Come as You Are and Identify Your Standpoint

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Overview

In 2017, The Lancet, a medical journal, reported that hearing loss is a risk factor for dementia; and thus, interest in hearing is increasing worldwide. It is often thought that hearing loss is equated with the inability to hear low-level or high-frequency sounds; however, the root of the problem is not limited to that inability. We asked Shigeto Furukawa, a senior distinguished researcher at NTT Communication Science Laboratories, who researches the auditory mechanism based on biological responses that seem unrelated to hearing (such as the pupil) and analyzes information about how sounds are heard subjectively, about his latest research activities and the role of researchers.

Keywords: hearing, auditory mechanism, brain stem

Understanding hearing from biological responses

—Tell us about your current research.

Although my research area has been written as "elucidation of the neural mechanism of sensory perception," I am now mainly studying the auditory mechanism (**Fig. 1**). Recently, I have been particularly interested in how we hear. For example, different people often hear the same sound differently, and even the same person hears the same sound differently depending on the situation. Moreover, so-called "hidden hearing loss" is a problem concerning how to hear, and it is manifested as deteriorated hearing that registers no abnormality in a hearing test.

It is often said that signals obtained from the eardrum and inner ear (lower-order processing) are recognized, understood, and interpreted in the brain (higher-order processing), especially in the cerebral cortex. However, various processes are also performed in the brainstem between the ear and cerebral cortex ("intermediate processing"). It is the brainstem that retrieves basic information, such as pitch, and selects information that reflects the degree of importance. The brainstem also plays an important role in unconscious actions such as looking back in response to a voice spoken from behind.

—The function of the brainstem is key to elucidating the auditory mechanism.

We are therefore focusing on the intermediate processing carried out in the brainstem. The auditory and brain mechanisms are often analyzed by inserting an electrode into the brain of a test animal and measuring the electrical activities in the brain. However, we cannot insert an electrode into the human brain in this manner, so we analyze the brain in an indirect way

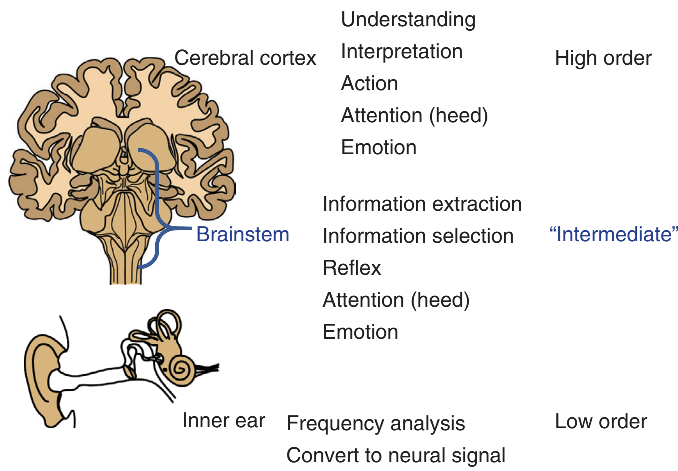

Fig. 1. Processing flow of auditory information.

using non-invasive measurement techniques, such as electroencephalograms (EEG) and eye movements, and computer modeling.

For example, an EEG of a person hearing a sound often includes the frequency components of a pattern that is similar to the sound presented (**Fig. 2**). These frequency components are thought to originate from the brainstem, so analyzing them is a means to investigate brainstem activity. Moreover, it has been shown that pupil size is linked to arousal level and attention-related neuronal-cell activity in the brainstem. On the basis of these measurements and analyses, it is possible to access the functions of the brainstem without having to pierce the brain with electrodes. Although we are still far from elucidating the auditory mechanism of the brainstem, we hope that by combining various measurement methods and modeling, we will be able to reveal—from outside the body—the mechanism of hearing that occurs naturally at an unconscious level.

—What applications can be considered in the future?

Let's consider listening to music as an example. Liking or not liking a song differs from person to person, and even if the same person listens to a song, his/her enjoyment of the song changes from time to time. By measuring the biological response of people listening to a song, it may be possible to objectively measure how each person feels at that time. Although it seems that making that possibility a reality is a long way off, I am researching the idea that we can obtain hints by elucidating the relationship between attention and hearing.

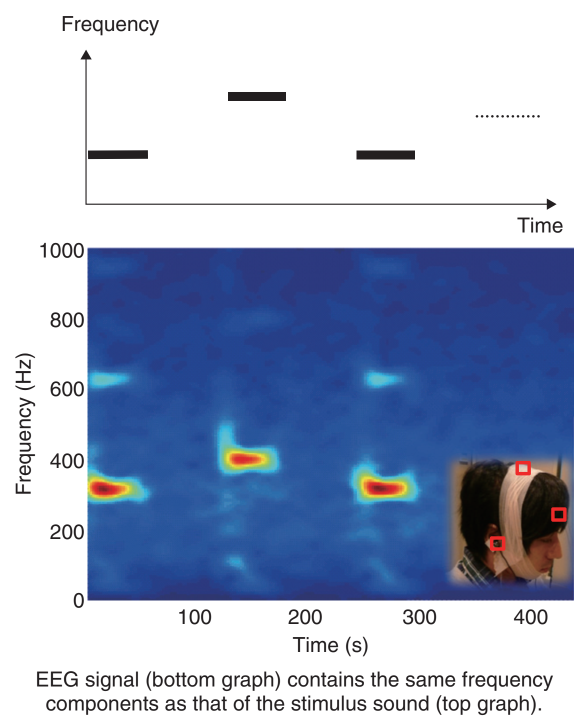

Fig. 2. Brainstem-derived EEG (frequency-following response).

Let me introduce some of the research my team is working on regarding attention. For example, I'm considering whether the sound a person is paying attention to can be determined by measuring the pupil. In fact, it has recently been reported that the pupil changes with perceived brightness as well as physical brightness. We have found that this phenomenon can also be applied to auditory attention (**Fig. 3**). In an experiment, a participant listened to a sound through headphones while looking at a screen divided in half; bright (left) and dark (right). Different sounds were emitted from the left and right speakers of the headphones. We found that when the participant was told, "Pay attention to the sound from the left speaker without moving your eyes," the size of the pupil changed according to the brightness of the screen on the side of attention (left), despite the fact that the participant did not move his/her eyes. In this example, when the left side of the screen was bright, the pupil diameter decreased. In other words, the participant's attention directed toward the sound can be detected visually from the outside as a change in pupil size. By using this phenomenon, it may be possible to determine to which speaker a person is paying attention when multiple people are in conversation.

Regardless of the intent of the individual, some attention is directed according to external stimuli. This attention is called "exogenous attention," the study of which is more challenging. If someone is asked, "What are you paying attention to?", they will become aware of their attention, and it will be impossible to measure their spontaneous attention correctly. Owing to this fundamental difficulty, exogenous attention to sound has not been extensively investigated. We believe that measuring pupil and eye movements can also be used to assess exogenous attention. Although not well organized yet, these measurements are providing new insights.

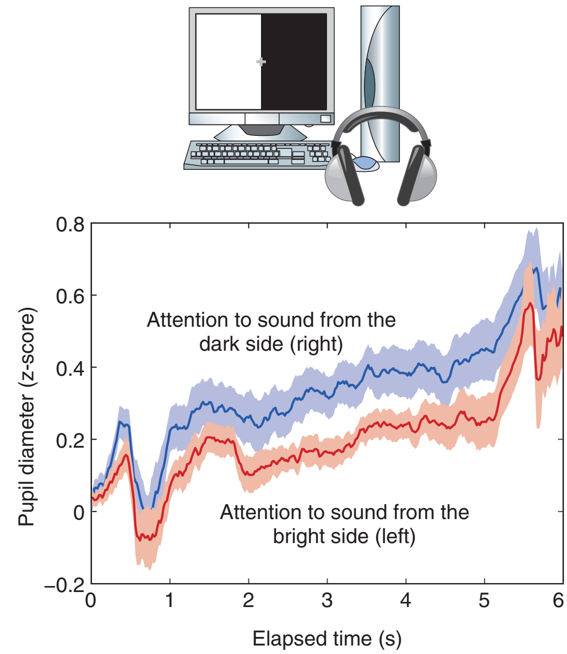

Fig. 3. Change in pupil diameter when attention is paid to a sound to one ear while looking at the center of a screen divided into light on the left and dark on the right.

Explore essential problems with an open mind because the basic research field has a high degree of freedom

—Why did you decide to become a researcher?

According to my parents, I wanted to be a doctor when I was a child, and I seemed to have longed to become a researcher since I was young. As I went through high school and university, that longing faded; however, as I watched others get office jobs at companies before graduating from university, I realized that I wanted to do something different. I think that my consciousness of becoming a researcher was greatly influenced by my supervising professor at that time. The department in which I was enrolled (sanitary and environmental engineering) is strongly focused on solving social problems; in fact, when I first enrolled, I was interested in environmental issues. However, over time, I gradually became unable to identify the social issues I wanted to address. There was a reluctance to plant the seeds of research by saying, "There is a problem" when there was no such problem, so I became fascinated by pure science. One trigger of my interest in hearing came from entering a lab studying noise at university, even though the mainstream research undertaken in the department was on sewerage, water treatment, and air pollution.

—What is the moment like when you are glad that you have studied something?

Because the human brain is complex, examining neural responses gives mixed results. Even if we make a hypothesis, it is often not possible to clearly show from experimental results whether the hypothesis is correct. However, during the trial and error used as an analysis method, even the mixed data of complex neural responses of the brain may reveal something useful depending on one's ingenuity. I feel most satisfied when I could make such revelations. What you see at that time of a revelation is something seen for the first time in the world. Even if similar research has been reported, you are the only one possessing the data that you measured on site, and you are the one who chooses the analysis method.

—What do you do to devise research and analysis methods?

It is often said that you should first set a goal, break down the challenges posed by that goal, and finally address what you need to do from then onwards. I'm not saying that process is wrong, but I'm not too concerned about following those steps. As for basic research, if you come across something interesting during one of the steps, you have to have a sense of following it up by taking a detour. Something unexpected always happens at the research lab. I think that applying one's way of thinking at such times will lead to unique research.

When I reflect back, my activities sometimes diverge too much or sometimes I am too particular about what is in front of me and being too committed to not knowing if it makes sense. Such a commitment is an important quality for a researcher to have; even so, I think it is necessary to pursue one's research while continuously questioning whether a small thing is just a small thing or whether it has importance.

The field of basic research has a high degree of freedom. However, the fact that you are responsible for deciding what to research is actually a great deal of pressure. You can either apply your expertise to academic research that focuses on details or you can aim for major easy-to-understand results that meet the expectations of top management. Although both approaches must sometimes be taken by researchers, I think that to ultimately contribute to the company, society, or learning, I must pursue things that are important.

However, some things are important regarding solving social problems, while others are essential regarding understanding the principles of the universe. Although some problems are apparent because of one's uniqueness and expertise, some of the problems faced by many people in society are vague but essential and lying dormant. Therefore, I don't think too much about the problems I need to solve and want to keep an open mind.

You can identify your standpoint only when you look back later

—Please give a word to junior researchers.

As I continue my research, there are times when I find it tough. When I was conducting physiological experiments with animals, it was physically tough, and when I was doing detailed tasks like looking at cells, I was worried that I would not be able to see the way ahead. When you reach an impasse like that, you can do something else or seek a way around it. For example, an idea may be revealed by discussing certain topics with the research community and colleagues. Even in simple discussions like chats, knowing what other people are interested in can confirm your standpoint. If you know that you are such a person without deciding what you should be, you will know the best way to live your life.

You may be able to identify your standpoint and way of life only by looking back later. Your work as a researcher will vary. In addition to writing papers, the role of a researcher includes teaching people and running organizations such as research institutes and academic societies. Even if you think that it is troublesome at the time, you may realize who you really are one day while fulfilling the roles as requested. Although it may seem that there is nothing you can control, because researchers ought to have a strong personality, your standpoint won't change so easily even though you let it be.

In interviews with young people, I tell them that people do not change much, so it is better to accept them. No matter what you do, you will have a sense of self-worth. Advice to researchers such as, "That's wrong, so go in a different direction." will not work. I tell them to concentrate on whatever is going well, and you'll eventually get some interesting results over time. I think a good approach is to consult with others and help each other while being yourself; in this way, each of us will be able to exert our abilities.

—What is the role of researchers in society?

In one sense, a researcher conducting basic research is like a monk. Monks practice their religion, but that practice does not immediately help grow vegetables and fill bellies. However, believers donate to monks because they appreciate something in that practice. Basic research (i.e., "practicing") conducted by researchers may not be immediately useful to the world. However, if something overlooked or that was vague is elucidated and made concrete by research, some people will come to consider making that research useful. Also, when confronting the world's problems, we might find clues to solving them by taking a step back and looking at them abstractly. Both the practice of monks and basic research are exactly transitions between the abstract world and the real world, and I think our responsibility lies in that transition. Some monks, such as novices, set themselves apart from the world, while other monks live in society and connect with the world. I think that researchers can also take either path. I believe that it is better for each of us to contribute to society through our research while thinking about our own path.

—Please tell us about your future prospects.

Up until now, the main target of auditory research has been the accuracy of correctly hearing information contained in sound and the mechanisms that support that process. I think that rather than the accuracy of hearing, the content and quality of perceived sounds in daily life could become part of the research. Assessing subjective hearing is not straightforward. I believe that it is necessary to investigate and understand the perception, behavior, sensory nervous system, autonomic nervous system, and their close interactions. Fortunately, devices that measure biological responses, such as eye movements, pupils, and brain activity, are rapidly evolving. As seen in the boom in artificial intelligence, machine-learning technology has made remarkable progress, and neuroscience has benefited from the analysis and modeling that it enables. I didn't talk about this technology in this interview, but I'd like to try applying such new technology to clarify the previously unknown mechanism of hearing. We have already obtained interesting results concerning this mechanism. We also want to develop technologies to evaluate and design sounds that are easy for humans to hear. While I want to achieve results that have a social impact, I also want to work on research that will be of interest to me only. That may sound selfish, but if you don't find yourself interesting, being a researcher will be boring.

Reference

[1] S. Furukawa, S. Yamagishi, H. Liao, M. Yoneya, S. Otsuka, and M. Kashino, "Biological Measures that Reflect Auditory Perception," NTT Technical Review, Vol. 13, No. 11, 2015.
https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr201511fa3.html

■ **Interviewee profile**

Shigeto Furukawa

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He received a B.E. and M.E. in environmental and sanitary engineering from Kyoto University in 1991 and 1993, and a Ph.D. in auditory perception from University of Cambridge, UK, in 1996. He conducted postdoctoral studies in the USA between 1996 and 2001. As a postdoctoral associate at Kresge Hearing Research Institute at the University of Michigan, USA, he conducted electrophysiological studies on sound localization, specifically the representation of auditory space in the auditory cortex. He joined NTT Communication Science Laboratories in 2001. Since then, he has been involved in studies on auditory-space representation in the brainstem, assessing basic hearing functions, and the salience of auditory objects or events. As the group leader of the Sensory Resonance Research Group, he is managing various projects exploring mechanisms that underlie explicit and implicit communication between individuals. He is a member of the Acoustical Society of America, the Acoustic Society of Japan, the Association for Research in Otolaryngology, the Japanese Psychonomic Society, the Japan Audiological Society, the Japan Neuroscience Society, and the Japanese Society for Artificial Intelligence.