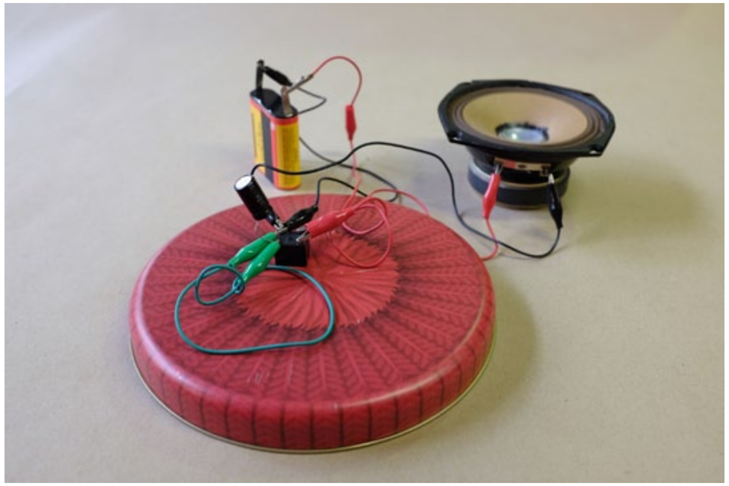


Figure 3.12. The Electro Cricket on a metal lid, connected to a loudspeaker and battery.

<u>Extensions</u>

1. We can connect the relay to the loudspeaker from Section 2 as follows: we connect the loudspeaker's positive terminal to the relay's pin 5, and the negative terminal to pin 4. To connect the loudspeaker on pin 4, we have to connect the black alligator clip from the loudspeaker's negative terminal, "biting" on the clip that is already on pin 4 and connects that to the battery's negative terminal (see Figures 3.09 & 3.12).

2. We can try something more demanding: we can build a more permanent set-up, fixing our relay on the speaker we liked the most, by gluing it with hot silicone glue.[33] We can also solder[34] the cables and capacitor to the relay, add a switch or a lamp, etc.

[33] Silicone gun which connects to a wall socket and liquefies silicone.

[34] See soldering with solder and iron, <u>Section 4 "Making: Contact Microphone"</u>.

LISTENING AND WATCHING

In the ensuing videos we can watch various experiments with relays, different capacitors, resonators and loudspeakers.

<u>Katydid Phase, Electro-Crickets and DIY Music:</u> Sound experiments and installation with John Richards' Electro Crickets.

<u>Improv with Relay 1:</u> Trying out resonator-boxes made of different materials.

<u>Improv with Relay 2:</u> Trying out different capacitors.

<u>Improv with Relay 3:</u> Improvised piece with different capacitors, speakers, rhythmic and timbral variation.

<u>Relay and loudspeaker:</u> Improvisation with relay connected to a loudspeaker.

KNOWING AND UNDERSTANDING: IN PURSUIT OF A BEAUTIFUL SOUND / THE FUNNY AND UNEXPECTED / THE PAUSE / NOISE

Musicians and sound artists, just like all artists, dedicate a lot of time to familiarize themselves with their instrument and find a way of playing and a sound they like and enjoy. An instrument or sound object can make many different sounds, depending on how it is used. Every creator is different and can discover new, unpredictable ways of utilizing an instrument or sound object. Depending on an artist's aesthetics, knowledge, abilities and distinct features, an instrument can be made to sound in many different ways. It may produce soft sounds or loud noises; it may be funny or serious; it may sound atmospheric and calming or rhythmic and exciting, and much more!

PLAYING

Free experimentation with the instruments. We dedicate 15 minutes (or more, if possible) to try out our relay, with different capacitors, on smaller or bigger boxes/resonators made of different materials (cardboard boxes, biscuit tins, coffee jars, plastic cups or tumblers, wooden boxes, anything else we can think of or can get hold of). We can also place our Crickets on different surfaces (bench desk, or any other wooden, plastic or glass surface available in the room) and notice the differences in sound. We can also fix our relays on different surfaces or boxes by using insulating tape (or any other sticky tape) so they make better contact and become more audible (see video: *<u>Improvisation with relay 1</u>*).

We connect the loudspeaker to the Cricket. We can use other materials on the loudspeaker too, as in Section 2 (tin foil or paper with rice, salt, a lid and light coins, other small metal objects like paperclips or bolts). We experiment until we are happy with our sound (see video: *Relay and loudspeaker*).

DISCUSSION

We discuss in class which sound we like the most, out of all the sounds we tried, and why. Perhaps we like a sound because it reminds us of something, or because it is funny; perhaps it is very soft, or very rhythmic. It is important to know the reason we like something and to be able to express this in words!

KNOWING AND UNDERSTANDING: SOUND INSTALLATION, SOUND SCULPTURE

Sound Installation is an artform where artists create an environment made of recorded sounds or sounds coming from various sources (musical instruments, sound objects, speakers, devices, etc.); this environment can be indoors or outdoors. There may be musicians / performers involved, but this is not necessary. The viewers – listeners of this installation are usually free to wander around the space to listen to the soundwork. Most of the times, a sound installation also has a visual component. For instance, it may coexist with a physical sculpture or other visual artwork, such as video, photos, drawings etc. It may also be interactive, i.e. require some participation from the viewer-listener.

Sound Sculpture is a three-dimensional work of art which has been constructed or installed in a space so as to produce sound, either on its own, or through interaction with the environment and the audience.

LISTENING AND WATCHING

In the ensuing videos we can watch examples of sound installations and sculptures. We can notice several similar sounds, different rhythms, the ways they are produced, the types of materials and objects that can function as resonators and sculptures at the same time.

1. Sonic and visual installations and sound sculptures by the artist Zimoun.

2. *Fatamorgana* (1985) an installation by Jean Tinguely.

3. *Shadow Orchestra* and *Sound Wall*, two installations by Peter Vogel, which can be activated by the visitors and the shadows made by their hands.

4. *Phobos, Dysfunctional Robotic Orchestra* (2008) an installation by the Sonoscopia community (Portugal).

PLAYING: SOUND INSTALLATION

In small groups (3-5 people) or all together, we connect our relays without loudspeakers. We pick the sound we like most for each relay, by selecting a capacitor or a resonator, and we let them play on their own. This is a sound installation. We will need to take a few steps away to listen carefully to the result, i.e. how sounds blend with each other and complement each other. What does this sound mix remind us of? In the beginning, we can gather all the relays together in a particular spot inside the room, and move away to listen to them. Later on the same day, or during a different meeting, let us try something different: we can place the Crickets in different parts of the room, and move slowly between them. We can take this soundwalk in pairs. One child can keep his/her eyes closed and the other can guide her/him, slowly and carefully, among the different sounds. Then, we can swap the roles between leader and follower. In the end, we can talk about our impressions (also watch video: *Katydid Phase, Electro-Crickets and DIY Music*, for the sound installation).

PLAYING: MORE EXPERIMENTS AND EXERCISES

1. Rhythm piece

We attempt to play the rhythmic values and the pieces developed during the "Improvised Rhythm Piece" activity, with the relays. To perform the different lines / values we need to interrupt the sound: we hold the red cable clip on our hand and let it touch the battery's positive pole for as long as necessary. Alternatively, we can control the Electro-Cricket sound by allowing one of the capacitor legs to touch the relay pin, or moving it away from the pin. We try out pauses of various durations and combine our sounds with those of other members of the group.

2. Graphic score

We read lines of different styles that we have drawn on the board, i.e. graphic scores,[35] as in Section 1. Using the Electro-Cricket, we try to create sounds that correspond to these lines. For instance, if we lift the capacitor pin and quickly put it down again two or three times, we may interpret a wavy line. We try to read and interpret lines sonically, adding some loudspeakers to the connection as well.

3. Sound pieces with a beginning, middle and end

We dedicate a bit of time with our small group to decide on a sequence of sounds that we would like to play with our Crickets. We combine Electro-Crickets with different capacitors, different resonators, loudspeakers etc. We decide which child or children will play first, how long our sounds will last, how many rests we will include and/or how long they will be, when the next children will start, if there will be a climax (i.e. a moment

[35] You can watch again *Pithoprakta* by Iannis Xenakis on video.

with very intense sound), how the piece will end etc. When we are ready for a performance, we can move our instruments to the teacher's desk and present our work to our classmates.

4. The circle
With our desks in circle or in a U shape, we prepare our Electro-Crickets with the sounds we prefer (using one of the capacitors and a resonator/box, without the loudspeaker), without connecting the battery's positive pole. We then follow the instructions from Section 6 ("Playing: The Circle").

COMMENTS

The Electro-Cricket relay and the trials and performances on this instrument can take place individually or in pairs of children: one can handle the battery and the other can handle the capacitor, or one can handle the loudspeaker and the other the capacitor.

Some pupils may find it difficult to make the connections. It is best to allow enough time for any unexpected problems, mistakes and corrections that may come up.

It will be useful to have some additional relays available, in case any of them are faulty or burn out during the try-out stage.

To avoid burning the relays, we should be careful not to let the alligator clips touch each other when connected to the different relay pins.

The relays can be connected in series or in parallel[36] or even play through the same battery.

From the start of the section, the children should know that the Electro-Cricket is a low-volume instrument, which can only be audible in relatively quiet conditions. When played in combination with loudspeakers, the improvisation should be thought-out and structured in such a way as to allow the relay's discrete sound to be heard.

[36] See Section 2, «Knowing and Understanding: The Battery».

4. CONTACT MICROPHONES AND SOUND AMPLIFICATION

We discuss microphones and amplification. We make contact mics and through them we turn everyday objects into instruments.

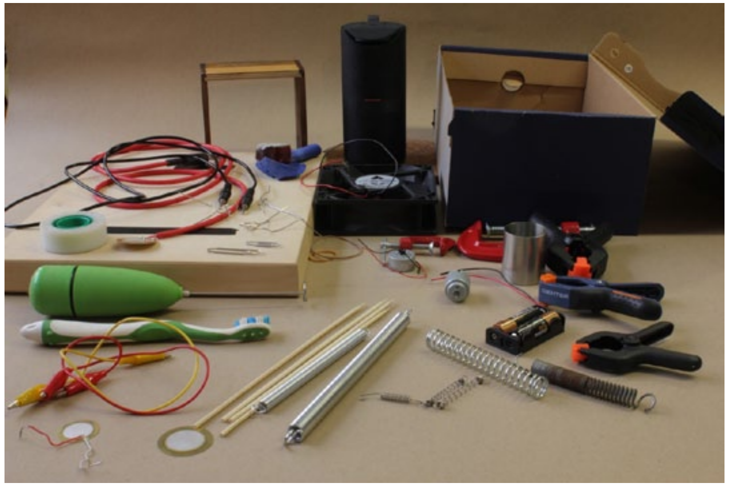


Figure 4.01. Contact microphones and materials to be used for experimentation.

WORKSHOP MATERIALS

- Self-amplified battery-powered speakers with a mini jack or jack input.
- Piezo buzzers
- Sound cables (mini jack or jack, depending on the speaker input)
- Alligator clips in various colours
- Metal, wooden and thick cardboard boxes, tin cans, glass jars etc.
- Bamboo skewers, rubber bands, metal springs, paper clips, binder clips, C clamps, pegs etc.
- Paper tape and/or insulating tape
- Motors, electric toothbrushes, coffee mixers etc.

KNOWING AND UNDERSTANDING: WHAT IS A MICROPHONE

A microphone's operation is to collect soundwaves moving through air, in order to amplify them (e.g. the microphones used in a concert), to capture/record them (like the microphones used in cameras), or even to broadcast them (like the microphone in our mobile phones)

All microphones have a very thin and delicate surface which vibrates every time it is touched by sound waves. This way, the membrane in the microphone mimics the way the human ear works. Every time a vibration is generated, the air molecules move in waves; once they reach the membrane, they transmit their movement to it.[37]

These soundwaves, however, do not only move through air, but also through liquids and solids. Each different material plays an important role in determining what the resultant sound will be like.

There are different microphones for listening to sound as it passes through different materials. The microphones we most commonly see are the ones which work with sounds moving through air. For instance, these are the types of microphones we have in our mobile phones or tablets and personal computers, or the ones that singers are seen holding in concerts (Figure 4.02). The same type of microphone is also found inside guitars and other instruments, and is also sometimes called a pickup microphone (Figure 4.03).

However, there are also microphones especially designed so we can hear sounds underwater (hydrophones, Figure 4.04), as well as microphones that help us hear through solids (contact microphones, Figure 4.05).

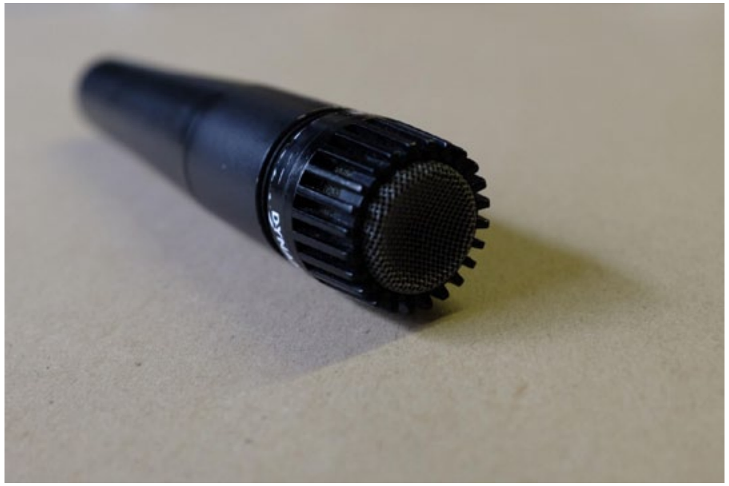


Figure 4.02. Vocal microphone (dynamic).

[37] For a detailed account of how microphones work, and a more in-depth explanation of electric currents and their mechanics, see <u>Section 2 "Knowing and Understanding: Sound and Electricity"</u>.

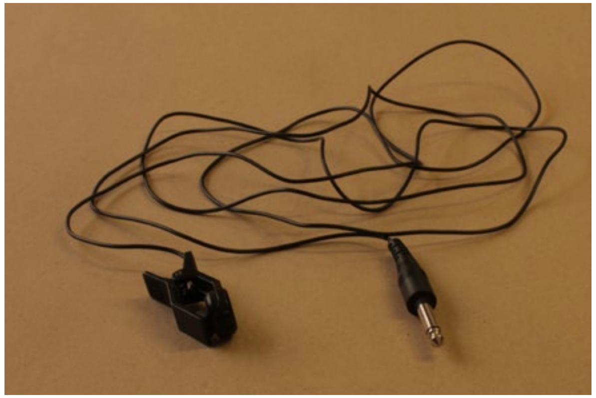


Figure 4.03. Pickup microphone for acoustic instrument (guitar).

Figure 4.04. Hydrophone.

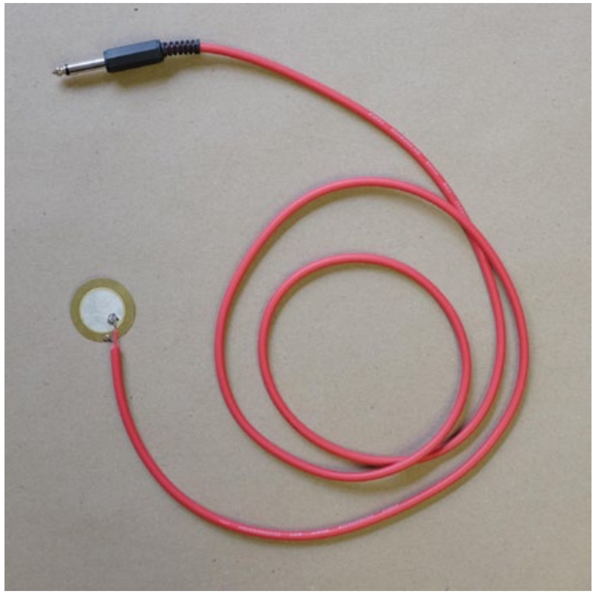


Figure 4.05. Contact microphone.

DISCUSSION

Have we noticed how sounds are heard when we are inside the sea or inside a pool? When we go swimming, how do boat motors sound underwater and out of the water?

KNOWING AND UNDERSTANDING

1. Recording & Amplification

When the microphone membrane captures the waves that are circulating in the environment, these are converted into an electric current, which can move through the cable we connect to the microphone. This way, we can do many different things we the sounds we collect.

For a start, we can record sounds, if we connect our microphone to a recording device (e.g. a computer).

We can save them and store them, as we do with our photographs, then listen to them whenever we want, combine them with a video, or even mix them with different recorded sounds.

We can also amplify them, using a device called an amplifier, and a speaker. The amplifier does exactly what its name suggests: it amplifies or strengthens the sound's volume – as if adding more electric current to the sound signal coming from the microphone. Therefore, when the sound reaches the speaker, it sounds much louder. This way, a singer's voice can be heard across a whole football arena.

Once the sound has been converted into a current, we can process it and transform it through various electronic tools that are called effects; these tools are very widely used in music.

2. Contact / piezo microphones

Through contact microphones, the subject of this section, we can hear sounds that would normally not be audible. These are faint sounds that would normally go unnoticed or sounds that we would not usually think of in musical terms, like the little sounds our fingers make when we rub a dish dry, or the sound of raindrops on a metal surface. These microphones are very commonly used in film music and music for videogames, whenever there is a need for eerie sounds, or for a certain type of atmosphere.

Contact microphones are also frequently used in experimental music, a type of music that makes more use of uncommon sounds, and is less concerned with melody and rhythm.

LISTENING AND WATCHING / DISCUSSION

We listen to the following examples, without watching the image, and consider:

- What images do they bring to mind?
- Can we think of any similar sounds we may have heard in a film or series?
- Have we heard anything similar in a piece of music?

Example 1: Alan Lamb

Example 2: Johannes Bergmark (16:20 - 18:30)

After discussing the images, environments and musical examples brought to mind by the sounds we heard, we play the videos and watch them normally (with image) this time, discovering how all these strange sounds were made.

In example 1 we hear the sound of rain falling on a metal fence, and notice that it has been recorded using contact microphones. The contact mics are fixed on the fence and the sounds (which are a bit like the lasers in Star Wars!) are generated through the drops as they hit the fence. The other sound that is audible is that of the wind on the fence. Alan Lamb had recorded entire albums using only sounds recording with contact microphones on giant metal fences.

In example 2 we hear the sounds of various small metal, plastic and rubber objects. Johannes Bergmark has stuck a contact microphone under a large wooden surface so that any object placed on the surface can be heard. We can think of the entire surface as a giant microphone, which captures all the tiny sounds made by objects as they rub together.

MAKING: CONTACT MICROPHONE

!!!Attention!!! We must not connect the microphone to a loudspeaker or amplifier plugged into a wall socket. We only work with battery-powered amplifiers!

The loudspeakers we will use may be self-powered, rechargeable speakers for a mobile phone or computer, or small guitar or bass amplifiers. In any case, they must have a cable input (a mini jack or jack) and be battery-powered (rechargeable or not). Alternatively, we can try to make our own amplifier, following *this* diagram made by John Richards for a more demanding construction.

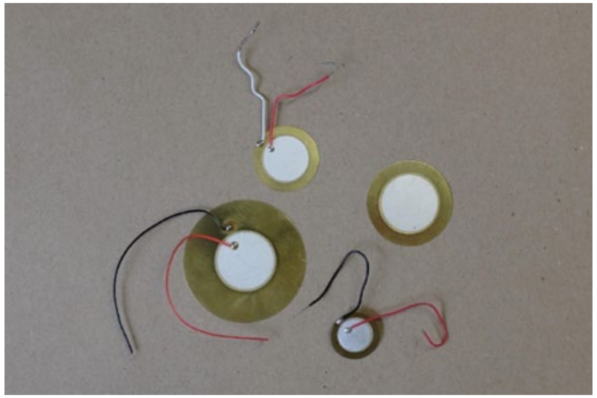


Figure 4.06. Piezo buzzer.

Figure 4.07. Mini jack audio cable.

A contact microphone is a piezoelectric buzzer, in other words a small metal disc (Figure 4.06). We will connect this disc with an audio cable (Figure 4.07) and then connect the cable itself to an amplified speaker.

Using an alligator clip (preferably red), we connect the cable that ends on the inner small disc to the tip of the jack (positive). With another alligator clip, we connect the cable ending on the outer big disc to the base of the jack (negative - see figures 4.08 & 4.09).

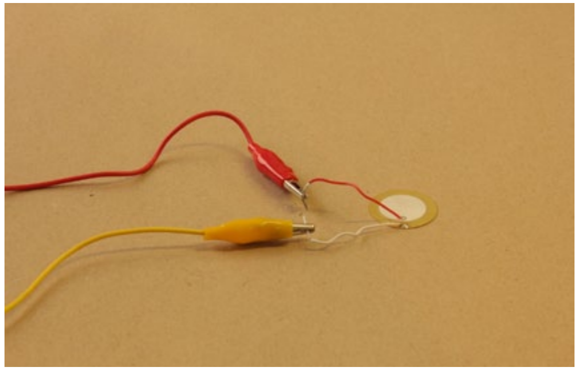


Figure 4.08. Piezo connection with alligator clips.

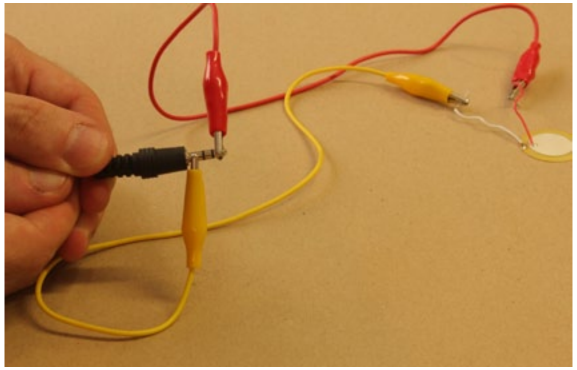


Figure 4.09. Connecting a piezo to a mini jack.

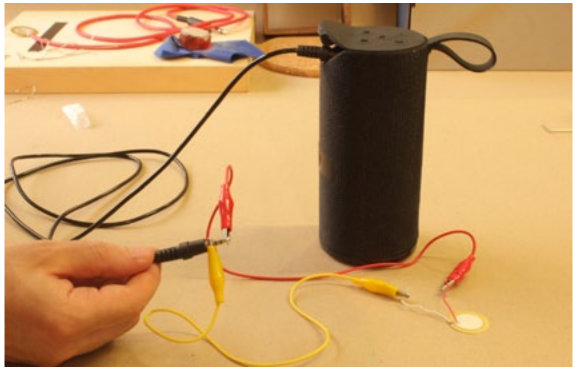


Figure 4.10. Connecting a piezo to a loudspeaker.

This connection can happen either with alligator clips, or with a simple solder, using a soldering iron. A solder provides a permanent connection, which is more durable and allows for a stronger signal. It is therefore preferable to the temporary alligator clip connection. The soldering process can either be carried out by the teacher outside of class, or by older pupils, if they work very carefully.

For the soldering, we need a soldering iron and solder. Another very useful accessory are the so-called “soldering helping hands”, which usually include a magnifying glass.

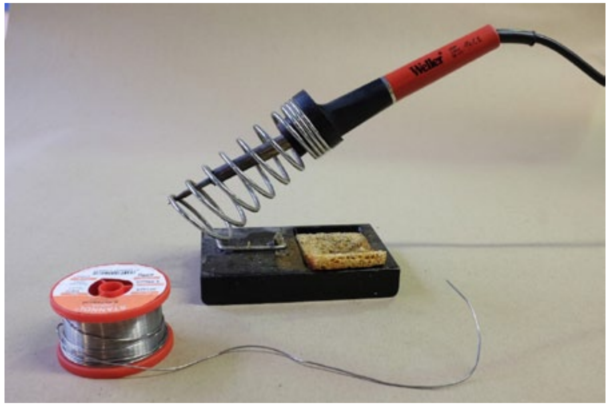


Figure 4.11. Soldering iron with base and solder.

Figure 4.12. Soldering helping hands with piezoelectric buzzer.

Once we have cut the audio cable in half, we strip it from its outer cover at a length of 3-4 cm. (using a cable stripper or very carefully with a universal cutter or knife). We will see 2 or 3 smaller cables of different colours, which we will also strip (at a length of ~1 cm) so that the metal wire on their inside is visible. Usually the red wire is the positive one and corresponds to the jack tip, and the black is the negative, which corresponds to the base. If there are 3 cables, in order to figure out which two of the three wires we can use, we try them out in pairs on the poles of a battery. We simultaneously let one of the wires touch the positive pole and the other touch the negative one, keeping the jack connected to our speaker, which is turned on. When a “clack” is audible from the loudspeakers, it means we have found the two wires that we can connect. We then cut any wires that the disc may already have (Figure 4.13) and solder the negative wire to the outer disc, and the positive wire to the inner disc (Figures 4.14 & 4.15).

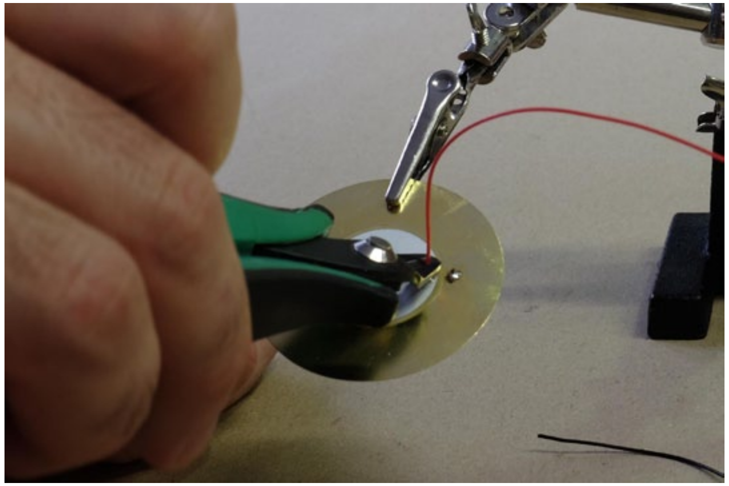


Figure 4.13. Piezo wire stripping.

Figure 4.14. First piezo soldering.

Figure 4.15. Second piezo soldering.

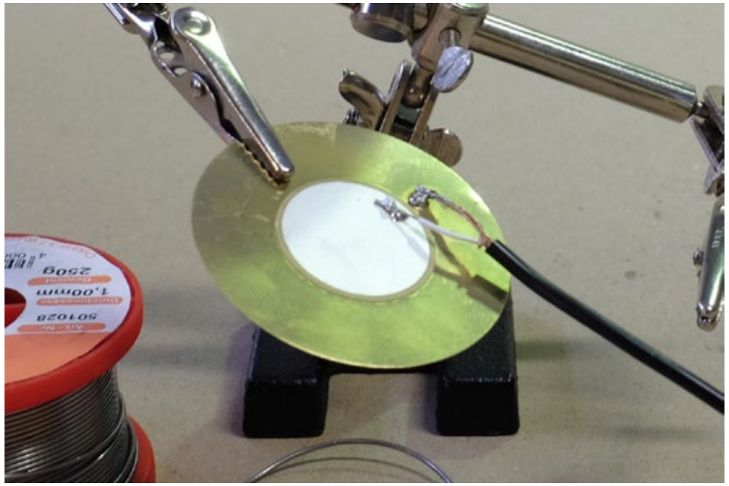


Figure 4.16. Piezo soldered to the wires: white = positive, brown = negative.

Our microphone is now ready to use. We can apply it to any surface we want, and listen to the sounds as they travel through it.

For our microphone to work properly, we have to make sure it is very well fixed on the surface. To attach it to surfaces, we can use insulating tape or paper tape, which are easy to remove and do not leave a lot of residue. It is best not to cover the inner disc of our microphone with tape, and to attach it in the following way:

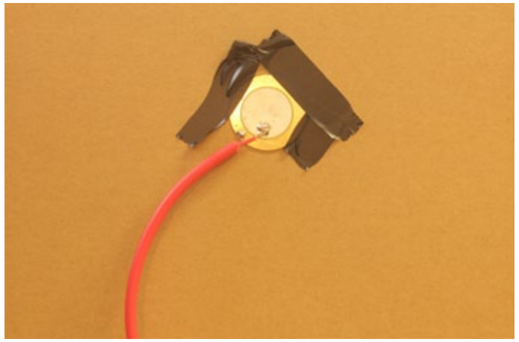


Figure 4.17. Contact microphone attached to surface with insulating tape.

The contact microphone works much better on thin surfaces made of resonant materials, such as glass, metal, wood or plexiglass. On thicker surfaces, it will not pick up sounds so easily.

Below we list a few indicative ways of playing, which can be used as starting points. With our microphones, we can try out any surface and any material, to check how they sound:

PLAYING

Experiments and exercises with contact microphones
1. The box: Introductory activity for the whole class
2-8 children play (depending on the size of the box),
but everyone can participate, either watching and making suggestions, or by alternating between players.

We use a big box, preferably made of thin wood (a thin metal sheet or very hard cardboard will also do). The choice of material will play a big part in how well we will end up hearing our sounds. Thin wood is the best for resonance, whereas metal has a very distinct timbre.

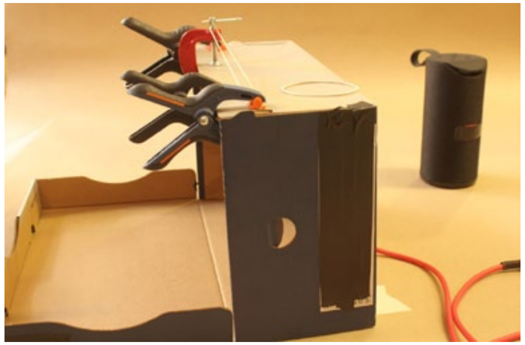


Figure 4.18. Box I.

We place the box on a table / desk in the centre of the classroom, and we gather around it. We carefully attach a contact microphone on the side of the box using tape. We take care not to cover the small disc in the centre of the microphone.

We place the box on its side, so that we have a clean surface at the top, and the opening in vertical position (so we can attach pegs to it). We connect it to our amplifier or self-powered speaker, as mentioned above. We raise the volume as much as possible, but not too loud, to avoid making the speaker “whistle”.

Figure 4.19. The box II.

We then place small objects on the box and experiment with them, exploring the sounds they can make.

Suggested materials: Springs, opened-up paper clips, bamboo skewers attached with pegs or C clamps.

Figure 4.20. C clamps and pegs.

We can lightly tap the springs as if they were bells, or rub them with skewers. We can use springs of different lengths and elasticities (*Lee Paterson* for example, is a musician who uses them a lot).

We stretch the different sizes of rubber bands over the box (no worries if they break, but we should be careful not to hurt ourselves), and use them as strings or rub them with a skewer as a bow.

The bamboo skewers and pegs, when firmly attached across different lengths, can be used as percussive lamels, and we can play them with our fingers, like a kalimba (thumb piano). To do this, we need strong pegs and clamps, like the ones used for frames. We can look for those in tools and hardware stores.

We can fix the springs in place in a similar way. We explore possible sounds for 10 minutes, with children approaching and trying out sounds in small groups of 3-5 people. We keep in mind that we are looking for small sounds that would not be naturally audible, and avoid playing very loud or percussive sounds that could be heard on their own without our microphone.

LISTENING AND WATCHING

In the ensuing *video* we watch an example of “The Box” and how it might sound.

2. The Big Clock

Having explored possible sounds in our introductory activity, we form a small group (4-7 children). We sit in circle around the box and every child chooses an object (a skewer, rubber band etc.) with which to play. We make a pause so that we can have a complete silence for a few seconds. We start playing in circle (clockwise) one after the other, each one making only one sound with the object (s)he has chosen.

After having gone around the circle 2 or 3 times, we keep going with a small variation: now every 2nd player repeats their sound twice. After 2-3 rotations, we stop.

The rest of the class observes and listens. After the first group has finished, a second group takes charge of the clock etc., until everyone in class has played.

The aim of the game is to imitate a big old clock which is losing time. We do not need to keep our rhythm static all the time; we can accelerate or slow down our pace.

3. Sound Cinema

Improvisation with many boxes. After completing “The Box” and “The Big Clock”, we form groups of 4 people. Each group has a box and various small objects (rubber bands, skewers, paper clips and springs), a contact microphone and a self-powered speaker. We can add to our box any other object that sounds interesting. We also spend some time experimenting with objects we may have on our bench desks, our schoolbags or pencil cases. Paper sheets, pens, pencils, rulers, small scissors etc. may all hide sounds beyond our imagination.

We dedicate around 15 minutes for each group to make their improvised instrument, and to prepare a small musical piece for presentation.

We think of each piece as a scene from a film or series and we make up the sounds that will accompany it. Is it a comedy? We make a funny piece. Is it a thriller or horror film? We make a piece that sounds scary or full of suspense. Is it an action film? We make a fast-paced piece, etc.

Each group performs their piece.

If possible, we keep each group’s constructions after the end of the presentation. The instruments can be stored and extended. This activity can be repeated many times, and developed further. As the children get familiar with the different materials and their capacities, they enjoy this activity even more.

4. Activity: The Mechanical Box

In this activity, we will see how various small motors can make up a sound piece when put to work together. We can start by using the Crickets we made in Section 3, but also small motors, coffee mixers, electric toothbrushes, wind-up toys, and in general any small motor that vibrates.

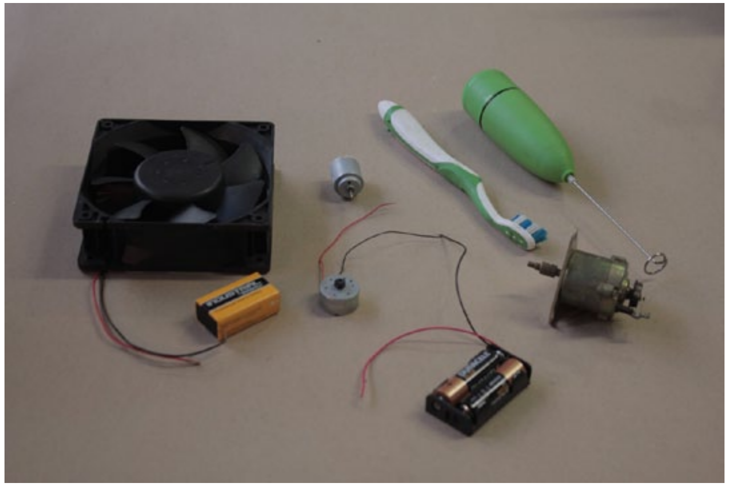


Figure 4.21. Motors and electric toothbrushes.

We attach a contact microphone on a relatively large wooden surface or box, as described in the previous construction.
We then assemble the Crickets as shown in the previous section, but keep one of the battery poles disconnected. In this activity we try to use the large capacitors, so that we can achieve slower rhythmic patterns when we connect the Crickets. We now connect the Crickets to the battery, listen to them for a little while, then place them on our surface.

We notice how they sounded before and how differently they sound now, with the contact microphones.

We turn on the other toys, notice how they sound on this surface, and explore for 5 minutes the sound we can make, depending on how they touch the surface. Can we make them sound like insects? Do they sound like cicadas or bees, if we press them firmly on the wooden surface? Can we make them sound like a hopping ball, by holding them so lightly that they barely touch the surface?

LISTENING AND WATCHING

Our box has now acquired some new sounds. Let us watch an *example*.

5. Inside the beehive *(For 5-6 children)*

We gather around our box. Half of the children have Crickets, while the others have another small motor. The children with Crickets give a pulse, and others follow. We start by putting 2-3 Crickets with large capacitors on the box. One child will be the conductor. (S)he starts silently counting to ten, and signals the others, who all place their motors on the box so that they sound like buzzing insects. The conductor counts to ten again and signals them to remove the motors. We notice the rhythms made by the Crickets. Our conductor counts to ten again and signals a new start, then after ten counts stops us again. We do this four times in total. The aim is to synchronize and coordinate as much as possible, so that we may all start and stop almost together.

Playing: Lines and dots *(For 2 children)*

We split into pairs. One child plays with long-drawn, sustained sounds, the other with sharp, intermittent ones.

Each group makes a simple score to organize how they will play. We divide a page in half. On the top part we draw lines, and on the bottom we draw dots. The lines correspond to continuous sounds; the dots correspond to brief ones.

For example, we can look at Figure 4.22.

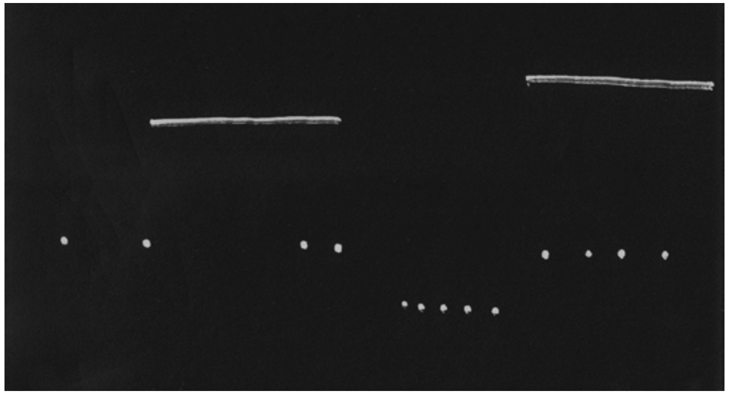


Figure 4.22. Graphic Score.

We read our score from left to right and play one symbol after the other.[38]

In the example, we notice the gaps between the symbols (which are rests), the places where symbols coincide, and the way the coincide. For instance, when our percussionist (the child who plays the dots) makes their second sound, the performer who plays the long, whistling sounds (lines) has to start at the same time, then make one long-drawn sound on their own, while the percussionist pauses.

COMMENTS

The constructions in this section are based on the work of several musicians who have been exploring sounds for many years. Some of those musicians are:

Johannes Bergmark (*https://www.bergmark.org/*),
Adam Bohman (*https://adambohman.bandcamp.com/*),
Lee Patterson (*https://vimeo.com/114857629*),
Dimitris Sarris (*http://sarris.mysch.gr*) and John Richards.

[38] Remember or watch again the work Pithoprakta by Iannis Xenakis, from Section 1.

5. A DIVE INTO ELECTRONIC CIRCUITS: BREADBOARD

We build a Breadboard Synthesizer (BBS) and play with it.

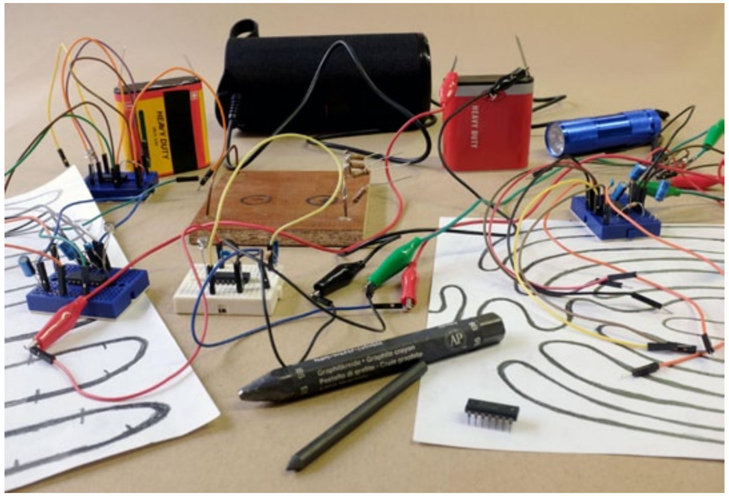


Figure 5.01. Breadboard with photoresistors, conductive drawings and all the necessary materials.

WORKSHOP MATERIALS

- Breadboards, ideally one per 2-4 pupils.
- Integrated circuits (ICs), also known as microchips type cd40106, at least as many as the breadboards.
- It might be useful to have a few more, as they are a little sensitive.
- Jumper wires for breadboard (jumper wires), “male-to-male”, one package per 6 breadboards.
- 1K και 100K resistors and photoresistors 100KΩ, one per group.
- Electrolytic capacitors 47μf, 100μf, 1000μf, one per breadboard.
- Ceramic capacitors 100nF, one per breadboard.
- Small flashlights, 1-2 per breadboard.
- 4,5V batteries, one per breadboard.
- A4 or bigger papers, preferably quite thick, so they do not tear easily.
- Soft graphite pencils (or drawing pencils over 4B), one per pupil.
- Alligator clips, 1 pack of 4-6 per breadboard.
- Small active (self-powered) speakers and audio cables with a jack (suitable for the speaker input), one per breadboard.
- Mixer, one per group (DIY, see Section 6 “Making: DIY Mixer”).

KNOWING AND UNDERSTANDING

In this section we will build and play with a purely electronic instrument: a very simple synthesizer, which we will construct on our breadboard. The synthesizer is something one may have heard of, but what on earth is a breadboard, and what does it have to do with electronic circuits?

The breadboard

Up to now, we have built some simple circuits, using alligator clips for the connections between the various circuit components. There are, however, also circuits that are more complex and require more components and more connections. For these circuits, instead of using dozens of different wires, we use certain electronic test boards, which are called breadboards. These boards have the wires (and the insulating material) already built into them, in vertical and horizontal lines; this way our components are easily attached to them and allow us to make quick temporary connections, so we can test a circuit. The name “breadboard” comes from a time when, in order to build a test circuit, electronic technicians used a wooden board that looked very much like (or literally was!) a bread chopping board. Technicians would place nails on the board and on them they would attach the various wires and other components to be used for the test circuit. It is called a test circuit, because the components we connect can easily change, so we can make several trials and tests before we settle on a finalized circuit. A finalized circuit is a soldered circuit, and therefore cannot change easily.

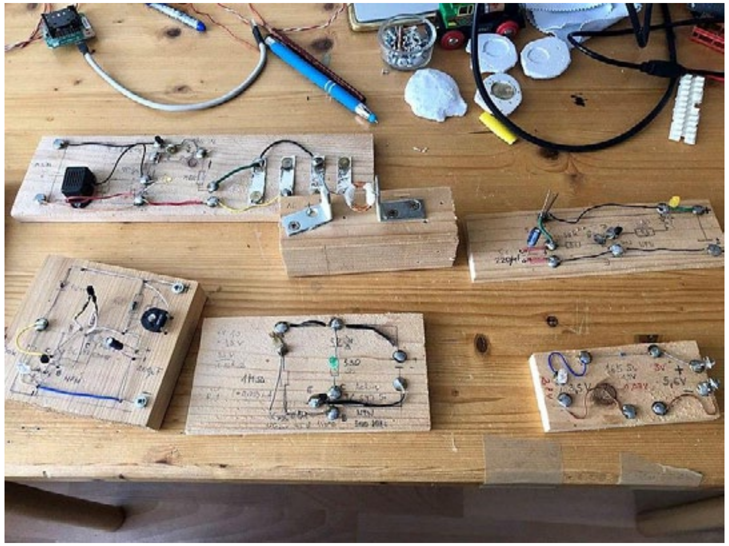


Figure 5.02. Test circuits on “breadboards”.

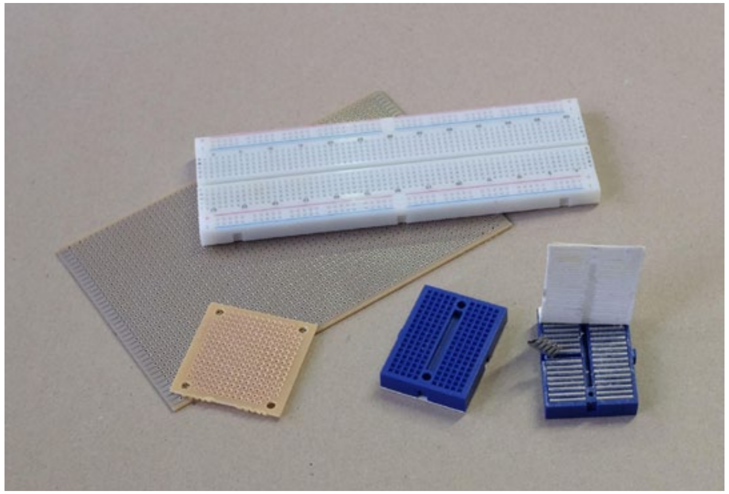


Figure 5.03. Testing boards, i.e. modern breadboards.

In this section we will build a more complex circuit than the ones we have made so far, so we will require a testing board like the breadboard.

The synthesizer

The synthesizer is an electronic instrument, made of many different circuits, with which we can create an electrical vibration from scratch, without the need for a natural sound source. This vibration generates a synthesized sound, a simple tone. Depending on the circuits contained in a synthesizer, we may intervene and process this tone, changing all of the sound’s parameters: timbre, volume, duration etc. This way we can create more complex sounds. Sometimes these sounds may be similar or even identical with the familiar sounds of musical instruments, and sometimes they may be nothing like them. Often, the synthesizers come with keyboards just like the ones we find in pianos, but this is not always the case. As we will see in this workshop, we can find other ways of playing, without the need for keys!

The integrated circuit (chip)

The main component we will place on the breadboard is an integrated circuit, otherwise known as a “chip”. More specifically, we will use the cd40106 chip. These are the chips we find everywhere these days, from mobile phones to washing machines and cars. This is a complex circuit contained in a little flat package. It comprises various different electronic components and is made of silicon. There are countless such chips, each one with a different function; their “legs” (pins) may be at least 4 or more. Each leg needs to be connected to a different part of our exterior circuit. The appropriate position and function for each leg is usually described by the chip designer in the manual that comes with the chip.

COMPREHENSION ACTIVITY

A simple connection on the breadboard

In order to better understand how the board works, we can make our usual circuits using the breadboard. Apart from the board itself, we will also need a battery, our jumper wires, alligator clips and a loudspeaker.

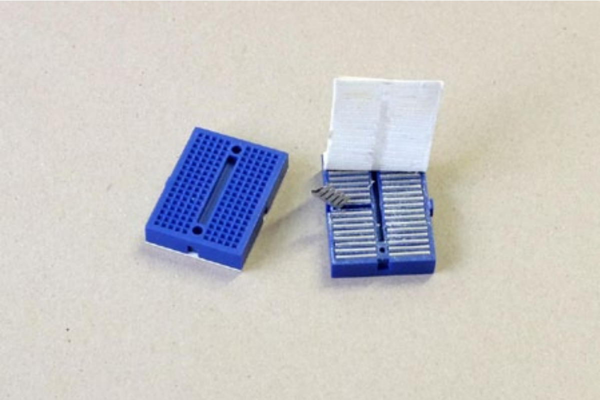
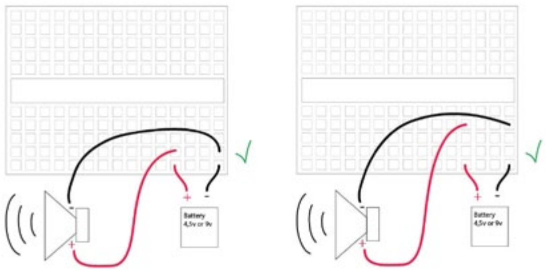


Figure 5.04. Small testing board (mini breadboard) and its interior.

In Figure 5.04 we see the small board, with its top part on the left and its bottom part on the right, after having opened it to look at its interior. The little holes we see on the outside are connected vertically in relation to the gap (empty line) in the centre. This gap is where the connection stops, and there are no horizontal connections. We will therefore connect our battery to two parallel holes, and then our loudspeakers to two holes, just over the ones we just used for the battery, along the same vertical column. We use jumper wires on the breadboard because they are the only wires that can fit through these tiny holes. We then grab the other end of the wires with the alligator clips, in order to connect them to the loudspeaker or battery.



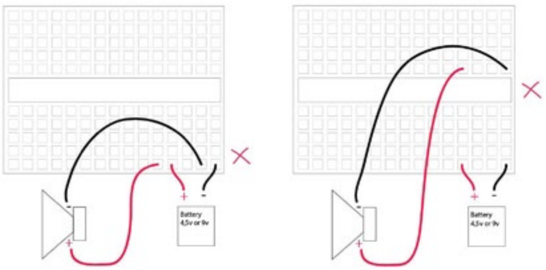


Figure 5-05-1,2,3,4. Right and wrong connections on the testing board.

We will see that, whichever hole we use along the same column to put the loudspeaker connection wires, whether over or under the holes where our battery is connected, the circuit will close and we will hear our usual “clack” on the loudspeaker. If we put them left or right of the battery connection holes (i.e. not on the same vertical column), the circuit will not closed, because as we saw earlier the conductor follows a vertical rather than a horizontal path. The same will happen if we put the loudspeaker wires on the same vertical line, but beyond the middle gap. Again, the circuit will not close, because our conductor is interrupted by the gap. We try out different connections with our wires, to confirm this in practice!

MAKING: BREADBOARD SYNTHESIZER (BBS)

Let us start building our circuit. For each chip, we have in mind the legs numbering scheme, depending on how many the legs are. This will help us a lot in making the right connections. We notice that each chip has a notch, a half-circle. If we place the half-circle so that it faces left, then we start counting under this notch. On the bottom left corner we always put the number 1, and over the half-circle, on the top left corner, the last number; in our case, number 14.

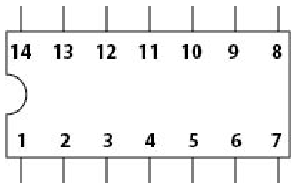


Figure 5.06. The chip and its numbered legs (pins).

After distributing the necessary materials to each group / pupil, it will be useful to draw our numbered chip on the board, so we can gradually draw in every new connection. By the end, our drawing should look like this:

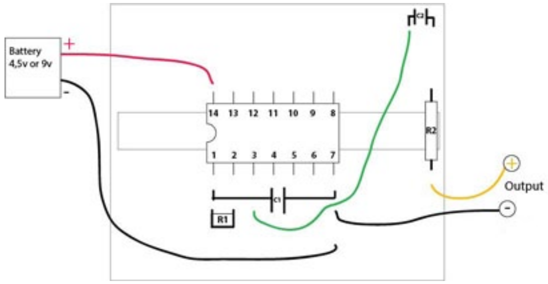


Figure 5.07. Circuit diagram for the Breadboard Synthesizer.

To begin with, we placing our chip parallel to the board's gap, so that legs 1-7 are on the one side of the gap, and legs 8-14 are on the other. Before pushing it so it fits firmly into the board holes, we make sure that all the legs are exactly over the holes, so we don't twist and break them. If they do not fit exactly, we can bend them very lightly and carefully with our fingers, so they get into position. Once we are sure they are all ready to fit in, we push the chip carefully, to drive the legs fully into the holes.

We begin with our first connection, which we also draw on the board. On the hole right under leg No. 1 we will put the small C1=100nF capacitor's leg. We will put the other leg of the capacitor under No. 7. It is best to put the wires on the holes closer to the chip, because if we start from the farthest ones, the wires will gradually fill up the available space and block our access.

Our second connection will be with the R1=10K photoresistor. Its one leg also goes to No. 1, right under the capacitor; its other leg goes right next to that, under No. 2.

We then take a jumper wire and place its one end under No. 3 and its other end on the penultimate hole from top right; this way we leave open the hole over it, and the hole on its right.

Right over that, we place the large C2=10nf capacitor's short leg. We place its other leg on the right, exactly next to the first one, on the top right corner hole of the board.

A little further down, on the same vertical column, we also put our linear R2=1K resistor. Its one leg goes in under the capacitor, before the board gap; the other leg goes in after the gap.

From there, from the same column, we will take the positive terminal of our speaker output, putting in a jumper wire on a hole under the resistor. We grab its other end with an alligator clip, then attach it to the top part of our mini jack, so that it leads to our amplifier / speaker.

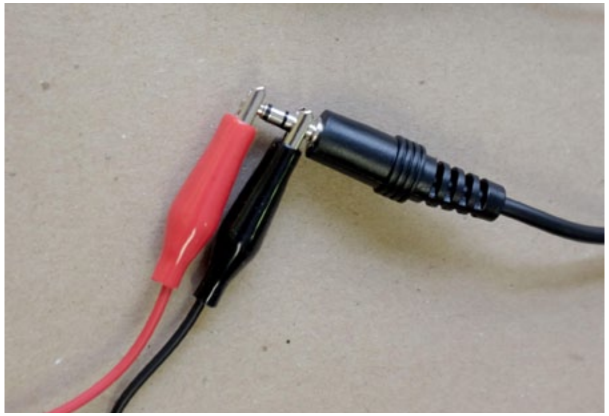


Figure 5.08. The cable jack with the positive and negative alligator clips.

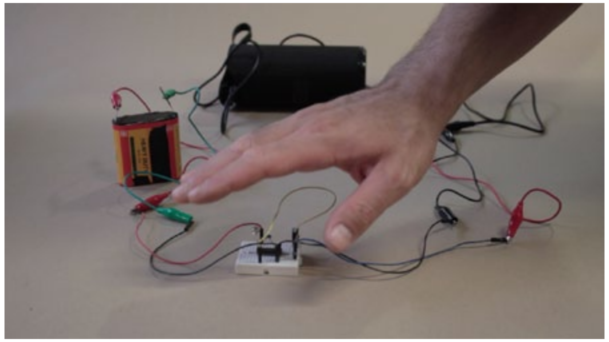
At the bottom of the jack we will attach another alligator clip, which will lead to a hole under No. 7 of our board – the negative terminal.

Finally, for our circuit to work and make sound, we have to connect the battery. The + should go to a hole over No. 14, and the - under No. 7.

When we have completed the final two connections, we should be getting some sound. If nothing is heard, we have to check the board and our connections carefully, to make sure that everything is connected in the right order and that all the connections are firmly inserted in the holes, so they make good contact.

LISTENING AND WATCHING

In the ensuing video we watch the synthesizer in action and notice how the sound changes with each hand gesture, as the light changes too.



Playing with the BBS

MAKING: ALTERNATIVE CONSTRUCTION / GRAPHITE RESISTOR

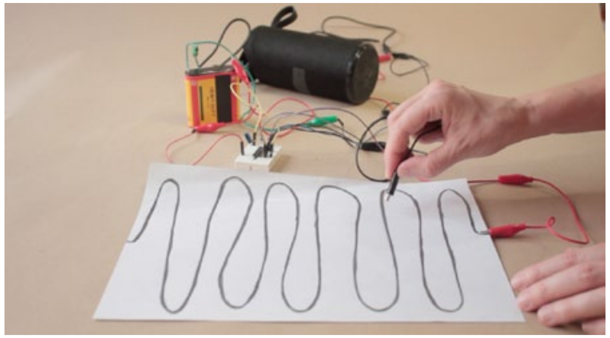
If we remove the photoresistor, our circuit will open, and therefore will not make any sound. We will now try the same instrument with a different resistor: this time it is a line, drawn in pencil!

On an A4 sheet, we draw a continuous line, with one end reaching the edge of the page. For instance, we draw a spiral, a straight or a wavy line. With a thick and soft pencil or graphite if we have one, we press on the line firmly, to make sure it is thick and dense across its entire length.

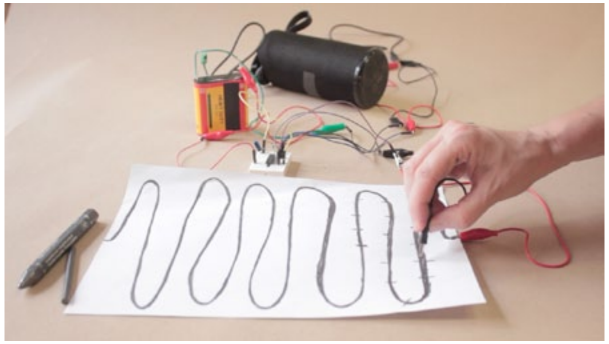
We replace the R1 photoresistor on No.1 and No. 2 with two jumper wires and attach the alligator clips to their other end. With the one alligator (no matter which one), we grab the paper’s edge, right at the end of our hand-drawn line. We use the other alligator to touch various spots on the line, thus closing our circuit through our drawing. The graphite line, which is a good conductor for electric current, acts as a resistor, and therefore sound is heard! As we move along the line, the closer together the two alligator clips come, the higher the sound. The further apart, the greater the resistance, and therefore the sound becomes bassier!

LISTENING AND WATCHING

In the ensuing videos we watch the breadboard with conductive drawings. We notice how sounds change as the distance between the alligator clips changes. In the second drawing, we have noted specific pitches on the line. This way, we can even play melodies!



Playing the BBS with a drawing



Playing notes with the BBS

Extensions to the construction

With the ways described above, we control only our sound’s pitch, while the volume remains the same. Through a small addition to our circuit, we can also control the volume. This will help us in our playing, and will also make our instrument far more interesting.

To do this, we remove the linear resistor R2 from the output, and in its place we put a second photoresistor (R3).

The resistor we just removed (R2) will now be placed in another spot: one leg will go right under the audio output wire, and the other under No. 7.

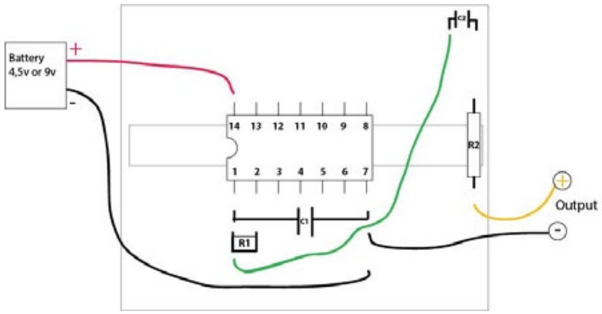
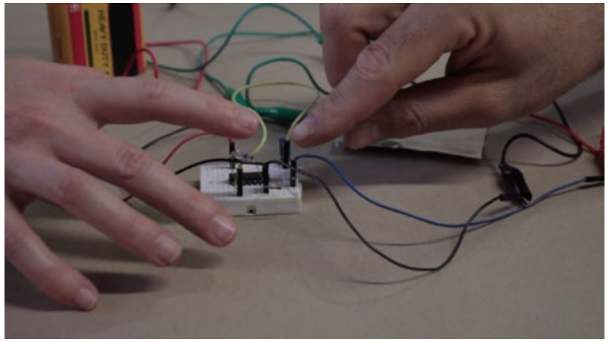


Figure 5.09. R1 and R3 are the photosensitive resistors. R2 is our linear resistor.

LISTENING AND WATCHING

We watch the extension in the ensuing video, and notice the difference in sound.



Playing the BBS with volume control.

Further extensions

If we have understood the function of this simple circuit and want to extend it further, we can develop it into something more complex. Until now we were using only the first pair of legs on our chip, No. 1 and No. 2 (and the power input legs, No. 7 and 14), to make a simple synthesizer with an oscillator, controlled either by light or by graphite. There are 5 pair of legs available (3-4, 5-6, 8-9, 10-11,12-13). By using the remaining legs on our chip, we can make a synthesizer with six oscillators in total, which can interact with each other, generating much more complex and interesting sounds. A very good presentation of such circuits, as well as many relevant links, can be found *here*.

COMPREHENSION ACTIVITY

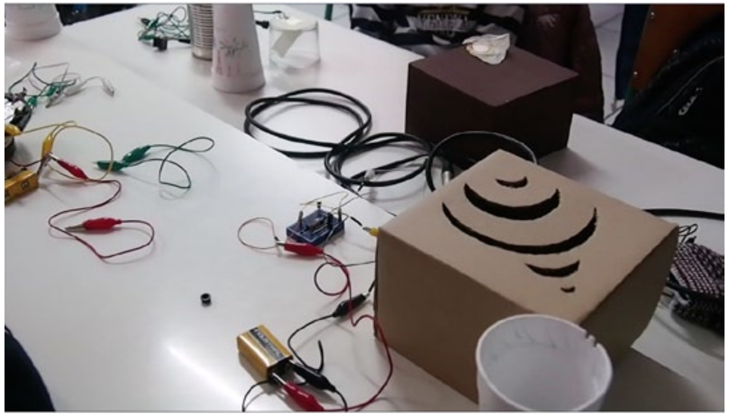
1. Divided in groups, we take some time to explore the capabilities of our new instrument. As mentioned, its sound is the continuous sound of electrical flow.

Comment: The Breadboard Synthesizer sound is continuous and harsh, and may quickly become tiresome or annoying, so we need to be careful and not let it play ceaselessly. When we are not trying out something specific, we are careful not to keep it connected to the battery or at least we make sure to turn the speaker volume down to 0. Also, it is important to incorporate rests in the playing of this instrument, and search for ways to make it silent or quiet, and to introduce variety in its volume. We take care not to keep its volume too high all the time, at least not so much that it becomes tiresome (especially when everyone is playing together), or covers the sound of all other instruments (when we are playing with other instruments).

How to control the sound on the Breadboard Synthesizer

1. We can create an extension (see above), through which we will control our sound volume.
2. Volume is also controlled through the amplifier or speaker that we have connected to the synthesizer.
3. We try out the sounds as we play with a flashlight, either a simple one, or one with a flash function (which gives a steady pulse).
4. We can intervene using our hand or a box, to obscure the lighting in a controlled way. What will happen if we block the photoresistor completely with our finger? We notice that the main change occurs in the parameter of pitch.
5. What happens if we change the capacitor and put another one, with a different capacitance value, in its place?

2. We place one or more BBS somewhere near the centre of the room, and experiment with turning the room's central lighting on and off (having drawn any curtains or obscured any other source of natural lighting beforehand). If the room lights have many switches, we try to turn them on one by one, and then switch them off and on again in different combinations. Watch video for example.



DISCUSSION

How many different sounds can we get through the BBS (melody, noise, rhythm)?

What kinds of features does the BBS sound have? How does this instrument sound? Do we like it? Does it remind us of something? Does it inspire us to think of a sound piece (or a sound installation / performance) where it could be used? With what other instrument, out of the ones we have made, could we combine the BBS? How / why?

PLAYING

1. Activity: Scores for Breadboard Synthesizer with photoresistor

We draw various long lines on a single A4 sheet each. Each sheet can be used as a score for a small BBS solo (e.g. Figure 5.11). It can be a straight line, but for the sake of the game it is best to have a more “adventurous” shape in mind. We consider also how a line can be used to guide someone into playing what we have imagined. After shuffling the papers, each player takes one in random, and then “performs” it with the BBS. Afterwards, the creator of each line reveals what they had in mind when drawing it (was it more or less what the player performed or something completely different?)

2. Group play in circles, with photoresistor

We place all the BBS in the centre and split into two groups. One group forms a circle around the instruments and points at them with flashlights, while the other group’s members enter the circle’s inside and try to prevent the light from the flashlights reaching the BBS, obstructing it with their hands and bodies.

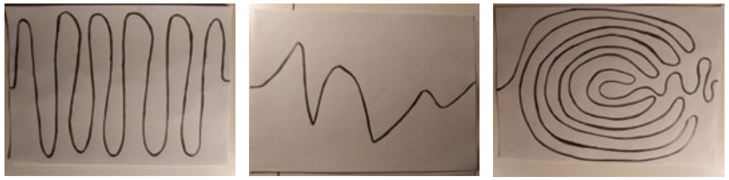


Figure 5.10. Graphite drawings.

3. Making a melody, with graphite

On our graphite line (on the A4 sheet) we search for points in the line that represent certain “notes”, and mark those points.[39] We make a melody using these notes and playing it.

We then think of an orchestration,[40] including sounds from the other instruments we have, and play our melody with this “orchestra” of instruments.

[39] If we want to find all the notes of western art music with precision on our line, we will need a tuner like the ones used for string instruments. If we do not have one, there are similar applications available for mobile / tablet.

[40] When a musician composes a piece, (s)he selects the different instruments that will be heard in this piece, and the parts where each instrument will play, in order to achieve the result (s)he has in mind. This process is called orchestration.

LISTENING AND WATCHING

1. We learn about Daphne Oram’s synthesizer, the *Oramics*, which can “read” lines and generate sounds. In the sound file, we can listen to an excerpt of some of the sounds it produces.

2. Some composers use synthesizers to generate very intense and rough sounds, sometimes almost annoying ones. Here the important thing is not the melody, but how we sense the sounds in our body. In *Gendy3*, Iannis Xenakis uses sounds which resemble sirens, and are very similar to the sounds of the BBS.

3. One of the first “synthesizers” to be played with hand gestures in the air is the *Theremin*.

4. We listen to *Rainforest* by David Tudor, if we have not listened to it before.

COMMENTS ON BBS CONSTRUCTION

The most definitive elements in our circuit are the C1 capacitor and the R1 resistor.

The C1 capacitor is what will determine the total range of frequencies for the BBS. If we use a bigger capacitor instead of the 100nF (i.e. a capacitor with 1000nf or even greater capacitance) we will end up with much bassier sounds, and frequencies so low that they will sound more like rhythms and less like tones. If we exchange it with a smaller capacitor, e.g. 10nF or 1nF, we will have much higher frequencies.

The R1 resistor is what allows us to play the available frequencies with greater or smaller accuracy within this frequency range. A resistor with much smaller value than 10K, like 1K or even 0,1K, would deliver a very small frequency range, but we could modulate from one frequency to another with greater accuracy. On the contrary, a large resistor, 100K or 1000K, would deliver a very big frequency range, but the move from one frequency to another would happen much more abruptly. If we have the time and interest, we can experiment with different value capacitors and resistors and thus discover all the different sounds we prefer.

There is also another point from which we can take the audio for our speaker output, instead of No.3 that was used initially: under leg No.1, where the R1 resistor and C1 capacitor are inserted.

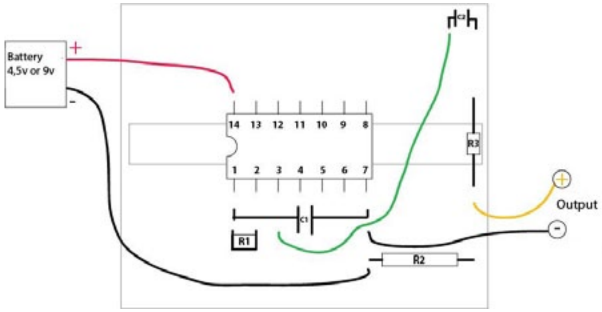


Figure 5.11. Circuit variation diagram for the Breadboard Synthesizer.

From that hole, we can get a much milder sound, both in terms of volume and timbre, which may be preferable. As with all our activities, experimentation is our friend here too!

In general, we should be careful with the connections on this board, as they are very sensitive and the component pins (legs) do not always fit in well, or may touch each other because of great proximity. If sound is not coming out, we can first take a good look at what is happening, and use our fingers to lightly test or move any connections that may be too loose, before getting disappointed!

6. MIXING AND ORGANIZING SOUNDS: PRESENTATION

Having completed our instrument building workshops, and having experimented and played with them, we can find possible ways of organizing sounds and presenting our work in public.

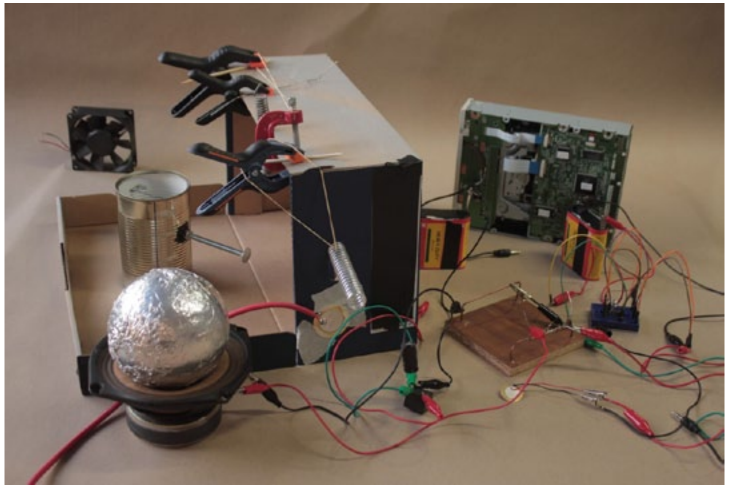


Figure 6.01. All the DIY musical instruments connected to the mixer and ready for experimental performances.

WORKSHOP MATERIALS

- Insulating surfaces (bad conductors of electricity), made of wood or plastic, as many as the performing groups.
- Thick wire (ideally copper) in pieces, two for each mixer / group.
- 1K ohm resistors, 4-5 for each mixer / group.
- Wood glue.
- Pliers, hammer and a nail (to open up holes).

COMPREHENSION ACTIVITY

You can adapt the activities in this section for experimentation and try-outs in all the previous sections too.

Namegiving
We can think up our own names for every instrument we have constructed! In our small groups, we discuss the features of each construction, the sounds it can make, and its overall capacities. We also consider whether it reminds us of something in nature, like an animal, insect etc., and give it a suitable name. We can also give it an entirely imaginary name, by making our own new word, if we consider that more fitting. In the end, we can announce all the names in class, and decide all together which name is the most appropriate for each instrument!

KNOWING AND UNDERSTANDING

Types of instruments / sounds
The first step in this process is to have already explored our various instruments in great depth, so that we know their capacities and differences.

Some instruments can more easily produce sharp, intermittent sounds. Such instruments are more suitable for providing rhythmic elements when we play. Loudspeakers, Crickets and contact microphones are great for providing sounds that are brief, sharp, and abrupt, with clear attacks. The sounds they produce when we play start abruptly, and last very little.

Some other instruments can provide sustained sounds that last. Such instruments are great for making melodies over the rhythms, or holding a tone, like voices in a choir, or instruments in a string orchestra. The Breadboard Synthesizers (BBS), the Sudophones, the Crickets (when they have small capacitors), the Victorian Synthesizers and the contact microphones can provide these sounds. Depending on their construction and the way we will choose to play with them, contact microphones can make both long-drawn and sharp, brief sounds.

If we want to include clear melodies in our performance, we can also use instruments such as bamboo skewers of different lengths or BBS with graphite drawing. It is best to avoid instruments that cannot offer variety in terms of timbre and pitch, like the loudspeakers.

Music Ensembles
After reflecting on the sounds we have available, we can make a series of decisions on the types of ensembles we want to form, and how we want to structure our musical pieces. Moreover, we can decide what kinds of instruments we want each ensemble to have. Some pieces work best if we have a uniform ensemble, where all players have the same or similar instruments. If, for example, we want to make a musical piece using only abrupt pitch glides, like sirens, we will form a music ensemble using only BBS to perform it.

Other times, we may want to make pieces with more varied sounds, e.g. a piece with some percussive rhythmic sounds, combined with sustained tones. Here, we have to orchestrate a little, and form an ensemble with many different instruments that can work together. Some will be more rhythmical, and some will generate sounds of longer duration. Such varied ensembles are also great for improvisation exercises, as the end-result is richer in sound colours.

MAKING

DIY Mixer: How the sounds of many performers can come through one single speaker.

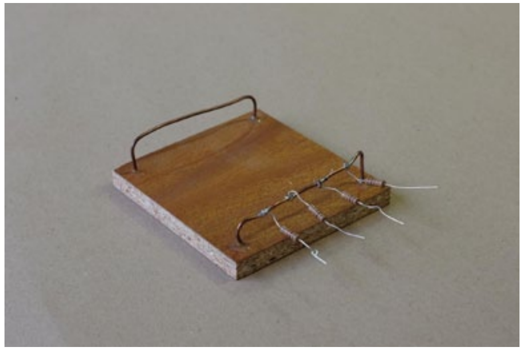


Figure 6.02 DIY mixer for four instruments.

To connect more than one instrument to a speaker, we have to build a simple mixer. As the name suggests, a mixer is a device that collects different sounds from many instruments and mixes them into an output. Depending on the number of active speakers and performer groups, we have to make the corresponding number of mixers. To build them, we need an insulating surface, wire and resistors (see above, “Materials”).

We bend the thick wires at their ends (Figure 6.02) and attach them very firmly to the surface. To do this, we have to pierce the plastic / wood where the wires will go – ideally at a distance from each other – and use a little glue (e.g. wood glue) to fix them in the holes. The glue should remain in place for a long time to work properly (see glue instructions). Handling the wire also requires caution, as it has been cut at the ends and may be very sharp.
Each of the two wires corresponds to the positive and negative terminal of our speaker, as well as the respective terminals from each instrument’s output.

For the wire we will use as a positive terminal, we will solder a series of resistors. They can be around 1K ohm each, but this does not matter too much, provided they are all of the same value. Each resistor corresponds to a different instrument going into the mixer.

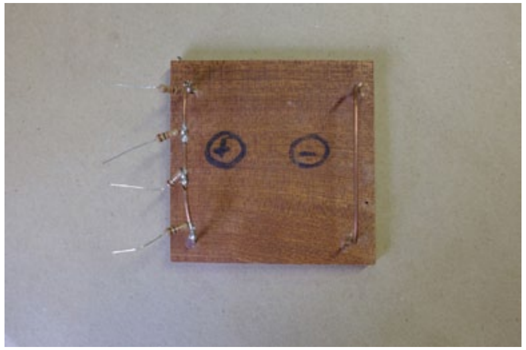


Figure 6.03. Mixer – positive & negative.

Our mixer is now ready. Now let us look at how to make our connections.

We connect the mixer to our speaker audio cable using alligator clips, as follows: the negative wire is connected to the jack base, and the positive one to its edge (Figure 6.04)

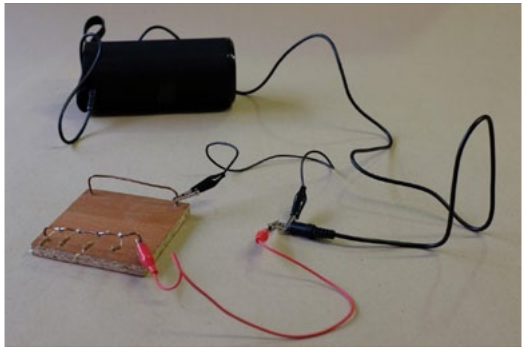


Figure 6.04. Mixer connected to the speaker.

We then connect each instrument's output using alligator clips. We connect the instrument's positive output to one of the mixer's capacitors, and the negative one with the plain wire (Figure 6.05).

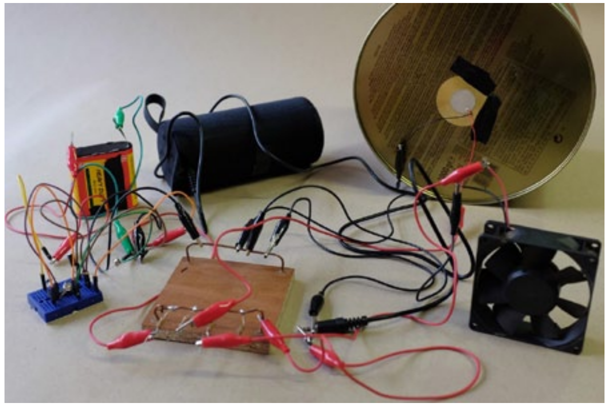


Figure 6.05. Mixer connected to many instruments.

KNOWING AND UNDERSTANDING

Concert

Our aim is to explore ways of playing together and combining our sounds by making musical pieces. To achieve this we can:

I. Improvise by agreeing on some limitations and rules
II. Make a sonic narrative / story
III. Make simple graphic scores

I. Improvisation

Improvisation is a spontaneous way of making art without trying everything out in advance. It can happen in all artforms: music, dance, theatre, visual arts. It may be completely free, without any prior commitments, but usually we put down certain rules and limitations that help us coordinate and have a more interesting result. For instance, there may be a time limit (e.g. we all play together for a minute, then stop suddenly and only two of us play for another minute) or a desired result in terms of mood (e.g. we play angry or sad music). When improvisation adheres to limitations of this type, it is called structured improvisation, i.e. it has a predefined form and requires particular ways of playing from the participants. Below are a few examples of playing with simple rules of this type, for improvisation in small or bigger groups. All of the little sound games below are better thought of as departure points for exploration, rather than as complete works. We encourage classes to modify some of these ideas at will, and to customize them and adapt them to their own needs.

In all of the exercises below, it is very important for everyone involved to listen carefully to the sounds produced by their co-players, the sounds produced by themselves, and the ways these sounds blend with each other.

PLAYING

1. The circle

For small group of 3-5 people / Duration: 5-10 minutes per group

After placing the bench desks in a circle or U shape, we prepare the instrument we want to play, and each one of us selects only one sound to play with their instrument. The first child from left begins playing by making his/her sound. We count to 4, then the second child starts. As soon as the second child starts, the first one stops. We count to 4, then the third child begins and the second one stops. We continue rotating this way, until the sounds have gone through the circle three times (three complete cycles).

We then start the circle again, but each child who plays does not stop when the next ones start. In other words, the first child from left begins playing by making a sound (if it is percussive / sharp, (s)he repeats it, if it is sustained it lets it take its time). After 4 seconds, the second child starts and the two sounds keep sounding together. After 4 seconds the third child starts and the three sounds keep sounding together, then the fourth enters and all four sound together, and so on, until everyone in the group is playing together. When that point is reached, the first child who started the circle counts to 4 and stops. Then the second child counts to 4 and stops and so on, until everyone has stopped.

2. Question & Answer

For small group of 3-5 people / Duration: 5-10 minutes per group

We split into groups (3-5 people per group) and sit in circle (or put our desks in U shape). We choose the instruments we will play with and prepare them. In this improvisation, the aim is to play small musical phrases in dialogue, like a question and answer.

Someone starts first by playing a short musical phrase (a fast rhythm, a small melody, or even a single sound). The second child tries to imitate what the first child played, then the third child follows etc. After everyone has played, the first child starts again, this time with another, different and slightly more complex sound.

Various additional parameters can be introduced in this exercise. For instance, we can agree from the start that we will accelerate as we go along, or that we will split in pairs of participants who “question” and “answer” (e.g. the first child responds to the second child, and the third responds to the fourth).

3. The conductor

For small group of 3-5 people / Duration: 5-10 minutes per group

We split into smaller groups; every child chooses the instrument (s)he will use and prepares it. The teacher takes on the role of the conductor first. In collaboration with the teacher, the whole class agrees what the conductor’s gestures will mean. For instance, when the conductor points at a child, it starts playing. When the conductor signals at them with a sharp motion, it stops. The rhythm and speed of the conductor’s hand gestures designate the tempo for each performer (s)he points at. The higher the conductor’s arms, the louder each performer plays – and the opposite. Once we have agreed on these simple instructions – or any other instructions we might choose – we can all play, following the conductor’s signals. The conductor decides how our piece will develop. Once the teacher has done this 1-2 times, the conductor’s role is taken up by one of the children. Ideally, this role can be rotated so that all the children in the room get to be a conductor.

4. The conductor II

For the whole class / Duration: 10-15 minutes

Each child chooses the instrument (s)he will play and prepares it. It is best to allow some time for children to think about what sounds they want to make and how they will achieve those sounds with their instruments. To begin with, a simple repetitive sound is enough. The conductor’s role in this exercise is mostly to control which children will play their sound, by using his/her hands. The conductor uses his/her palms as brackets. Whoever is mentally “inside” the brackets at any given time, produces sounds with the instrument he/she has chosen; those who are outside the brackets are in a state of pause. The conductor can therefore select a solo instrument, a number of instruments, or even all of them together, while controlling the sounds and volume each time.

5. The forest

For large group, perhaps the whole class / Duration: 5-10 minutes

In this game we are all together, trying to make a sonic environment that resembles the sounds of a forest. We can use all of our instruments. The more variety we have in terms of sounds, the better. We choose which instrument each one of us will play, we prepare it, and we are ready to play. We all keep quiet for a little bit, while listening to the sounds of the room we are in. As we keep quiet, we think about the small sounds we would hear in a forest: insects buzzing; birds; animals from afar; the wind between the branches; the rustling of leaves. To imagine this more vividly, we can also close our eyes for a little while.

After about a minute of silence, the teacher signals us to start and we begin making sounds very sparsely – small, quiet sounds with long gaps in between. We try to keep our playing sparse for about 1-2 minutes. We then gradually start making things more dense, and our sounds become more and more continuous and repetitive. We imagine this like the awakening of forest creatures, who wake up slowly, one after the other and start their day. We continue until all sounds are audible, with all the different whistles, creaks, beats etc. blending together.

We stay there, inside the forest noise, for another 1-2 minutes.

When the teacher signals us, we start spreading our sounds out again. The day is ending and the forest is getting tired. The sounds are getting sparser, the animals and insects are going to sleep, and all the instruments and sounds gradually come to a complete silence. We take a breath, keeping absolutely quite all together, and our forest excursion is completed.

This exercise can be repeated many times. After the first time, there is no need for the teacher to participate. The children, on their own, can have the compositional structure in mind, and decide when to pass from one section to the next one.

We need to be careful to keep the volumes relatively balanced, so that the louder instruments do not overpower the quieter sounds.

We may also record our playing, then listen to it all together and discuss it. Did we follow the instructions? Would we like to change anything in the way the improvisation developed? What kinds of sounds do we like more?

II. Sound Story

Another way of organizing the piece we will make is to think of it as a sonic narrative, a little story that we craft using sounds.

All the stories we read in books and watch in films and series have a certain form, with a beginning, middle and ending. This is the kind of form that our sound story will take.

The beginning and the ending should be pre-decided and agreed collectively. The first thing to consider is how we will start. We need to agree if we will all start together, or if some participants will start first, and who these participants will be. We then need to consider if we will all stop together at once, or if we want to stop gradually, one by one, with the last player closing off the piece. We may also want to end our piece through a slow fade out.

Afterwards, we can think about the middle section of the piece, and we want to happen there. For example, we may decide together if we want to include rests at certain points; or whether we want to have certain parts that are more sparse or more dense, faster or slower. Moreover, for every change we decide on, we also need to consider how we will coordinate to make this happen. One way is to decide that a specific player will give a signal for the change.

Generally, it is better to avoid playing together all the time. As we decide on the structure of our sonic narrative, we may also decide who will play and when. We may also decide if some players will have a particular role, e.g. if some participants will be responsible for keeping the rhythm, whereas others may make melodies or construct an atmosphere.

Along these lines, we can think of an idea of our own, and agree to play "on" this idea. For instance, I play the music that would accompany me on my way to school, or during the break. I play the sounds that would accompany a car race. I play the music made by waves at sea etc.

For example, we could play a piece entitled "Walking and running". In this piece, we would try to follow the pace of a person who walks slowly at first, then runs, then gradually slows down and stops. In other words, this would be a piece that starts slowly, continues in a fast tempo, then slows down again.

III. Graphic Score

Another way to organize our sounds is to make scores with simple shapes, lines and colours. Again, since we are not using conventional notation (i.e. notes on staves), we have to agree about what each one of these symbols corresponds to. Lines (straight and curved) are great for this exercise, as they can easily denote sounds that rise or fall in terms of pitch, sounds that get louder or softer in terms of volume etc.

The children can therefore make their own drawings, individually or in group, with an aim of using them as score. They will also agree on how they will perform them, deciding what each shape, colour, and position on the page will mean.

Figure 6.06. Examples from children's drawings from an Arts class. These can be used as scores in various ways during the workshop, either individually or in combination. (6th Grade Primary School pupils, 3rd Primary School of Galatsi, February 2020).

Beyond that, however, we can easily use as scores any images that bring sounds to mind. Such images can be a departure point and an inspiration for a free form performance, in an attempt to visually accompany the image we see. Here, we do not need to delimit what we are about to do with strict rules. It suffices to have a good discussion on what sounds an image conjures. Then, we can just play.

Figure 6.07. Other examples of children's drawings from the Arts class, which can be used as scores following the free form paradigm described above (6th Grade Primary School pupils, 3rd Primary School of Galatsi, February 2020).

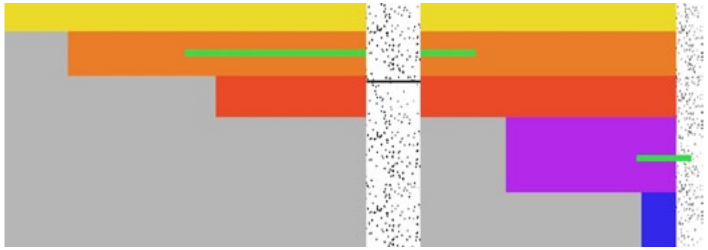


Figure 6.08. Example of graphic score.

In the ensuing video we hear the performance of a musical piece based on the score above (variation of colours on screen), by the 6th Grade pupils of the 5th Primary School of Irakleion, Attica (April 2019).

COMMENTS

The improvisation exercises suggested here may be used as material for a presentation-concert in school at the end of the year or at any other time. Moreover, they can be recorded as a mini-album and become a departure point for new music ensembles or bands. The sonic compositions with improvised instruments could also accompany a theatre play as a kind of narrative, or enrich a school event or showcase with "special sound effects". Another idea is to create a complete performance using sound, movement, texts and theatrical action, in collaboration with teachers from other subjects. The teaching and learning materials for "DIY-Making our own instruments" could be adapted to suit children's and educators' interest and become a springboard for exploration, collaboration and creativity in school. We hope this will be an entertaining and revealing activity for pupils and teachers alike!

Below are a few examples of exercises and improvisations, like the ones mentioned above, from primary school classes in Athens, during the school years 2018-19 and 2019-20.

1. Improvisation in groups:
Sound file from 4th Primary School of Galatsi, 2020.

2. Improvisation with the whole class:
Sound file from 8th Primary School of Dafni.

3. Playing with a "conductor":
Video from 21st Primary School of Athens "Lela Karagianni", 2019.

4. Improvisation in groups:
Video from 1st Primary School of Psychiko.

COMMENTS

We would like to share here a few observations made while realising this program; we hope these will be of use to teachers who are about to make their own realisations.

First, we would like to highlight the teacher's important role as a coordinator and animator, especially when children are reluctant to try out some of the suggested experiments and improvisations. It is good to make frequent statements emphasizing the importance of trying things out and playing, rather than aiming at a perfect result; this will help encourage children to participate actively, and boost their self-confidence. It is also important to allow ample time for improvisation each time – both for each child to experiment and try out new sound objects and musical instruments, and for the whole class to spend time together performing organized games, either in smaller groups or all together. By dedicating time to these activities, children become familiar with the instruments, find their own way of playing them, acquire preferences, form ideas, collaborate, enjoy themselves and develop relationships. It is also crucial to highlight the degrees of freedom they may have. Experimental music examples play an important role in opening up any potentially narrow mindsets and preconceptions children may have about music.

The smaller sub-groups in which children collaborate for a given task should ideally consist of three to four members, who can choose a conductor – coordinator among them. The members of this group / band can take turns with this role, although some children tend to take on such tasks more responsibly and can ensure that the group runs smoothly. The groups may be formed on the basis of children's preferences, through a draw, or through teacher selection, depending on the educational aims and overall composition of the group. It is best if these sub-groups do not change during the course of the workshop, so as to allow relationships to develop, and help each band become "tighter" in their playing.

All the constructions and circuits should ideally be tried out and tested by the teacher before being assembled in class. It is also important to have checked the materials for any faulty components prior to the workshop. It is advised to let children know that electronic components are sensitive and require careful handling, but also that faulty or broken components are quite common and can be easily repaired. As it is possible that something might not work as expected, we suggest acquiring a greater number of materials and components than the ones needed for each construction – their cost is actually quite small.

It will also be useful to repeat terms and concepts learned from previous sections at the start of each new section. One group could be in charge of this recap activity for each new meeting, so as to refresh everyone's memory and bring important concepts to mind for the continuation of the workshop. A few minutes of discussion and recap at each meeting are very valuable as an introductory activity, and also help with concentration. This activity can be structured as a set of questions; it can be a quiz, or take any other form that the group comes up with.

To save time and space, but also to foster a sense of autonomy and responsibility, it is important to ask children to tidy up and store the tools and materials. At the end of each meeting, all members of the group gather and store the materials for next time.

The sections contain a rich body of theory, suggestions for discussion, recommended activities and exercises. Depending on their available time and workflow of each class, the teacher can decide to change the order, minimize or increase the timeframe for a particular activity, omit certain activities in order to focus on other ones that feel more fitting for his/her particular class, and/or return to these activities later. It is important to follow the group's internal learning flow and keep a consistent structure for the class, depending on what the teacher deems more appropriate for each occasion.

For the examples in the listening activities, we noticed that children concentrate and focus more when we ask them to close their eyes. With eyes closed, listening becomes predominant as there are no visual cues to distract our attention, and imagination is activated. A kind of pause is elicited this way, allowing children to calm down and rest. It is also best if every sound or video example is followed by a discussion. Below are some indicative questions for initiating a discussion after listening to or watching an example:

- Did the children recognize some sounds or some instruments, materials or objects?
- Did the sounds create images or bring up memories from experiences, images, landscapes or stories?
- Did the sounds conjure any kind of emotion?
- Are there any similarities between what they heard and any sounds of their own, i.e. sounds made in the workshop with the improvised musical instruments?

Some examples may be played / heard more than once, as the workshop develops, so as to allow children to listen differently, with the added experience accumulated through the activities carried out in the meantime.

It is useful to record the groups' experimentations and play / listen to them in future meetings, so that children are encouraged to listen to their improvisations as an audience, and perceive positive features or elements that might require a different approach if played again.

For the documentation and presentation of the workshop, we suggest creating a website, where examples relating to each class can be uploaded, along with photographs or recordings from each workshop meeting, so that children can refer to those whenever necessary. The ability to visit this online repository

at any time will help them consolidate what they are doing, remember or repeat any activities if they want to, solve any problems / address any questions, but also show their work to friends and family.

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IMAGE AND VIDEO CREDITS

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Figure 1.06
https://www.youtube.com/watch?v=T9QwiBFN9gI

Figure 1.07
https://www.simplifyingtheory.com/timbre/timbre-of-the-instruments-2/

Figure 1.08
https://www.atas.gr/product.php?products_id=5283

Figure 2.09
https://coolweb.gr/leitourgia-mikrofonou/

Figure 2.13
Life - Science Library – Sound and Listening (Greek Edition), Time inc. 1976

Figure 3.02.1 *https://el.wikipedia.org/wiki/%CE%91%CF%81%CF%87%CE%B5%CE%AF%CE%BF:Wooden_hourglass_3.jpg*

Figure 3.02.2 *https://el.wikipedia.org/wiki/%CE%91%CF%81%CF%87%CE%B5%CE%AF%CE%BF:Greenwich_clock_1-manipulated.jpg*

Figure 3.02.3
https://en.wikipedia.org/wiki/Metronome#/media/File:Metronome_Nikko.jpg

Figure 3.04
https://upload.wikimedia.org/wikipedia/commons/6/61/PortoCovoJan07-4.jpg

Figure 4.04
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Figure 5.02
https://en.wikipedia.org/wiki/Breadboard#/media/File:Wooden_Breadboard_Circuits.jpg

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AUTHORS

Aris Droukopoulos, Audio technician, loudspeaker and electronic audio equipment designer
Thalia Ioannidou, Musician, sound artist
Yannis Kotsonis, Musician, sound artist
Gelina Palla, Musician, sound & visual artist, educator

Translated from Greek by Danae Stefanou (Associate Professor in Musicology, Aristotle University).

PUBLICATION COORDINATION & CURATION

Myrto Lavda, Head of Educational Programs, Onassis Stegi

PRODUCTION & CONTENT COORDINATION

Eleanna Semitelou, Educational Programs Assistant, Onassis Stegi
Leonidas Panagopoulos, Educational Programs Assistant, Onassis Stegi
Veroniki Petmeza, Networks & Strategic Partnerships Assistant, Onassis Stegi

INTERFACES NETWORK COORDINATION

Christos Carras, Executive Director & Music Program Curator, Onassis Stegi
Dora Vougiouka, Networks & Strategic Partnerships Coordinator, Onassis Stegi

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