

日本人類学会進化人類学分科会

ニュースレター

2017/7

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第39回シンポジウム

「ヒトにとってオトナになるとはどういうことか？」

日時： 2017年 6月17日（土）13:00～17:45

場所： キャンパスプラザ京都 6 階・第 8 講義室

オーガナイザー：鈴木 滋（龍谷大学）

近年の日本では少子高齢化がすすみ、成人年齢の引き下げが話題になっている。そこにはさまざまな社会的な思惑があるが、ヒトのオトナとはどういうことかについての人類学的知見は、あまり議論の対象とはされていない。霊長類一般に、ワカモノ期は性成熟からフルアダルトまでの発達段階のひとつとして認められ、進化人類学では青年期が長いことはヒトに固有の進化的特徴とされることもある。そこで、今回のシンポでは、形態・生態・生理・発達・認知などの人類学にかかわる諸分野から話題を提供していただき、ヒトの成長、発達、成熟、青年期などについて、サルとヒトとの共通点や、進化傾向などを、多面的に検討したい。

13:00 趣旨説明 鈴木滋（龍谷大学）

13:10 濱田穰（京都大学）「オトナになること：身体成長・発達・成熟から」

14:00 今村薫（名古屋学院大学）「サンの子ども期の行動と、成人儀礼」

14:50 休憩

15:00 山内太郎（北海道大学）「ヒトの成長：ライフヒストリーの進化と成長パターンの変化（仮題）」

15:50 明和政子（京都大学）「思春期に特徴的なヒトの脳発達と社会的認知」

16:30 休憩

16:40 コメント 1：國松豊（龍谷大学）

16:55 コメント 2：田島知之（京都大学）

17:15 総合討論

17:45 終了

第 38 回シンポジウム (SPIRITS Program Workshop との共催)

“Biology and Evolution of Speech”

2017 年 2 月 23 日 京都大学・理学セミナーハウス

Science Seminar House, Kyoto University, Kyoto, 23 February, 2017

趣旨

ヒトの話しことばは、異なる音を、一息の中で、すばやく連続的に変化させながら発する点で、他の哺乳類に類を見ない。その進化プロセスを知るためには、進化の隣人であるサル類の音声の仕組みを明らかにし、何がヒトと同じで、何が異なるのかを知る必要があります。2015 年度に、京都大学 SPIRITS プログラムより支援を受けて、京都大学(代表者:西村剛)とオーストリア・ウィーン大学(代表者: Tecumseh W. Fitch)との国際共同研究がスタートしました。国内外の最先端の技術を有するメンバーが、それぞれの特長を融合させて、これまでの技術的限界を克服し、新たなアプローチで、音声生成のステップごとに、ヒトでの観測分析と比肩できる高度なデータを生み出す試みです。この 2 年間で、日本とオーストリアの研究者の相互交流と共同研究を実施し、サル類の音声生理の理解を深め、ヒトとの共通点と相違点をいくつも明らかにすることができました。2016 年には、隔年で開催されている言語進化に関する国際会議 (EVOLANG2016、米・ニューオリンズ)で The Evolution of Speech というワークショップを開催し、このプロジェクトの中間成果の取りまとめと今後の展望を議論しました。今回のワークショップは、このプロジェクトの最終報告と今後の新たな共同研究の開拓を目的としています。サル類の音声生理とその制御機構に関する成果を取りまとめるとともに、ヒトを対象とした先端的な音声生理学研究を推進している研究者を招待し、今後の”生物音声生理学”(Biological Voice Physiology) の新たな展開を探ります。

PROGRAM

- 10:10-10:40 Voice physiology and its flexibility in macaques
Takeshi Nishimura (Kyoto University, Japan)
- 10:40-11:10 Is volitional control of macaque vocalizations really homologous with those of human speech?
Hiroki Koda (Kyoto University, Japan)
- 11:10-11:40 Preliminary acoustic analysis of the external nose
Hironori Takemoto (Chiba Institute of Technology, Japan)
- 13:00-13:30 Electroglottographic investigation of primate vocalization
Christian T. Herbst (University of Vienna, Austria)
- 13:30-14:00 Novel insight into the comparative study of primate vocal production through excised larynx experiments
Maxime Garcia (Univ. Lyon /Saint-Etienne, France)
- 14:00-14:30 Opening the black box: Comparative studies of vocal production mechanisms in primates
Jacob C. Dunn (University of Cambridge/Anglia Ruskin University, UK)
- 15:00-15:30 Role of reactive oxygen species and anti-oxidant on voice
Shigeru Hirano (Kyoto Prefectural University of Medicine, Japan)
- 15:30-16:00 Brainstem neuronal mechanisms for the periaqueductal gray-induced vocalization in guinea pigs
Yoichiro Sugiyama (Kyoto Prefectural University of Medicine, Japan)
- 16:00-16:30 Nonlinear dynamics of animal vocalization
Isao Tokuda (Ritsumeikan University, Japan)
- 16:30-17:00 Visualization and characterization of vocal fold dynamics
Ken-ichi Sakakibara (Health Sciences University of Hokkaido, Japan)

The evolutionary process of the speech has been challenged by little knowledge of voice anatomy and physiology in non-human primates. The comparative approaches of the supralaryngeal vocal tract (SVT) provide evidence of the primate origins of two-tube configuration of human SVT. The developmental descent of the larynx is also found in chimpanzees and in part in macaques [1,2,3]. Varied call repertoire of non-human primates has been described based on acoustic evidence. The physiological mechanisms of animal vocalization are often examined by the acoustics of ‘helium voices’. Our analyses of helium voices in gibbons, macaques, and marmosets provide empirical evidence supporting for the view that voices in non-human primates are usually produced by source-filter independence that vibration of the vocal fold is modified independently from the resonance of the supralaryngeal vocal tract (SVT) as seen in human speech [4,5]. In these experiments of a gibbon and marmosets, the subjects have few experience of training including vocal operant conditioning, and they arbitrarily vocalized in the heliox atmosphere. The animals keep the fundamental frequency (f_0) close to the first formant (F_1) of the SVT, to amplify f_0 , for producing their calls examined. f_0 does not shift but it is significantly suppressed and $2f_0$ is emphasized [4,5]. Here, we use well trained macaques to examine their vocal physiology using X-ray movies. The subjects were trained to produce a coo call by presenting the visual stimulus, and they repeatedly produce a call with similar acoustics. X-ray movies show that the hyoid actively descends and the laryngeal cartilage also descends

against the hyoid for producing coo calls. Such an “active” laryngeal descending potentially enables monkeys to produce varied call repertoire and underlies their acoustic flexibility. Such an active descending is, however, contrast to the case in human speech where the hyoid and larynx move in range restricted. The acoustic flexibility rather depends on active laryngeal descending in non-human primates, whereas it can be brought by dynamic modifications of the tongue topology independently to the laryngeal position. This distinction depends in part on a “static” descended larynx in humans.

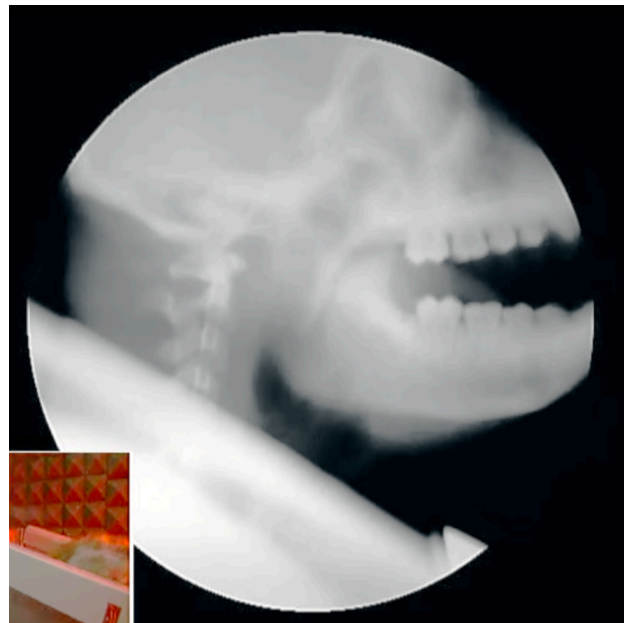


Figure 1: Lowering of the larynx for vocalization in Japanese macaques.

References

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- [2] Nishimura T, Mikami A, Suzuki, J, Matsuzawa T. (2006) Descent of the hyoid in chimpanzees: Evolution of face flattening and speech. *J Hum Evol* 51: 244–54.
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Is volitional control of macaque vocalizations really homologous with those of human speech?

Hiroki Koda

Kyoto University, Japan

Traditional views for origins of human speech had emphasized the great differences of vocal anatomy and physiology between humans and nonhuman primates, but the recent evidences have begun to reveal the anatomical foundations are pre-acquired in a common ancestor of monkeys and humans, far before emergence of speech. Consequently, physiological modifications required for vocal voluntary control is an essential component for speech emergence, ultimately distinguishing us from other primates. Here we showed Japanese monkeys can learn to vocalize voluntarily in response to visual cue, however vocal action was learned by the different ways of manual action. Based on our evidences of vocal conditioning, we will discuss the possible causation underlying these evolutionary shifts

from poor vocal controller, monkeys, to fine vocal controller, humans.

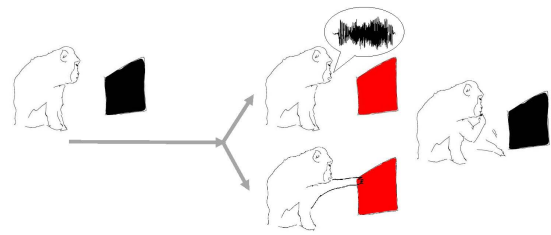


Figure 2: Schematic representations of procedures using differential reinforcement of low rate (DRL).

Humans have a prominent external nose, but its functions are still unclear. To examine the acoustic function, the present study was carried out. First, the surface of the airway from the glottis to the nostrils, the external nose, and its surrounding facial area was extracted for one male and one female subject from image data obtained by a cone-beam X-ray CT. Then, the surface was extruded externally by 3 mm to construct a 3D model of the upper respiratory tract with face. Consequently, the internal space of the 3D model precisely represented the nasal cavity, paranasal sinuses, pharynx, and larynx. Using the model, the acoustic transfer function was calculated by the finite-difference time-domain method when a source point was placed just above the glottis and an observation point was placed in front, 1 m away from the nasal apex. Also, after manually removing the external nose from the model, the transfer function was calculated with the same simulation settings. As a result, for both subjects, the transfer function without the external nose was remarkably higher in spectral level around 2–4 and 7–8 kHz, and lower around 4–6 kHz, compared with that including the external nose. In other words, the external nose depressed the transfer function around 2–4 and 7–8 kHz, while it enhanced the transfer function around 4–6 kHz. One possible reason is acoustic interference. Without the external nose, acoustic radiation occurs from the end of the inferior, middle, and superior meatuses, respectively, while with the external nose, the sound waves through the different meatuses join together in the external nose and

radiate from the nostrils. Thus, the external nose provides a path difference. Although the path difference between the inferior and middle meatuses was very small, the difference between the inferior and superior meatuses was approximately 7 cm for both subjects. Thus, at around 2–4 and 7–8 kHz, which correspond respectively to a half and three-halves of a 7 cm wavelength, the sound waves passing through the inferior and superior meatuses could cancel each other. On the other hand, at around 4–6 kHz which corresponds to one whole wave length, the sound waves could enhance each other. These results indicate that although the external nose could not have any affirmative acoustic function such as generating prominent spectral peaks and dips, it causes a path difference between the nasal meatuses to provide an increase and decrease pattern to the transfer function. [This research was supported by JSPS KAKENHI Grant number 15K00263, 25280066, and 25240026.]

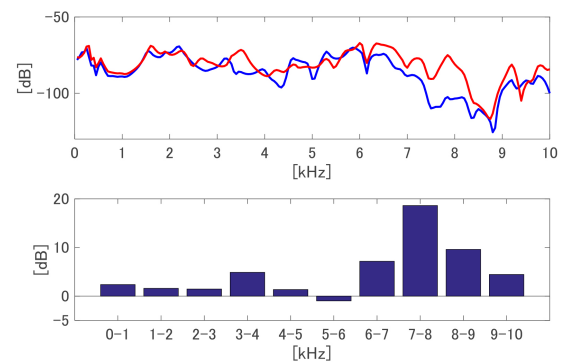


Figure 3: Upper panel, transfer functions of original data (blue) and data without the external nose (red) for the female subject. Lower panel, spectral difference.

In analogy to humans, primate sound production can, as a first approximation, be explained by the source filter theory [1]. While the filter function of the vocal tract can be approximated by acoustic analysis [2], assessment of the sound source would require invasive investigative techniques like laryngeal endoscopy, which are quite challenging in vivo. A low-cost non-invasive alternative is electroglottography (EGG). A low intensity, high-frequency current is passed between two electrodes placed on each side of the larynx. The admittance variations resulting from vocal fold (de)contacting during laryngeal sound production are largely proportional to the time-varying relative vocal fold contact area [3]. Whereas EGG is relatively widely used in human voice research, it has only been sparsely applied in primate in vivo investigations [4].

In this progress report the potential of EGG for primate voice production analysis is examined in closer detail. Part one critically reviews fundamental frequency (f_0) extraction the EGG signal when applying different computational algorithms. For this purpose, the signal quality of database of EGG recordings from six different new world monkey species was analyzed, and a total of 15625 synthetic EGG signal were generated while varying six parameters that control EGG signal quality: random f_0 variation, subharmonics, amplitude drift, mains hum, baseline drift, and noise components. Preliminary data analysis suggests a strong dependency of f_0 results on the chosen algorithm.

In the second part of this presentation the findings of a pilot study pilot study performed with a female Japanese Macaque who was trained to vocalize upon a visual stimulus are summarized. A total of 369

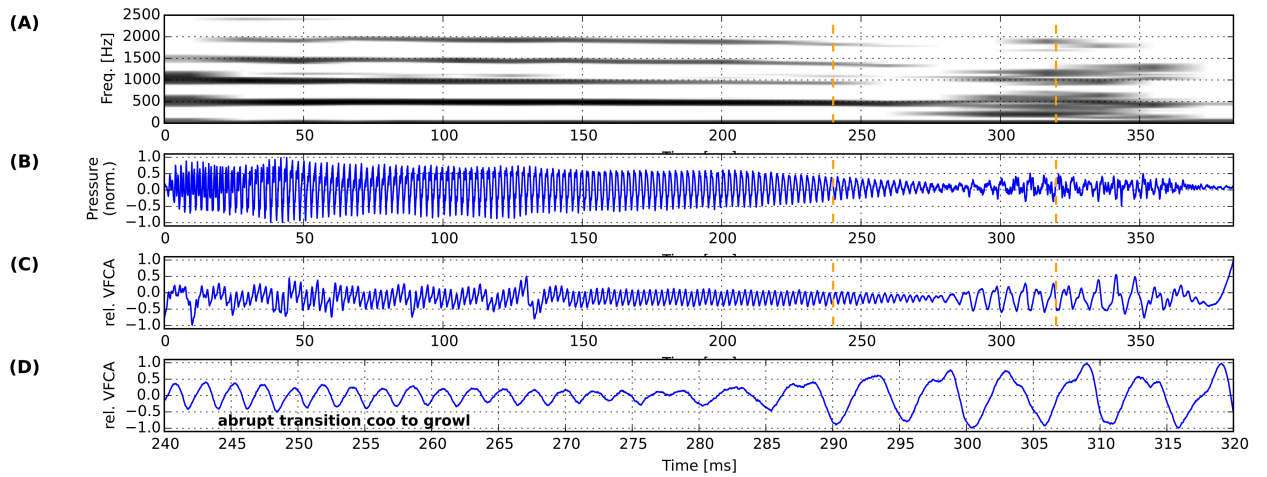


Figure 4: Abrupt transition from “coo” to “growl” phonation in Japanese Macaque phonation. (A) narrow-band spectrogram of electroglottographic (EGG) signal; (B) acoustic signal; (C) EGG signal; (D) portion of the EGG signal, extracted at $t = 240$ ms to 320 ms.

“coo” calls, 17 “grunts” , and 5 “chirps” were documented with SPL-calibrated microphone signals and simultaneous EGG recordings, generating the first phonetogram [5] for a non-human species. 26 recorded calls contained transitions between coos and grunts, and the EGG evidence suggests that the coos and the grunts constitute distinct laryngeal mechanisms (comparable to “registers” in human singing), potentially generated by the same vibrating structures.

References

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- [3] V. Hampala, M. Garcia, J. G. Svec, R. C. Scherer, and C. T. Herbst, “Relationship between the Electroglottographic Signal and Vocal Fold Contact Area,” J. Voice, vol. 30, no. 2, pp. 161-171, 2016.
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Novel insight into the comparative study of primate vocal production through excised larynx experiments

Maxime García

Université de Lyon/Saint-Etienne, France

A fundamental issue in the evolution of communication is the degree to which signals convey accurate (“honest”) information about the signaler. Better understanding of signal production mechanisms can be an important source of insight to this problem. For vertebrate acoustic communication, this requires understanding of the acoustics and physiology of the larynx and vocal tract. In the present comparative study, we conducted excised larynx experiments to explore the determinants of fundamental frequency, examining specimens from eleven primate species for which the length of the laryngeal vocal folds and size of the entire body was known. The assumption that fundamental frequency (f_0) should correlate with the body size of the caller is widespread, but this belief has been chal-

lenged by recent studies showing f_0 to be a poor predictor of body size within a given species, possibly because larynx size can vary independently of body size. Our excised experiments allowed us to investigate this hypothesis rigorously. We investigated correlations between the minimum f_0 produced by the sound source, body size and vocal fold length, finding that body size predicted minimum f_0 less strongly than vocal fold length, clearly demonstrating the potential for decoupling of larynx size and body size in primates. These findings shed new light on the diversity found in primate vocalizations and vocal morphology, and support the relevance of vocal physiology to understanding the evolution of vocal communication

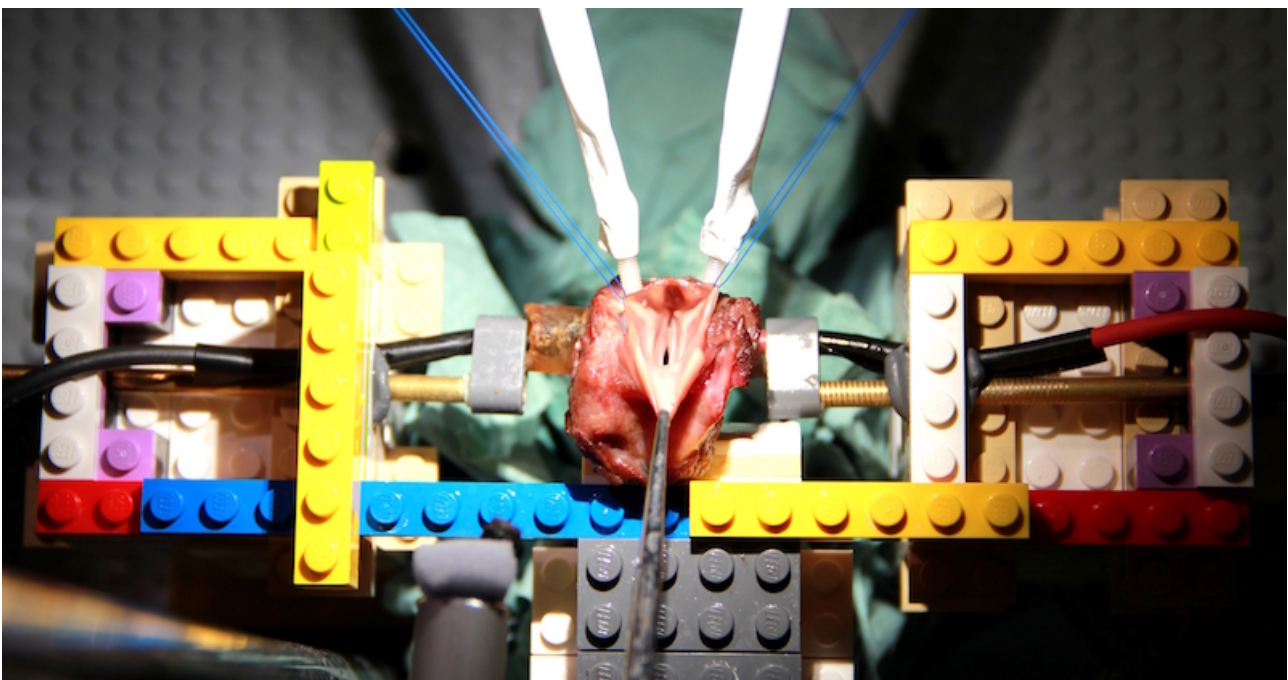


Figure 5: Excised larynx experiment in Japanese macaques.

Opening the black box: Comparative studies of vocal production mechanisms in primates

Jacob C. Dunn

University of Cambridge/Anglia Ruskin University, United Kingdom

Research in vocal communication has offered profound insights into primate cognition and behaviour. However, for the majority of species, vocal production remains a black box, with measurable acoustic outputs, but little understanding of sound production mechanisms. For researchers interested in primate vocal communication (and, by extension, the evolution of speech), an understanding of vocal production is important for a number of reasons. Firstly, the neural control, functional anatomy and physiology of sound producing organs determine the sounds that are physically producible by a given species, thus providing constraints and opportunities for the evolution of vocal communication. Secondly, commonly used methods in acoustic analysis and playback studies (e.g., linear predictive coding) depend on our knowledge of vocal production for proper implementation. Thirdly, a better understanding of vocal pro-

duction across species provides a broader comparative framework for understanding the evolution of vocal communication systems, and more meaningful comparisons with human speech. In this talk I will present data from three comparative studies of vocal production mechanisms in primates. I will begin by briefly highlighting recent work on the extraordinary sound production mechanisms of a genus of particularly vocal primates - the howler monkeys. I will then present some preliminary results from a recent and highly novel field study of vocal production using electroglottography on several different species of semi free-ranging New World primates. Finally, I will discuss a recent study of the coevolution of vocal repertoire and brain architecture across 30 primate species, arguing that vocal complexity coevolves with increases in higher cognitive processing capacities.

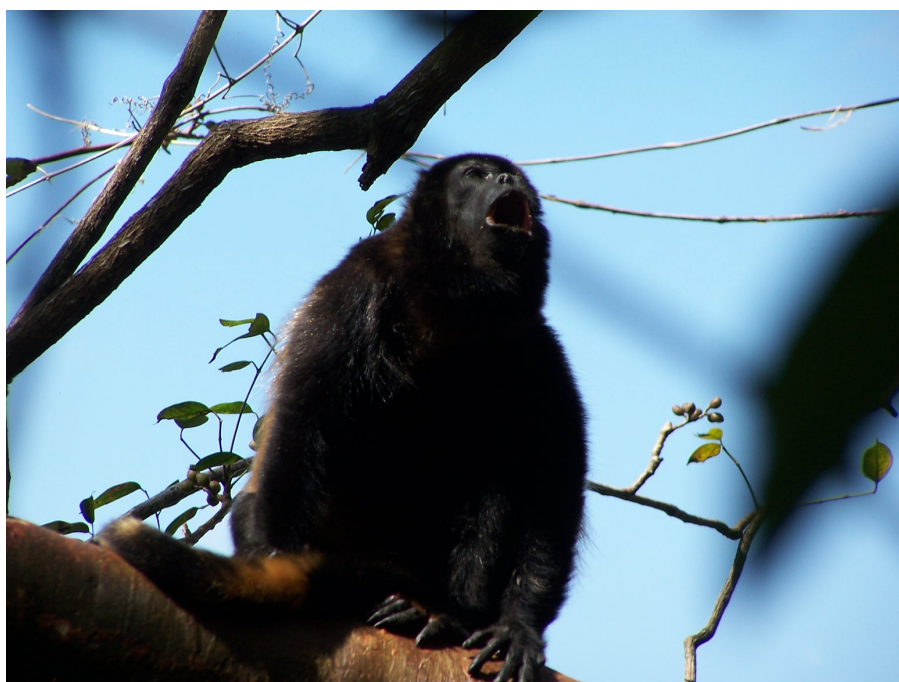


Figure 6: Howler monkeys in Bolivia. © Jacob C. Dunn

The vocal fold is a vibratory mucosa which produces voice sound by high frequent vibration. The vibratory property is never seen in any other mucosa and thus is specific for the vocal fold. It can be deteriorated by aging or wound, and once the vocal fold is irreversibly damaged, retractable or permanent dysphonia occurs, which can be seen in cases of vocal fold scar and atrophy. The maintenance or protection of the vocal fold is excessively important.

Reactive oxygen species (ROS) is one of the most important factors that damage tissues, and causes several morbidities, aging, and death. We have examined the production of ROS in injured vocal folds using vocal fold injury model of rat. ROS was significantly increased at day 1 through day 3, and excessive ROS during this period led to severe scar formation of the vocal fold finally. We have also confirmed that ROS increases in the aged vocal fold mucosa as compared to young vocal folds of rats.

Antioxidant neutralizes ROS, and protects tissues and organs. It is expected that anti-oxidant protects the vocal fold by reducing ROS in case of injury or aging. Astaxanthin (AST) is a carotenoid which has strong antioxidant effects. In our injured vocal fold model of rats, when AST was applied to the rats, production of ROS during injury was significantly reduced, and final scar formation of the vocal fold was avoided to considerable degree. In aged vocal fold model of rats, AST was applied to rats for 10 months until the rats became senile. The rats fed with AST showed significantly lower level of ROS in the

vocal folds as compared to non-treated rats. These data suggest that AST can protect or maintain the vocal fold against injury or aging effects.

Subsequent human trials examined the effects of AST on protection of the vocal fold during vocal loading. Healthy adult volunteers were instructed to perform vocal load task with or without intake of AST before the task. Without AST application, they showed worsened voice just after the task, and recovered from dysphonia 30 minutes after the load. With AST application, the dysphonia after the vocal load was not observed in the same subjects.

In conclusion, it is suggested that ROS has a significant role on vocal fold damage, and prevention of ROS is an effective way to protect and maintain the vocal fold.

Reactive oxygen species and anti-oxidant

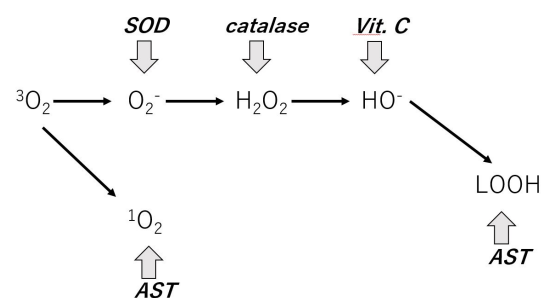


Figure 7: Reactive oxygen species and anti-oxidant.

Brainstem neuronal mechanisms for the periaqueductal gray-induced vocalization in guinea pigs

Yoichiro Sugiyama & Shigeru Hirano

Kyoto Prefectural University of Medicine, Japan

The midbrain periaqueductal gray (PAG) plays an important role in producing phonation. The repetitive patterned movements of lung inhalation followed by the vocal fold adduction and tension with abdominal constriction can be induced by either electrical or chemical stimulation of the PAG. Previous studies have revealed the role of the neuronal networks that control vocalization. In these studies, the bigger experimental animals such as monkeys and cats have been used. However, nowadays, these animals have not been used in acute experiments. We, therefore, have examined the neural pathway of the PAG-induced vocalization in guinea pigs. The call areas in which electrical stimulation of the PAG could evoke vocalization were identified continuously from the PAG to the lower brainstem. In addition, in order to record the neuronal activity during vocalization stably, we have

established the fictive vocalization model using the paralyzed artificial ventilated guinea pigs instead of cats. Although this neuronal pathway evoking vocalization has a large contribution of producing vocalization, the other central pattern generators can possibly participate in the regulation of vocalization. Breathing is mainly controlled by the specific neuronal networks in the medulla and pons. These respiratory neuronal networks are flexible networks, so that the breathing patterns can be easily altered in response to environmental changes. We have also studied the role of the respiratory pattern generator located in the medulla in the regulation of the PAG-induced vocalization. The activity of the neurons in the ventral respiratory group was altered in synchrony with vocal-related respiratory movements in the specific manner.

Animal vocalizations are inherently nonlinear. Comprehensive study on a diversity of nonlinear phenomena such as limit cycles, subharmonics, biphonation, chaos, and bifurcations provides a key to understand animal communications. In this talk, we introduce the concept of nonlinear dynamics and its methodology applicable to bioacoustics. As the basic methodology, three approaches are presented to investigate nonlinear features of animal vocalizations: 1) time

series analysis, 2) mathematical modeling, 3) physical modeling of the vocal tract and vocal folds. Through several examples including mathematical modeling of soprano singing in gibbons and physical modeling of source-filter interaction, it is suggested that combined use of different approaches is of significant importance for extracting key features of nonlinear dynamics in animal vocalizations.

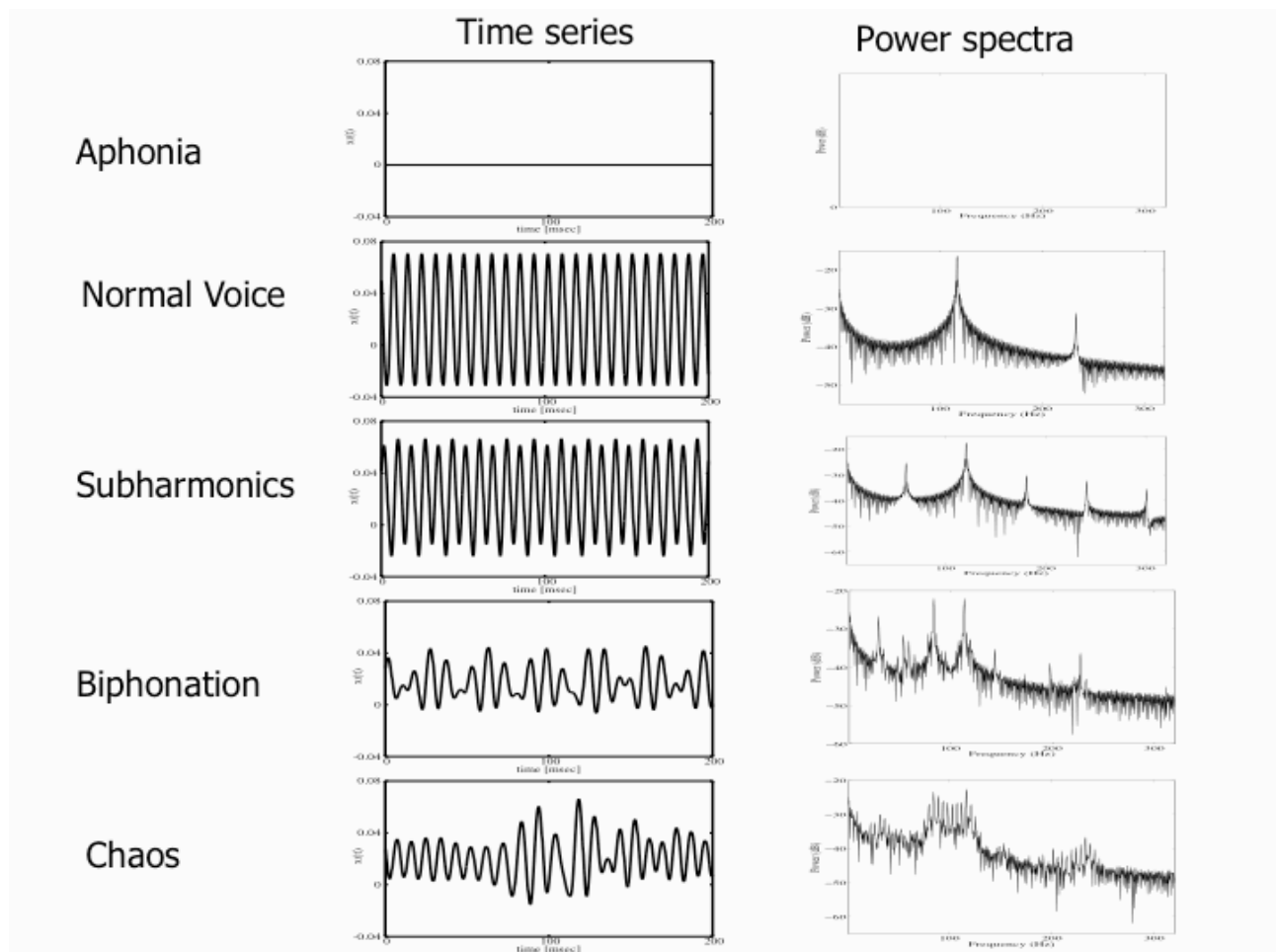


Figure 8: Variety of nonlinear dynamics generated from a vocal fold model. Time series and its power spectra are drawn for aphonia (stable equilibrium), normal voice (limit cycle), subharmonics, biphonation, and chaos.

The characterization of the vocal fold dynamics by analyzing the visual information of the vocal fold vibration has been used to understand the physical properties, the physiological function of the vocal folds and the larynx. In particular, high-speed imaging is one of the most powerful tools for analyzing rich spatial information of

the vibration of the vocal fold, and various methods of analysis have been proposed. In this presentation, we review known high-speed digital imaging techniques and important characteristics, and discuss the future direction and current project on this topic.

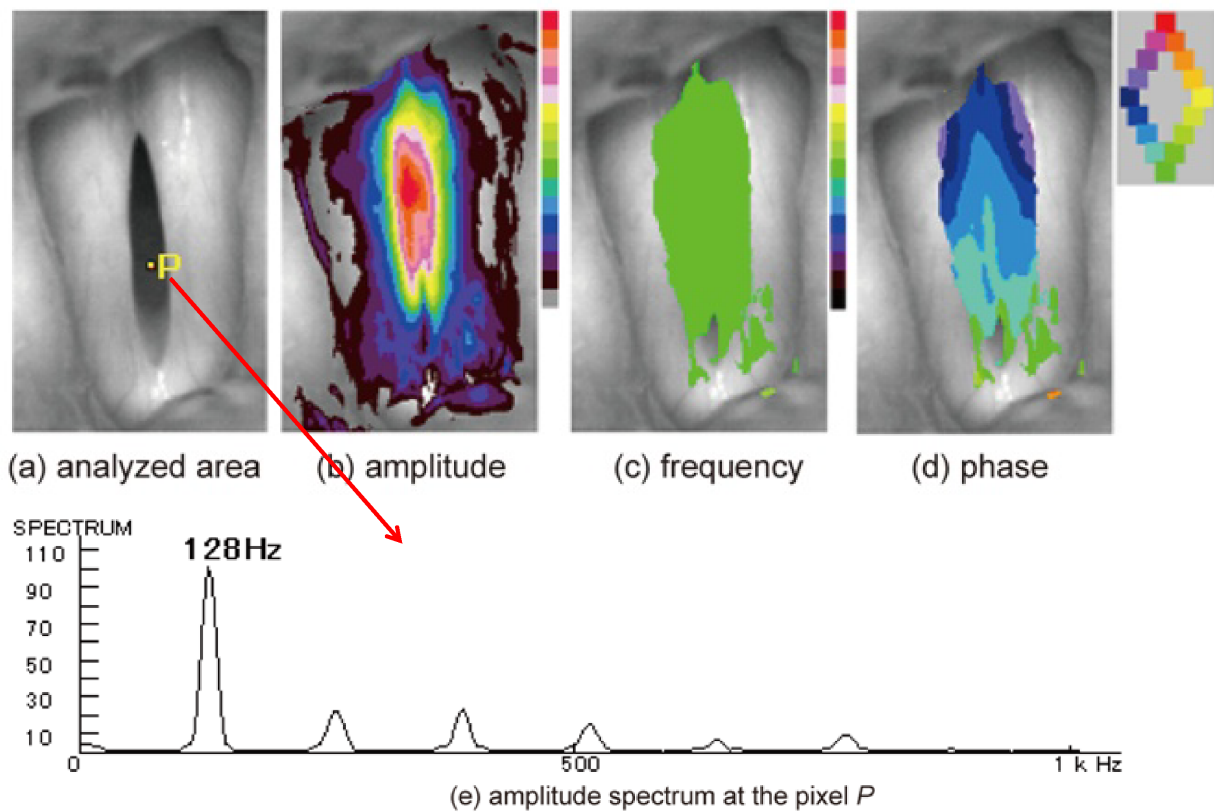


Figure 9: Laryngotopographic analysis for a modal voice of a human.

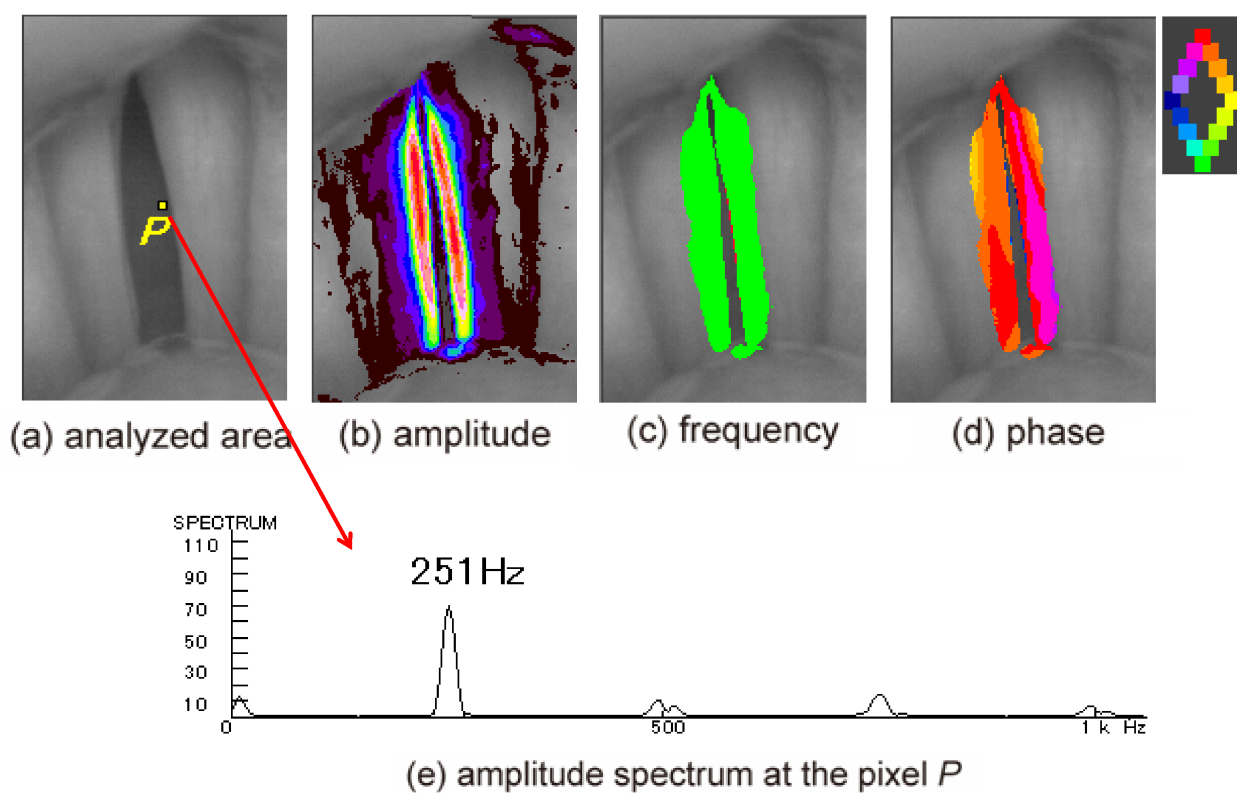


Figure 10: Laryngotopographic analysis for a falsetto voice of a human.

「京都大学 融合チーム研究プログラム SPIRITS」との共催のご提案をいただき、特別に開催いたしました。
平成 27 年度採択プロジェクト（国際型）西村 剛：話しことばの進化プロセスの解明に向けた国際共同研究

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