C3 Sense of hearing

Subexperiment C3.1 Parade of ears
Subexperiment C3.2 Directional hearing
Subexperiment C3.3 Making loud noises quiet

1 Main question

The following questions underlie the subexperiments and guide the activities:

- How does hearing work and what happens in our head? (functionality)
- How can you distinguish loud and quiet sounds and the direction? (self-awareness)
- How can I keep my sense of hearing healthy? (care/prevention)

2 Background

2.1 Relevance to the curriculum

We are constantly surrounded by background noise. We often no longer consciously perceive car horns, voices, or the clattering of dishes in the kitchen. Hearing is an important sense for humans, and examining it allows us to acquire our first conscious experiences with the topic of sound (for example, how sound is generated, propagated, and perceived). The promotion of health – meaning how we treat our own bodies – can also be addressed based on the example of our sense of hearing. As we become aware of the sounds, harmonics, and noises surrounding us and explore the human sense of hearing, we quickly come to the anatomy of the ear. The topics of music and speech can also be linked with the sense of hearing.

Topics and terms

Attenuation, bundling of sound, directional hearing, hearing loss, noise, pinna, sense of hearing, sound, sound conduction, sound transmission, source of sound

2.2 Skills

The students will ...

- develop a better understanding of the function of the anatomical parts of the ear (primarily the pinna).
- become aware through experience of how important the sense of hearing is.
- grapple with the verbal descriptions of sensory impressions (for example, loud, soft, high, low, bright).
- be knowledgeable about the dangers of loud sounds or too much noise, and they can take initial preventive measures.
- develop technical strategies for protecting their ears from loud sounds or noises.

3 Additional information on the experiment

You will find additional media for preparing or for further study of this experiment on the Siemens Stiftung Media Portal: https://medienportal.siemens-stiftung.org

4 Conducting the experiment

Note: The listed materials are designed to allow **one** group of maximum **five** students to conduct the experiment.

4.1 Subexperiment C3.1 Parade of ears

4.1.1 Required materials

Material	Quantity
Pen	2
Packing tape	1
Scarf (as blindfold)	1
Sound source* (smartphone, musical instrument, tuning fork, etc.)	1
Tape measure	1
Twine (at least 10 m)	1 roll

* It should be possible to adjust the volume.

4.1.2 Organizational aspects

Facilities	In the classroom or outdoors A distance of approx. 10 m is required between the team partners.
Time required	Approx. 25 min (conducting and evaluating)
Experimental variations	▪ Instead of using the twine to mark the distance, the students can use a tape measure or a line in the sand or a chalk mark on the floor. ▪ Instead of measuring with their feet and converting, they can use a tape measure. ▪ If the classroom is not long enough, the experiment location can be moved to a quiet hallway in the school building.

4.1.3 Explaining the subexperiment in the teaching context

The students will learn how the shape and size of ears influence hearing.

Technical background

The ear is an organ of hearing and of balance at the same time. As a hearing organ, it collects sound waves as stimuli, and as a balance organ, it registers body movements as well as the body position and rotations (usually) relative to gravity. The information from the two organs is transferred to the brain via the eighth cranial nerve. The ear can be divided into three sections: the outer ear, the middle ear, and the inner ear. The ear canal, middle ear, and inner ear are surrounded by protective, bony structures. Although this is not the structures' actual function, they can also conduct sound.

The outer ear includes the pinna and outer ear canal. The pinna works like a sound-receiving funnel, channeling the sound waves into the outer ear canal, which leads to the eardrum. The length of the ear canal results in sound amplification due to resonance in the frequency range between approx. 2,000 and 4,000 Hz, thus the most important range for human speech.

The eardrum is a thin membrane resembling connective tissue that forms the border between the outer and middle ears.
The pinna's mobility is controlled by the ear musculature. In people, however, this mobility is greatly reduced.

4.1.4 Ask about the students' prior knowledge and ideas

The students may perceive their pinnas as "useless appendages" that must constantly be cleaned and do not perform a function for them (except that you can hang earrings on them). Many students have perhaps already observed that some people can "wiggle their ears."

4.1.5 The research cycle

Important aspects and information regarding the individual process steps of the research cycle during the experiment for students:

Recognizing the problem/phenomenon 	In this experiment, the students will learn the significance of ears' shape and size for hearing.
The research question 	The following alternatives to the research question stated in the student instructions are possible: ▪ How do sounds change when you cup your hands behind your ears? ▪ Why can dogs prick their ears but people cannot?
Collecting ideas and guesses 	Some possible guesses: **Related to the research question:** ▪ "Protective function against dirt" ▪ "Redirection of sound" ▪ "Amplification of sound" ▪ "Directional hearing" **Related to the experiment:** ▪ "No matter how you approach your partner, the distance always remains the same." ▪ "The pinna has no effect on how quickly you can hear the clock." Segue from the guesses to the experiment.

Experimenting 	**Experiment setup:** ▪ The measurement results may vary depending on the type of sound source. In this case, before the experiment is conducted the sound source must be tried out with the students to determine the distance at which the sounds are no longer audible under various conditions. ▪ Important: Children can often hear much quieter sounds than adults. **Conducting the experiment:** ▪ The experiment is structured to be conducted in several parts. The students may need assistance in implementing the structure (changing the position of the pinnas or moving around relative to the sound source). ▪ Instead of using tape to mark the floor, the students can also use objects such as shoes, sticky notes, or stones. ▪ The distance measurement by counting footsteps (always measured by one and the same child) and the conversion into centimeters encourages the students to work with lengths and variables. The tape measure can be used to check the calculated distance.
Observing and documenting 	The students will systematically record their observations here. As soon as the students can hear the sounds and give an indication, the distance can be measured. **Most important observations:** The sounds are perceived better when the pinnas are bent forward using the pens or the pinnas are made larger by cupping hands behind the ears.
Analyzing and reflecting 	**Technical explanation:** ▪ Sound waves that impinge upon the pinnas are broken on the pinnas' recesses and folds. ▪ Each sound frequency is attenuated to a varying extent and passed along to the hair cells in the inner ear. ▪ The brain can pinpoint the geographical origin of the sound based on how the sound is broken and attenuated at the edges of the pinnas. ▪ In this way, it is possible to determine whether the sound is coming from in front, from behind, from above, or from below.

	Reference to the story to get the students thinking about the topic: Dog ears are shaped differently from human ears. With their ears, dogs can hear much better to be able to identify potential attackers earlier. This is necessary for their survival in the wild. **Transfer:** “We have to turn our bodies or move our ears using our hands to be able to hear from different directions.” “This is different for animals.” “Our ears have muscles that are totally underdeveloped.” “We will more likely see a potential attacker than if we had to rely on laboriously locating him with our ears.”

4.1.6 Further information

In the student instructions

Doing further research 	Another experimental variation could be for the students to build an ear trumpet (funnel and tubing) for one side and repeat the experiment.

Miscellaneous

- The experiment can also be conducted with the entire class as one group by placing the clock on the teacher’s desk and asking the students about hearing differences depending on the position of their pinnas.
- The class could look at the animal pictures (or pictures of animal ears) together and discuss the apparent advantages of different ears and pinnas.

4.1.7 Reference to values

What is your opinion? 	In the discussion about values for this experiment, the teacher can provide a prompt or tell a story in which a problem is posed. Both actions lead to a discussion based on reflections. What’s important is that the reference to values can be established in the experiment. The discussion can focus either on learning-process-related values (for example, working reliably in groups) or on object-related values (for example, handling paper as a resource). The student instructions for **C3.1 Parade of ears** address object-related values. **Object-related dilemma:** An object-related dilemma can be integrated in the discussion of the values “openness” and “acceptance of responsibility” at the end of the student instructions. The students should express their opinions about it.

Dilemma regarding music: You are visiting a friend. You've made yourselves comfortable in his/her room and are listening to music. Suddenly your friend says, "Oh, it's boring when it's so quiet!" He/she turns the music up to full volume and starts dancing. This really hurts your ears, but you don't want to be boring.
Think about it: What would you do?

Possible statements by the students for and against loud music:

Reasons for loud music	Reasons against loud music
▪ You want to have fun. ▪ You don't want to be thought of as a boring person.	▪ It hurts the ears. ▪ It isn't good for the ears because the sense of hearing can become damaged.

Objective:

The students should reflect upon how they can handle the situation openly while being responsible with their health at the same time. The values of openness and acceptance of responsibility are addressed.

Alternatives:

Statements or questions as prompts related to the story told in the student instructions are also suitable for encouraging discussion.
The values remain the same.

- **Image for discussion:**

- **Question for discussion:** What situations are you familiar with in your everyday life when it is too loud for you?

Notes:

The students should reflect on values and express their opinions.
It may turn out that several values are addressed.

4.2 Subexperiment C3.2 Directional hearing

4.2.1 Required materials

Material	Quantity
Funnel, large	2
Packing tape	1
Pencil	1
Ruler, 30 cm long	2
Tubing, thick	1

4.2.2 Organizational aspects

Facilities	At a simple table in the classroom
Time required	Approx. 25 min (conducting and evaluating)
Experimental variations	Alternatively, one ear can be covered with a scarf or similar item before the funnel is pressed on it.
Safety instructions	With all ideas for implementing the experiment, make sure that the students tap only lightly on the tubing to prevent unpleasant volumes.

4.2.3 Explaining the subexperiment in the teaching context

The students will focus on directional hearing.

Technical background

By identifying the location of a sound source, people are capable of reacting appropriately to sounds. The acoustic perception of a sound source and localization of the sound in space is called **spatial hearing**. On the one hand, it depends on the binaural difference of the sound intensity, but especially on the binaural difference of the sound propagation time: The spatial position of a sound source is determined by the differences in sound propagation time. This means the different amounts of time the two sound paths need to reach both ears.
If the sound comes from the right, for example, it will reach the right ear first and the left ear a little later. There is no time difference if the sound source is located in the center in front of or behind the head because the sound paths are the same length. The nerve fibers of the eighth cranial nerve transfer the information from both ears to the central nervous system (CNS). The information from both ears is balanced there and thus the position and direction of a sound source are derived extremely accurately. **Differences of only 5 – 10 mm from the center of the head** are recognized, which corresponds to a sound propagation time difference of about 0.00003 s.

4.2.4 Ask about the students' prior knowledge and ideas

Sound propagation is difficult for the elementary school children to imagine. For this reason, the students associate their ideas about sound with past experiences. Viewed in terms of physics, sound is an alternating compression and expansion of the transmission medium, for example, air. This process is triggered by the oscillation of a sound generator, which pushes the surrounding air molecules of the transmission medium, and they in turn push the adjacent air molecules. Imagine this figuratively as the bellows of an accordion, which is expanded and compressed evenly.
The students know of the phenomenon of directional hearing from their everyday life, for example, finding their bearings in the dark or when visibility is poor. In these cases, their hearing takes over the early warning function, for example, for dangers in traffic.

4.2.5 The research cycle

Important aspects and information regarding the individual process steps of the research cycle during the experiment for students:

Recognizing the problem/phenomenon 	In this experiment, the students will be made aware how hearing can be affected by the different directions from which sound comes.
The research question 	The following alternatives to the research question stated in the student instructions are possible: ▪ How can we tell whether a sound is coming from the left or right? ▪ Why do we have two ears? ▪ When you're tracking a sound, do you turn away from it or toward it?
Collecting ideas and guesses 	Some possible guesses: **Related to the research question:** ▪ "We hear the direction because the respective ear is closer to the sound." ▪ "The brain has a register point for the left and one for the right." **Related to the experiment:** ▪ "You can never recognize for sure which direction the sound is coming from." ▪ "If I tap too lightly, nobody will hear the tapping." ▪ "The closer you get to the center, the harder it is to determine the direction." Segue from the guesses to the experiment.

Experimenting 	**Experiment setup:** ▪ The tubing should form a circle on the table behind the test person's head. ▪ The students will place rulers to the left and right of the center mark so they can define exact measuring points later. For this reason, they must be sure to place the rulers exactly at the zero point. **Conducting the experiment:** ▪ Here it is interesting to observe whether some students will be able to correctly identify the direction as the distance from the zero point decreases and use this information for their conclusions. ▪ The test person gives hand or finger signals to indicate the guessed direction of the tapping. ▪ The team partners then repeat the experiment after switching roles.
Observing and documenting 	Because both team partners can document their results in one table, this provides the option for the second partner to use the measuring points of the first partner in a different, random order. **Most important observation:** The students will recognize that it is clearly possible to distinguish between signals coming from the left and from the right.
Analyzing and reflecting 	**Results to be expected:** The farther the tapping is from the center, the easier it is for the students to determine the direction. Most groups should recognize this fact. **Technical explanation:** ▪ Identifying the location of a sound source is based on the different distances of the sound source from both ears. ▪ The sound reaches both ears with a time delay so that it is possible to exactly determine the direction to an accuracy of two degrees of spatial angle. ▪ Possible teacher prompt: Under clinical conditions, it is possible to differentiate the direction starting 5 – 10 mm from the center of the head. To visually illustrate this, the teacher can draw a measurement scale on the board or on the documentation sheet. This range can be marked in color. **Reference to the story to get the students thinking about the topic:** How do you protect your treasure? As soon as you hear a sound, you spray in the direction from which the sound came.

4.2.6 Further information

In the student instructions

Doing further research 	Repeat the experiment, this time with one ear covered with a scarf. Possible questions: ▪ What difference does it make whether you have one of your two ears covered or not? ▪ What could you do so that you could still identify the direction of the sound source?

Miscellaneous

Conduct the experiment with the entire class as one group (without the tubing). Have all students close their eyes. See who can identify the direction from which a hidden sound is coming. In a second round, the students should block one ear.
Does this change anything in directional hearing?

4.3 Subexperiment C3.3 Making loud noises quiet

4.3.1 Required materials

Material	Quantity
Cotton pads	2 (per student)
Reading text (four to five sentences with six to seven words each, for example, “Emma takes the kangaroo for a walk” or “An elephant is sitting in the tree”)	1
Thick wool cap	1

4.3.2 Organizational aspects

Facilities	In the classroom or outdoors
Time required	Approx. 25 min (conducting and evaluating)
Experimental variations	▪ Headphones can be used in place of the students’ own hands to cover their ears. ▪ Instead of a reading text, a sound recording can be provided, for example, an MP3 file.
Cleanup	The used cotton must be disposed of after the experiment.

4.3.3 Explaining the subexperiment in the teaching context

The students will listen to sentences read out loud. They will use various means to simulate hearing loss and, in this way, learn how it feels when someone can no longer hear properly. They will thus recognize that hearing is worth protecting.

Technical background

There are various causes and types of hearing loss. This subexperiment focuses particularly on sensitizing the students to limited hearing. In this context, noise-induced hearing loss is mentioned because people can protect themselves well from this by taking preventive measures. If people are exposed to loud noise for an extended time, this can result in acoustic trauma (hearing impairment). People who are exposed to sounds of greater than 90 dB are particularly at risk. The noise causes damage because large shock waves pass through the inner ear and destroy the sensory cells. The damage caused by noise manifests itself at first through reduced ability to hear high tones. If the damage caused by noise continues to worsen, it can result in inner ear hearing loss. A brief, very high noise exposure (explosion or gunshot) can also lead to hearing loss.

4.3.4 Ask about the students’ prior knowledge and ideas

The students can state their own associations with the topic, for example, their hearing impressions when they had an ear infection or interaction with grandparents with hearing impairment due to age.

4.3.5 The research cycle

Important aspects and information regarding the individual process steps of the research cycle during the experiment for students:

Recognizing the problem/phenomenon 	In this experiment, the students will become familiar with the condition of hearing loss:
The research question 	The following alternatives to the research question stated in the student instructions are possible: ▪ What are causes of hearing loss? ▪ What happens in the ear when hearing is damaged? ▪ How can you protect your ears against hearing loss?
Collecting ideas and guesses 	Some possible guesses: **Related to the research question:** ▪ “We don’t hear as well.” ▪ “We hear some things, but don’t hear other things.” **Related to the experiment:** ▪ “The listener will understand everything exactly as read aloud.” ▪ “If someone hears poorly, he or she often doesn’t correctly understand what is said.” Segue from the guesses to the experiment.
Experimenting 	**Experiment setup:** Make sure that the level of the reading text is appropriate for the students’ age. The sentences should be six to seven words long. **Conducting the experiment:** The experiment is structured to be conducted in several parts. The students may need assistance in setting up the experiment.
Observing and documenting 	**Most important observations:** ▪ How well the students understand the sentences will change from step to step during the experiment. ▪ With each step, the speech will become increasingly indistinct and be perceived as an unclear jumble of words that can no longer be understood. ▪ For the reader, it will become increasing difficult with each step to write down the sentence the test person repeats.

Analyzing and reflecting 	**Results to be expected:** ▪ This experiment provides only a rough idea of hearing loss. Volume is increasingly removed from the hearing impression. ▪ With actual hearing loss, however, the heard sounds are also distorted because certain frequencies cannot be perceived. **Transfer:** People with hearing loss can be assisted through technical devices such as hearing aids or cochlea implants. **Reference to the story to get the students thinking about the topic:** Now you have learned how important hearing is for you and how unpleasant it is to hear nothing. Therefore, in the future you will carefully consider whether you want to go to overly loud events and how you can protect your hearing if you do go.

4.3.6 Further information

In the student instructions

Doing further research 	Walk around the school grounds with a partner or through the city with a group: A “person with normal hearing” escorts a “person with hearing loss” (with cap, headphones, or cotton pads on the ears). What do you hear? First the test person answers, then the escort. The students will comment on a lot of sounds that the one will immediately consciously perceive and the other cannot hear.