

# Tokyo Lectures in Language Evolution

*Booklet of poster and talk abstracts*

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# Special Lecture Abstracts

## Three Levels in Human Communication: Emergence and Evolution

*Takashi Hashimoto*

In human communication, we can find three levels: 1) Non-symbolic communication, 2) Symbolic, non-linguistic communication, 3) Linguistic communication. Symbols are not used in the first level, thus it is automatic, unconscious, and non-inferential communication such as emotional contagion and sympathy. We often use social symbolic behavior, such as particular actions for greetings and facial expressions, in order to represent and understand intentional and emotional states. This forms the second level. The third one is communication using hierarchically structured linguistic sentences. While most of the first level is considered as shared with other animals, the second and third levels are characteristic in human communication. Especially, the third level is thought to be human unique. In the origin and evolution of human language, we need to understand the emergence and evolution of all three levels.

In this talk, I will introduce an effective approach to investigate the emergence and evolution of such features in human communication, called evolutionary constructive approach. In evolutionary constructive approach, an objective system is to be understood through constructing the system and operating it, where some autonomous changing processes are incorporated in constructing the system, such as genetic evolution, lifetime development, individual and social learning, and self-organization. The following researches are introduced as examples adopting this approach: an EEG measurement showing activity of human mirror neuron systems in the formation of communication systems (the first level), an experiment of the formation of communication systems and that of displaced communication (the second level), and a simulation of the evolution of ability to make hierarchical structure in object manipulation (the third level).

## **Integration Hypothesis and the Rapid Emergence of Language in Evolution**

*Shigeru Miyagawa*

The Integration Hypothesis (Miyagawa et al. 2013, 2014 *Frontiers*) starts with the observation that there are essentially two primary systems in the animal kingdom that underlie communication: L-type, for lexical, like the alarm calls, consisting of isolated verbal or gestural signals that have reference in the real world; and E-type, for expressive, like birdsong, that creates patterns, but the patterns themselves do not have unique meaning. The idea is that the L- and E-types integrated uniquely in humans to give rise to language. I will briefly review recent genetic and cellular research results that are compatible with the Integration Hypothesis (Pfenning 2014, Calabreze and Woolley 2015, Harris 2015). Taking these works as a starting point, I will argue that the Integration Hypothesis provides an articulated framework for viewing language as having emerged rapidly in evolution without the need for a protolanguage stage (Nóbrega and Miyagawa 2015).

**What is grammar all about?: A cognitive linguistic perspective**

*Yoshiki Nishimura*

*No abstract available at present.*



## The Roots of Merge (and Merge of Roots)

*Koji Fujita*

In accordance with current minimalist approach to language evolution, I take the emergence of the elementary combinatorial operation Merge to be the single innovative event in the making of the human language faculty. Hauser et al.'s seminal 2002 article, though not discussing Merge as such, suggested that this recursive capacity alone belonged to FLN, the uniquely human component of language, with all others being neither species- nor domain-specific. Chomsky maintains that Merge had no evolutionary precursor but appeared through mutation-triggered brain rewiring. I depart from both of their views and propose a theory of the motor control origin of Merge, which says that Merge evolved from the capacity to combine objects in a hierarchical and sequential way. This allows us to see the evolution of Merge as one instance of Darwinian descent with modification. It also implies that Merge can be uniquely human only to the same extent that other components of language are. They all have evolutionary roots in some remote functions which were shared by nonhuman animals and were originally unrelated to language at all. But then how did words evolve, if words were the most basic unit to which Merge could apply? Recent development in Distributed Morphology has shown that words are already syntactically complex objects, to be generated by Merging categorially unspecified roots. If this is correct, then Merge is all we need to create both words and sentences, which further corroborates the Merge-only theory of human language evolution. In a nutshell, Merge evolved first, and then everything else followed in its wake to make language what it is.

Suggested readings:

Bolhuis, J.J., I. Tattersall, N. Chomsky & R.C. Berwick. 2014. How could language have evolved? *PLoS Biology* 12(8): e1001934.

Fujita, K. 2014. Recursive Merge and human language evolution. In T. Roeper and M. Speas eds. *Recursion: Complexity in Cognition*. Springer.

## Evolved intelligence from the Darwinian principle

*Hirokazu Takahashi*

The Darwinian principle is one of the most likely mechanisms that underlie intelligence and problem-solving ability of living organisms. In the cerebral cortex, the theory of neural Darwinism predicts that variation and selection within neural populations are crucial to adaptive computation. We attempted to examine the Darwinian principle in both in vivo and in vitro experiments. First, we demonstrated in the auditory cortex of rats that the degree of response variance is closely correlated with the size of its representational area. Importantly, both the response variance and representational area increased during the early stage of learning and decreased after the completion of learning, supporting that the learning-induced map plasticity is a sign of Darwinian computation. Second, in dissociate primary culture of neuronal cells, we showed that reproducible spatiotemporal patterns emerges in spontaneous activities and that the variety of patterns increases with development of neural networks. Furthermore, we demonstrated that feedback signals based on ongoing activity are able to extract a coherent output from a chaotic neuronal network, endowing the network with problem-solving ability. Thus, these results in our recent experiments could be taken as evidences that the Darwinian principle underlies evolution of intelligent behaviors.

## Domestication and evolution of signal complexity

*Kazuo Okanoya*

Among vocalizations birds make, a class of sounds that are consisted of more than two types of sound patterns arranged in a certain temporal sequence is called as a ‘birdsong’, not only because of the organization of sound patterns, but also because our musical aesthetics intuitively allow such an analogy. Scientific investigations of birdsong to date suggest that certain properties of birdsong extend beyond the musical to the developmental analogies.

Bengalese finches (BFs) are domesticated strains of wild white-rumped munias (WRMs) imported from China to Japan 250 years ago. BF songs are composed of multiple chunks and each chunk is a combination of 2–4 song notes. Furthermore, chunks are arranged in a finite-state probabilistic automaton. We studied how and why BFs sing such complex songs. We found the following facts. 1) The ancestral strain sing simpler songs. 2) There is high learning specificity in WRMs but not in BFs. 3) BFs have larger song control nuclei and higher level of glutamate receptor gene expressions than WRMs. 4) Both BF and WRM females prefer complex songs as measured by the nest string assay and males with complex songs are physically fitter than the males with simpler songs. These results promoted sexual selection scenario of song complexity in BFs.

We further examined factors related with domestication. We examined songs of WRMs in sub-populations of Taiwan. Where there is a sympatric species to WRMs, songs were simpler. This leads to a hypothesis that in the wild songs needed to be simple to secure species identification, but under domestication this constraint was set free. We also examined socio-emotional indexes including neophobic tendency, tameness, behavioral stress reactions, and corticosterone levels. All indexes suggested that WRMs have higher level of stress and social shyness, which should be adaptive under natural environment, but could be limiting opportunities for learning complex songs.

Thus, evolution of song complexity involves not only factors related with strengthen of sexual selection and relaxation of species identification, but also socio-emotional factors due to domestication. Furthermore, recent suggestion of neural crest hypothesis that might account for the domestication syndrome fits well with the properties of Bengalese finches. These results on Bengalese finches must be useful in discussing possible biological origin of human speech in terms of proximate and ultimate factors.

**Poster Session 1**  
**Thursday 2nd April**

## **Primate models of autism failed to discriminate third-party reciprocal/non-reciprocal exchange between human actors**

*Miyuki Yasue, Akiko Nakagami, Taku Banno, Keiko Nakagaki, Noritaka Ichinohe,  
& Nobuyuki Kawai*

We are currently establishing a primate model for autism. We produce model marmosets (the VPA marmosets) by exposing to valproic acid during their fetal period. They had shown 1) biased useage from vocal repertoires, 2) weak social attention to unfamiliar conspecifics, and 3) deficits in reversal learning, demonstrating all three core symptoms of autism. Here, we investigated whether the VPA marmosets show impairments in higher social cognition. We have shown that marmosets discriminate third-party reciprocal exchange and its violations (Kawai et.al. 2014). In the same way, the VPA marmosets and the unexposed control marmosets observed two types of scene performed by two human actors in this study. In the reciprocal condition, two actors exchanged food each other. In the non-reciprocal condition, an actor (non-reciprocator) ended up with all foods and another actor with none. Then, the two actors offered the monkey a food. The unexposed marmosets avoided receiving foods from the non-reciprocal actor only in the non-reciprocal condition. However, the VPA marmosets did not show differential preferences in both conditions. In short, the VPA marmosets didn't pay attention to others' interaction. We propose that this test battery can be an ideal tool to qualify as animal models for autism.

## Waves in computer-assisted simulations of linguistic diffusion

*Luzius Thöny*

Since the work of Schmidt (1872), the wave has been used pervasively as a key concept in describing the diffusion of linguistic innovations in a speaker community. Recently, the study of language change through modelling and computer-assisted simulations has become more widespread (e.g. Baxter et al. 2006, 2009, Blythe/Croft 2012, Pierrehumbert et al. 2014). The aim of this research is to investigate whether computer simulations show wave phenomena as described by Schmidt and later linguists, and what we can learn from this about the mechanism of speaker interactions that lead to the propagation of innovations. For this purpose, a number of earlier models described in the literature (e.g. Nettle 1999, Livingstone/Fye 1999, besides the aforementioned) will be looked at and contrasted with results of own simulations.

The concept of the wave is predominantly used in dialectology, where the focus is on the areal spread of linguistic innovations (cf. e.g. Wolfram/Schilling-Estes 2003). Dialect maps provide rich data on the diffusion of certain features within a speaker community. A second aim of this research is to explore whether the empirical data provided by dialect maps, e.g. from the Swiss German Dialect Atlas (SDS), could be used to enhance and improve the models used in the simulations.

Baxter, Gareth J. et al. (2006). “Utterance selection model of language change”. In: *Physical Review E* 73:046118, pp. 1–20.

– (2009). “Modeling language change: An evaluation of Trudgill’s theory of the emergence of New Zealand English”. In: *Language Variation and Change* 21, pp. 257–96.

Blythe, Richard A. and William Croft (2012). “S-Curves and the mechanisms of propagation in language change”. In: *Language* 88 (2), pp. 269–304.

Livingstone, Daniel and Colin Fyfe (1999). “Modelling the Evolution of Linguistic Diversity”. In: *Advances in Artificial Life: 5th European Conference: Proceedings*. Ed. by Dario Florean. Berlin, pp. 704–8.

Nettle, Daniel (1999). “Using Social Impact Theory to simulate language change”. In: *Lingua* 108, pp. 95–117.

Pierrehumbert, Janet B., Forrest Stonedahl, and Robert Daland (2014). “A model of grassroots changes in linguistic systems”. In: *arXiv 1408.1985*, pp. 1–30.

Schmidt, Johannes (1872). *Die Verwandtschaftsverhältnisse der indogermanischen Sprachen*. Weimar.

SDS = Hotzenköcherle, Rudolf, and Rudolf Trüb, eds. (1962-2003). *Sprachatlas der deutschen Schweiz*. Vol. I-VIII und Abschlussband. Bern.

Wolfram, Walt and Natalie Schilling-Estes (2003). “Dialectology and Linguistic Diffusion”. In: *Handbook of Historical Linguistics*. Ed. by Brian D. Joseph and Richard D. Janda. Malden (MA), pp. 713–35.

## Factors affecting the use of the vocalizations in post-conflict affiliative interactions in Japanese macaques

*Noriko Katsu, Kazunori Yamada, & Masayuki Nakamichi*

How social contexts and the affective state of callers affect call utterances in nonhuman primates? We investigate affiliative vocalizations (“greeting calls”) of Japanese macaques (*Macaca fuscata*). Chimpanzees emit alarm calls according to recipients’ knowledge states (Crockford et al. 2012), not as an expression of arousal states. In contrast, greeting calls are seen as mere reflection of arousal states (Whitham et al. 2007).

In post-conflict situations, tension of individuals around increases and they tend to initiate affiliative interactions to reduce the post-conflict anxiety. We examined the effects of the preceding conflict, relationships between interacting partners, and the anxiety level of combatants on whether greeting calls are accompanied by affiliative interactions.

We found that combatants were more likely to utter calls after conflict than in a control situation. Calling was also affected by familiarity with interacting partners, probably reflecting high uncertainty between dyads. The scratching rate of the combatant, an indicator of anxiety, did not have a significant effect on call utterance. Monkeys seem to use greeting calls not as an expression of anxiety, but rather, to indicate callers’ non-hostile intent in high-tension situations. Our findings suggest that the use of vocalizations in nonhuman primates is adjusted according to social context.

Crockford et al. 2012, *Current Biology*, Wild chimpanzees inform ignorant group members of danger

Whitham et al. 2007, *Ethology*, Intended receivers and functional significance of grunt and girney vocalizations in free-ranging female rhesus macaques.

## Is language a no laughing matter? Emotional mechanisms in speech and birdsong learning

*Irene Berra*

A parsimonious account of language evolution could be based on the emotional mechanisms underlying vocal learning. Here I propose that juvenile songbirds and human infants may be driven to modify the production of vocalizations by different proximate mechanisms, although they coopted the reward system of the vertebrate brain in a convergent manner. First, it is shown that rudiments of vocal control in nonhuman primates indicate processes of affiliation and intimacy as potential pre-speech conditions (e.g., Watson et al., *Curr. Biol.* 25, 1-5, 2015), whereas mating and social reinforcement play a greater role than parental care tendencies on birdsong learning (Wickler and Seibt, *Anim. Behav.* 30, 943-944, 1982; Soma, *Ornit. Sci.* 10, 89-100, 2011). Second, empirical evidence is reviewed suggesting that emotional communication with caregivers motivates the infant's voluntary vocal behaviour, language included. In particular, turn-taking in mother-infant interaction reinforces pre-canonical vocalizations into speech, and volitional control of protophones, laughter, and crying vocalizations prelude articulatory control (Nwokah et al., *Inf. Behav. Dev.* 17, 23-35, 1994; Oller et al., *PNAS* 110, 6318-6323, 2013). Moreover, immediately rewarding mechanisms seem to support social negotiates in which laughter and language are involved over an individual's lifespan (see, f.i., Dezechache and Dunbar, *Evol. Hum. Behav.* 33, 775-779, 2012). To sum up, the voluntary control of non-verbal vocalizations, especially laughter, can have lifetime effects on social understanding, and may thus discourage assumptions of cognitive constraints on the evolution of linguistic capacities.



## Hunting communication: A possible model for the emergence of proto-languages

*Philip Hindley*

Hunter-gatherers as geographically disparate as the Khoisan ethnic groups of Southern Africa, the Hadza of Western Tanzania and the Penan of Sarawak all use similar systems of communication during hunting episodes. These systems are independent of the full semantic syntactic language of the hunters. They constitute vocal-gestural packages that include non-verbal audio signals, imperative hand waving, indexical pointing and iconic hand gestures (Takada 2008: 124–125 & 128–130). These communication systems serve to attract the attention of hunting partners, communicate directives and indicate the location of game. Additionally, iconic hand gestures are employed to convey the identity of the prey by using hands to mimic the salient features of the animal: horns, tusks, tails and, in some cases, spoor (Howell 1970: 184–185). An analysis of these vocal-gestural packages revealed proto-nouns and verbs associated with kinesthetic adverbial/adjectival features, a basic syntax and a shift from iconicity toward symbolism (Hindley 2014). Here, I describe these hunting communication systems and discuss on-going work concerning the feasibility of using them as possible models for the emergence of proto-languages. I postulate that imperative gestures might function as proto-verbs and that vocal-gestural packages could develop into narrations through dance and mime (Barnard 1992:155).

Barnard, A. 1992. *Hunters and Herders of Southern Africa: A Comparative Ethnography of the Khoisan Peoples*. C.U.P., Cambridge.

Hindley, P. 2014. Nominal and imperative iconic gestures used by the Khoisan of North West Botswana to coordinate hunting. *African Study Monographs*, 35(3&4): 149–181.

Howell, F. C. [1963] 1970. *Life Nature Library: Early Man*. Time, Inc., New York.

Takada, A. 2008. Recapturing space: Production of inter-subjectivity among the Central Kalahari San. *Journeys: The International Journal of Travel and Travel Writing*, 9(2): 114–137.

## Hour-scale slow changes in a song might reflect motivation and arousal in songbirds.

*Takuya Koumura, & Kazuo Okanoya*

Birdsong is a suitable model for the research on language acquisition because these two phenomena share several properties in common, such as learning process and neural basis of them (Bolhuis et al., Nat Rev Neurosci, 2010). Especially, songs in Bengalese finches consist of sound elements (notes), which are sequentially vocalized with a certain degree of variability in their sequences (Okanoya, Ann N Y Acad Sci, 2004). To understand the learning process and neural basis of birdsong, it is important to know how their sequence patterns depend on the motivation and arousal in birds. Since these parameters presumably change slowly, we have investigated hour-scale slow changes in the sequence patterns.

In the course of investigating slow modulation in note sequences, it is necessary to classify a large amount of song data. It is inefficient to do such classification manually. We therefore developed an automated note classification method for variable note sequences, based on methods from image and acoustic processing (LeCun et al., Proc of the IEEE, 1998). As a result, with smaller manual effort, we achieved robust classification comparable to that of manual classification. We then applied this method to songs recorded for several consecutive days. We found that some patterns in the note sequences showed significant slow changes. Moreover, some sequence patterns showed periodicity or circadian rhythms.

## Neural Responses to Auditory Stimuli in the Bengalese Finch Nucleus Taeniae of the Amygdala

*Tomoko Fujii, Maki Ikebuchi, & Kazuo Okanoya.*

Emotions are important in responding adaptively to communication signals (Oatley & Johnson-Laird, 1987). In recent years, studies on rodents and bats have revealed that the amygdala, a center of emotion in mammals, plays a role in recognizing conspecific vocalizations (Parsana, Li & Brown, 2012; Peterson & Wenstrup, 2012). Songbirds use a variety of vocal sounds to communicate, and evaluating relevance of these signals is essential for them. Thus, songbirds can provide a good opportunity to search for relationships between acoustic communication and emotions. Although anatomical studies have suggested that the Nucleus Taeniae of the Amygdala (TnA) corresponds to a part of the mammalian amygdala, the functional role of TnA remains unclear. Especially, investigating neural responses of the TnA to auditory stimuli is necessary to understand the contribution of this nucleus to acoustic communication. The present study aimed to explore auditory response properties of the songbird TnA neurons electrophysiologically. We recorded neural responses of the Bengalese finch TnA neurons during the presentation of conspecific and heterospecific vocalizations, as well as synthesized sound stimuli. We found that a population of TnA neurons exhibited responses to auditory stimuli and some of them showed songbird vocalization selectivity. Our findings suggested involvement of songbird TnA in communication sound recognition. Further investigation into the auditory response properties of the TnA is required to understand its function.

## **Ontogenetic Ritualization and The Emergence of Gestural Symbols in Autonomous Robot**

*Michael Spranger*

Ontogenetic ritualization (OR) is one of the key processes for the development of early gestural symbols in infants. OR has been widely studied in non-human and human primates (Tomasello & Call, 2008) and it has been identified as a basis for the emergence of meaningful gestures from bodily actions. For example, OR is a plausible mechanism for the development of pointing from grasping. Despite its importance there are few models of ontogenetic ritualization except for some initial work which does not focus on communication per se and omits modeling the role of the tutor in the dyadic interactions underlying gesture learning (Hafner & Schillaci, 2011; Arbib et al 2014; Sheldon & Lee, 2010). Our work incorporates the modeling of the emergence of gestures in a complete framework that can also handle other aspects of language development such as vocabulary and grammar learning.

In our experiments, gestures such as pointing emerge from the interaction of the learner with tutor robots from bodily actions of grasping. Our results demonstrate a promising route for modeling the development of symbolic communication in robots.

## Developmental diversity in infant cries through maternal interactions

*Yulri Nonaka, Jean-Julien Aucouturier, Kentaro Katahira, & Kazuo Okanoya*

Crying in human infants is a unique behavior among primates. Two hypotheses compete to explain this phenomenon (Soltis, 2004); one suggests the cry is a graded signal reflecting the infants degree of neediness or pain, while the other suggests the cry is a categorical signal conveying discrete types of needs. We present data suggesting that it is, in fact, a mixture of both. We focused on the social aspect of the crying behavior in its natural environment. Thirty-five infant-mother dyads during the first year of age were studied from recorded cries and verbal reports from mothers. Mothers attributed various meanings to their baby's cries: they judged the physiological and social needs of the babies from a very early stage. On the other hand, acoustical analyses of the cries revealed that each infant progressively adopts distinct vocal signatures of pitch (Nonaka et al., in preparation) and expiration rate (Aucouturier et al., 2011) for different needs. Together, these findings suggest that the infants communicate physiological states by a graded portion of the cry which is stable through development, and social needs by a categorical portion. Coding is probably done through interactive learning by the mother and infant (Okanoya & Merker, 2007). We argued these properties of early infant cry could be considered as communicative signal, especially in terms of the meaning of the sound, affecting later process of language acquisition.

Aucouturier, JJ., Nonaka, Y., Katahira, K., & Okanoya, K. (2011). Segmentation of expiratory and inspiratory sounds in baby cry audio recordings using hidden Markov models. *Journal of the Acoustical Society of America*, 130(5), 2969-2977.

Okanoya, K., & Merker, B. (2007). Neural substrates for string-context mutual segmentation: A path to human language. *Emergence of Communication and Language* (pp. 421-434). London: Springer Verlag.

Soltis, J. (2004). The signal functions of early infant crying. *Behavioral and Brain Sciences*, 27, 443-490.

## To what extent is Merge unique to human language?

*Yasuyuki Fukutomi*

It has been widely assumed under the Minimalist Program that there is a single computational operation, Merge, which is considered to be characteristic of human language. Computation is a biological activity implemented by specific structure of the mind/brain. The present paper examines to what extent the operation Merge is unique to human language and explores how linguistic theories account for human-specific nature of language. Gallistel (2011) points out that there is evidence that in vertebrates at least, the representation of actions takes the predicate-argument form of human language and suggests that other species have the capacity of processing complex symbols, which evolutionarily underlies human's computational capacity of processing language. It is shown that if this is on the right track, what distinguishes human language from non-human computational systems is not the operation Merge but the selection properties of functional categories, which constitute the genuine evolutionary novelty. I argue that the acquisition of functional categories, along with the operation Merge, enables human language to have evolved from its more limited predecessor found in other species into the more sophisticated computational system.

Fujita, K. 2014. "Recursive Merge and Human Language Evolution," in T. Roeper and M. Speas (eds.) *Recursion: Complexity in Cognition*, 243-264, Springer.

Gallistel, C. R. 2011. "Prelinguistic Thought," *Language Learning and Development* 7: 254-262.

Hurford, J. R. 2014. *The Origins of Language*, Oxford University Press.

## Knowledge of Comparisons: the Acquisition of the Meaning of Language

*Koji Kawahara*

Comparing objects according to some standards is one of the central components in human cognition. Every human language encodes a way to construct comparisons. Syrett et al. (2009) have explicitly shown that by 3 years of age children are sensitive to conditions on the felicitous use of gradable expressions in English that can vary depending on a context. Kawahara (2013) has also pointed out that almost the same patterns can be found in Japanese, which does not have a comparative morpheme. Taking these researches as a starting point, I will show that by 5 years of age children are sensitive to the distinction between the comparative use of gradable adjectives and the absolute or unmarked use of gradable adjectives. The research is based on twenty-two children, ranging in age from 4;11 to 5;11 (mean age 5;09, eleven males and eleven females). I point out that the absolute use is cognitively complex because of its linguistic simplicity and the use of gradable expressions provides a way to establish a well-organised and abstract comparative ability. I also compare the numerical and quantitative competence of human beings with that of other species, pointing out that the use of comparative constructions paves the way for enhancing the ability in humans (Feigenson et al., 2004; Carey, 2009; Ujfalussy et al., 2014).

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## Emotional contagion as measured by cognitive bias tasks in rats

*Yumi Saito, Kazuo Okanoya, & Hiroko Kagawa*

Emotional contagion is the process in which one became the same emotional states of the others via a behavioral signal. We demonstrate this phenomenon in rats by an operant experiment. Humans have the ability of empathy and emotional contagion occurs when they get emotional vocalizations of others, like laughter or crying. Likewise, rats emit 50kHz or 22kHz ultrasonic vocalizations (USVs) associated with positive or negative context. Whether or not such signals might cause other rats to be a similar internal state is not known. We utilized the cognitive bias task to measure the degree of emotional contagion in rats. Rats were trained to respond differently for two neutral stimuli. One resulted in a positive outcome while the other produced negative outcome. Then the intermediate stimulus between the two was used to test whether that was interpreted as being positive or negative. After the 50kHz USVs stimulation, rat interpreted the neutral stimuli as being positive, while after the 22kHz USV stimulation, the same stimuli were regarded as negative. Results that USVs can bring about positive or negative emotional contagion. Our findings indicated that rats have the empathy to others, via the USV communications.



## **Categorization and behavioral correlates of the rat 50 kHz ultrasonic vocalizations**

*Shoko Yuki, Ryosuke O Tachibana, & Kazuo Okanoya*

Ultrasonic vocalizations (USV) of adult rats are classified roughly into two types; 50-kHz and 22-kHz (Portfors, 2007). Some studies have suggested that 50-kHz USVs can be divided into some distinct patterns and each has different function. However, detection and classification methods for these USVs vary. This causes difficulty in comparison between findings. Therefore, it is important to develop automatic clustering method for the rat USVs with acoustic similarity indices. In this experiment, we used an unsupervised random forest algorithm as a preprocessing step to reduce bias of data. We then conducted hierarchical clustering by McQuitty method (McQuitty, 1966). The number of cluster was determined as using three indices (KL-index; Krzanowski & Lai 1988, Silhouette-index; Rousseeuw, 1987 and Marriot-index; Marriot, 1971). As a result, six clusters were successfully derived by the proposed method. Then we conducted linear discriminant analysis (LDA) to confirm that derived clusters are well separated by leave-one-out cross-validation testing. The linear discriminant function can correctly predict the cluster of test data with a probability of more than 99 percent. Moreover, the number of a type of USVs decreased according to the progress of operant discrimination learning. This study would contribute to studies on vocal communication of rats.

## **Absolute pitch labeling ability facilitates short-term pitch memory**

*Hiroaki Maeshima, & Kazuo Okanoya*

Absolute Pitch (AP) is the ability to label the pitch of musical tones without any reference tones. In this research, we aimed to clarify the relationship between AP and the pitch memory ability. Participants completed a pitch memory task similar to Schulze et al. (2009), which required participants to match the first and the last tones of a 7-tone sequence. Participants were divided into 3 groups according to their AP test scores: AP group (correct rate: 80%~), Partial AP (PAP) group (20~80%), Non-AP (NAP) group (~20%). We found the high correlation( $r = 0.846$ ) between the score of AP Test and the accuracy of pitch memory. Moreover, in the AP Test, white keys (C, E, etc.) were scored higher than black keys (C#, G#, etc.) in the PAP group. In relation to this result, the accuracy of pitch memory of white keys was also higher than that of black keys in the PAP group. AP possessors showed better pitch memory, perhaps because of the ability to label the pitch and to store in the verbal form. Moreover, the results of PAP group suggests that the pitch memory superiority in AP possessors may not result from the difference of tonal memory ability, but the difference of labeling ability.

## Changes in mouse ultrasonic communication during courtship

*Yui Matsumoto, & Kazuo Okanoya*

Vocalizations of adult male mice during courtship has become a model for vocal communication. Males produce ultrasonic vocalizations featuring a variety of syllables during male-female interaction. Moreover, different strains consistently produce different vocal patterns. However, it remains unknown whether vocalized patterns are changed depending on the instructional sequence during courtship behavior including several stages of interaction. In this study, we recorded male vocalizations during male-female interactions in order to examine the changes of vocalizations throughout courtship behavior. We found that mice emitted different pattern of vocalizations according to the male behavior and the contact time with females. Males showed many short syllables in the early phase of interaction and long syllables in the middle and late phases, with harmonics during the phase that mice displayed mounting behavior. These results indicate that mice produced different patterns of vocalizations depending on the phase of interaction. Our findings may contribute an understanding of acoustic signals during social interaction in mice.

## Contextual bias in negative polar questions

*Atsushi Oho*

The meanings of sentences in natural language often comprise multiple layers: in addition to the truth-conditional meanings, declarative sentences may contain the non-truth-conditional (or use-conditional) meanings such as presuppositions and implicatures; negative polar (or yes/no) questions (henceforth NPQs) may convey the speaker's epistemic bias toward a particular answer. Thus, it is fair to say that the multiplicity of the meanings is a characteristic nature of human language. In this study, I explore further layers of the non-truth-conditional meanings of NPQs, by examining two similar but distinct forms of the NPQs in Japanese, “p-nai?” and “p-janai?”. More specifically, I claim that there is an additional type of the speaker's epistemic bias regarding the addressee's accessibility to (strong) evidence for the answer to the question, which I call “accessibility bias”. I demonstrate that the two forms are different in the accessibility bias, resulting in the distinct distribution. I then propose a pragmatic function encoded in “janai”, which lowers a contextual threshold required for a felicitous utterance. Interacted with pragmatic principles (i.e., Gricean maxims of Quantity), “p-janai?”, but crucially not “p-nai?”, becomes felicitous when the speaker believes that the addressee does not access strong evidence for the answer to the question.

# Poster Session 2 - Saturday 4th April

## Lost Script and the Nature of Language Identity

*Fusa Katada, & Siverlyn M. Camposano*

In linguistic communities where literacy inculcation is part of the culture and starts as early as 2, 3 years of age, the orthographical knowledge of a language may merge into the knowledge of the spoken natural language developing in the child's brain. While mora-timed Japanese with the grapheme-rhythm matching Kana syllabary renders such orthographical influences, languages of Philippines such as Tagalog and Cebuano present a different picture. These languages once had the ancient script called Baybayin, which was CV-based syllabary. Baybayin came to decline in the 1600s in favor of the phoneme-based (Cs and Vs) Roman alphabet brought by the Spaniards. It has then been completely replaced by the alphabet under 400 and some years of the Spanish/English influences continuing to the present-day. This study nonetheless shows, based on the disguised language game played among Cebuano/Bisayan teenagers, that the psychologically real units in Cebuano are not phonemic, but remain to be CV-oriented moraic. We thus contend that the identity of language, manifesting as psychological reality in the speaker's mind, outlives hundreds of years foreign orthographical influences. Such truth of language is only superficially undetectable in the grapheme-rhythm gapless languages such as Japanese.

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## What cognitive phylogenies got wrong

*Constantina Theofanopoulou*

The study of language evolution has led to a reappraisal of phylogenetic issues, as reconstructing cognitive phylogenies has been considered a key for unveiling the cognitive novelties that set the stage for human language. In our opinion, existing studies have approached cognitive phylogenies in a non-optimal way, and we wish to propose ways to amend this.

We claim that their deficiency stems from the influence of the traditional “linear cladograms”, according to which every seemingly new or more sophisticated feature of a cognitive mechanism is represented as a node on top of the old and shared elements (cf. the FLN/ FLB distinction). We wish to stress that this kind of cladograms does not succeed in depicting the complexity with which traits are distributed across species and, furthermore, that the labels of the nodes of these traditional representational systems fail to capture the tinkering’ nature of evolution.

In addition, cognitive cladograms we have come across in the literature tend to represent fossilized behavioral patterns, thus giving a uni-dimensional character to the evolution of cognitive mechanisms. As an alternative, we argue for a multi-dimensional perspective, and a decomposition of cognitive mechanisms into more generic functions, subserved by rhythms generated in the brain.

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Fitch, W. T., Huber, L. & Bugnyar, T. 2010. Social Cognition and the Evolution of Language: Constructing Cognitive Phylogenies. *Neuron* 65, 795-814.

Hauser, M., Chomsky, N. & Fitch, W. T. 2002. The Language Faculty: What is it, who has it, and how did it evolve? *Science* 298, 1569-1579.

## **An EEG study of the role of human mirror neuron system during associative learning**

*Guanhong Li, Takeshi Konno, Jiro Okuda, & Takashi Hashimoto*

There has been speculation that language evolved from manual gestures, and the mirror neuron system provided a natural platform for this process [Rizzolatti et al., Trends in Neurosciences, 21(5), 1998]. Alternatively, the mirror neurons could be an evolutionary byproduct of sensorimotor associative learning [Heyes, Neuroscience and biobehavioral reviews, 34(4), 2010]. These two competing views are indissociable in a traditional before-after experiment. Accordingly, the experimental semiotics approach [Ganlantucci, Topics in Cognitive Science, 1(2), 2009] is employed to investigate this problem.

We conducted an electroencephalography (EEG) experiment, in which pairs of participants were invited to play a coordination game similar to that conducted by Konno et al. [Advances in Cognitive Neurodynamics (III), 2013]. To succeed in winning the game, pairs of participants need to develop symbolic communication systems to describe the locations of four virtual rooms located on a grid of  $2 \times 2$ . Upon receiving message from their partner in the game, the electrical brain activity of the recipient was recorded.

Compared with the baseline condition, we found significant power suppression for the mu and beta bands during the processing of symbols denoting virtual locations, demonstrating the involvement of the sensorimotor system. Moreover, as the causation view and byproduct view predict different result regarding the correlation between the intensity of mirror neuron system and the behavioral performance in the game, the analysis result could contribute to clarifying the in-debate problem about the role of mirror neuron system during the associative learning process.



## Sound symbolism on visual size judgment: Combinations of voiced and voiceless plosives with a vowel “o” or “i”

*Sachi Itagaki, Shota Murai, Kohta I. Kobayasi, Jan Auracher, & Hiroshi Riquimaroux*

Abstract: The sound symbolism is argued to help language acquisition and is possibly related to language evolution. In most of the previous psychology and linguistics researches, stimulus was presented visually with alphabets, and subjects directly answered the impression of the sound. The purpose of this study was to verify whether sound symbolism could be observed even when the sound stimulus was presented aurally. In this experiment, we focused on sound symbolism in visual size perception (e.g., Gallace A and Spence C. 2006) Subjects were required to answer visual size difference between the standard and target stimuli (a white circle on black background LCD screen). Sound stimuli were /bobo/ and /pipi/, and were assumed to have impression of “bigger” and “smaller” respectively, according to previous researches (e.g., Newman SS. 1933). Congruent trials were defined as those where circle sizes were correlated with the impression of accompanying sounds, and incongruent trials were with opposite stimulus contingency. As a result, reaction times in incongruent condition were longer than congruent condition. Moreover, the difference of reaction time was longer as visual size difference got greater. These results suggested that sound symbolism does occur even when the sound stimulus was presented aurally.

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Newman SS. (1933) Further experiments in phonetic symbolism. *Am. J. Psychol.* 45:53-75.

## Laryngeal nerve lesion evoked vocal plasticity in rodent

*Hiroki Iwabayashi, Kohta I. Kobayasi, & Hiroshi Riquimaroux*

Several species of animals, humans, bats and songbirds, adaptively control and change their spectro-temporal structure of vocalizations according to their environment. The physiological and phylogenetic basis of their vocal plasticity is still largely unknown. Most of the common laboratory rodent, however, generally vocalize relatively simple sound, and has been regarded as having only limited or no vocal plasticity. In this experiment, we conducted unilateral mutilation of the inferior laryngeal nerve in Mongolian gerbil, *Meriones unguiculatus*, and recorded the effect and recovery of vocalization for about 2 month for evaluating their vocalization plasticity. Their communication calls are classified in previous study, and they most commonly produce high frequency (>25kHz) short (<50ms) vocalization called “greeting call”. After the surgery, the number of vocalization decreased. Especially, greeting call almost disappeared, while low frequency call showed small effect. The symptom remained until 10 days after surgery (DAS). Sham-operated animals showed no observable change on their vocalization. From 18 DAS, denervated animal started to show recovery, and at 66 DAS they vocalized as nearly the same as pre-operation, demonstrating that Mongolian gerbil adaptively modified their vocalizations for compensating the lesion. The result suggests that even rodent has at least long-term vocal plasticity, and the capability could be a basis of the more highly developed vocalizations.

## **The entropic brain: Effortful speech reflected in the network graph organisation**

*Jeong-Sug Kyong, Chun Kee Chung, June Sic Kim, & Ki-Young Jung*

Language might have evolved to maximise information exchange over a wider network of individuals (Dunbar, 1996). We often confront with various vocal communication adversities, due to background noise or insufficient spectral/temporal detail of a speech. In order to deal with the adversity, humans might have solved the problem by increasing mental effort. One of the measures to quantify mental effort is the Shannon's entropy (Shannon, 1948): Entropy increases as the disorder (uncertainty or task complexity) increases. We put forward two hypotheses: 1) functional brain architecture will reflect the varying entropy and 2) the entropy will be modality-specific. Tests of these hypotheses were carried out by estimating network properties, while aiming to quantify the neural entropy dynamics. Results showed a pronounced task-specific difference in the network properties between linguistic and non-linguistic modalities. In the effortful tasks, the characteristic path length and the correlation coefficient were significantly larger whilst the linguistic tasks resulted in the significantly higher small-worldness, with the hubs at the usual language nodes. Our findings collectively suggest that task load is ubiquitous but is modality-specific in the brain network properties as is evidenced by the specific network graph measures.

## Computational study about evolutionary process and adaptability of recursive operation in behavioral level

*Toya Genta, & Takashi Hashimoto*

Human language has a notable feature in that words are organized hierarchically into sentences. According to generative linguistics, the hierarchical structure can be formed by recursive application of the syntactic operation called “Merge.” In addition, recursive manipulation was observed only in humans in an experiment where infants and chimpanzees combined cups (Greenfield, 1972). Adopting the hypothesis that recursive object manipulation is a precursor of the syntactic ability of language, we consider evolutionary environments and the processes of recursive operation using an evolutionary simulation of the tool making behavior. We found that recursive operation can evolve when the act of making a specific complex tool or making diversified tools were adaptive. This means that the recursive operation has adaptability for diversifying the methods used to make a specified product or for multiplying the variety of products. We also found that low manipulation costs encourage the evolution of recursive operation, and competition for resources prompts the formation of an environment where making diversified tools is adaptive. We consider that manual dexterity evolved in the Plio-Pleistocene period (2.4 mya) of the human evolutionary history, and climate change in this period could trigger low cost and a competitive environment. Furthermore, an observed evolutionary process implies that genes supporting tool using behavior neutrally evolved and preceded those of tool making and preserving.

Greenfield, P., Nelson K. & Saltzman, E. (1972). The development of rule bound strategies for manipulating seriated cups: A parallel between action and grammar. *Cognitive psychology*, vol. 3, pp. 291-310.

## Conceptualization for Sharing Images in Displaced Communication: A Comparative Analysis of Hearing and Deaf Communities

*Kaori Tamura, Tomohiro Okada, Mayumi Bono, & Takashi Hashimoto*

This paper analyzes differences in the conceptualization of image sharing between the hearing and Deaf communities. Displaced communication—for example, the speaker’s mentioning of something that the recipient has not known—is a unique characteristic of human language, whether spoken or signed. We assume that revealing the conceptualization process for sharing images in displaced communication is a valid way of illuminating the evolution of linguistic communication. Experimental Semiotics attempts to observe emerging processes of communication. Following this approach, we compared data from graphical communication games in hearing and Deaf participants to examine the general strategies and formative processes used in conceptualization. Pairs of participants engaged in a task in which the sender drew an assigned object on a tablet PC and the receiver applied an adjective and noun to the drawing. We found that hearing participants tended to represent objects using abstract descriptions such as typical entities and relevant physical motions to represent adjectives. By contrast, Deaf participants tended to use concrete descriptions such as a variety of facial expressions and real-life situations. In this presentation, we discuss differences in the level of conceptualization between the hearing and Deaf communities.

## Perceptual learning of distorted speech across languages: evidence from English-Japanese bilingual on the noise vocoded speech

*Takuma Kitayama, Shota Murai, Kohta I Kobayasi, & Hiroshi Riquimaroux*

Speech perception is a robust and highly adaptive process. Previous research showed that comprehension of noise-vocoded speech sounds (NVSS) rapidly improved with short periods of training. What level of information is required for this improvement, however, is still largely unknown. To address the question, we investigate the language specificity for the perceptual learning of NVSS comparing bilingual and monolingual speakers. Eight monolinguals (Japanese) and 8 bilinguals (English and Japanese) participated in comprehension training using 4-band-NVSS English words. Before and after the training intelligibility of 4-band-NVSS Japanese words were measured to quantify transfer of the adaptation across language. As results, both monolingual and bilingual showed significant improvement in understanding of NVSS English words, demonstrating the effect of training. Average correct percentage of mora of Japanese NVSS, however, showed significant increase only in Japanese monolinguals (by 15.9%), and no significant effect of training in bilinguals (the score decreased by 0.6%) was observed. Our data revealed that NVSS training on English affected comprehension ability of Japanese NVSS differently between Japanese monolingual and English-Japanese bilingual. The result suggested that language specific process was involved in the perceptual learning of NVSS.

## Action potentials generated by optical stimulation to the round window in Mongolian gerbil

*Yuta Tamai, Suguru Matsui, Kohta I. Kobayasi, & Hiroshi Riquimaroux*

Action potentials have been reported to be evoked by irradiating infrared laser to neurons. Optic stimulation is able to stimulate cochlea nerve without contacting the tissue unlike electric stimulation. Our long-term goal is to develop hearing aid using optic stimulation. Hearing aid using optic stimulation may be able to stimulate cochlear nerve without contacting the tissue. Therefore, hearing aid using optic stimulation has noninvasiveness unlike cochlear implant. We investigated whether pulsed infrared laser may generate optic brainstem responses (OBR) in peripheral hearing loss condition. Mongolian gerbils were used as subjects and their tympanic membrane and auditory ossicles in the middle ear were destroyed to cause peripheral hearing loss. The radiation exposure was set at 0.02 -1.17 W/cm<sup>2</sup>. Intensity of acoustic stimuli was 50-80 dB Pe SPL. The laser fiber was placed in the middle ear and was directing to a round window to stimulate the cochlear nerve. Auditory brainstem responses (ABR) and OBR were measured by electrode inserted into the inferior colliculus. As results, ABR was not observed but OBR was observed in the gerbil with peripheral hearing loss. Optic stimulation may be applied for the hearing aid because contactless stimulation may produce action potentials in the cochlear nerve in Mongolian gerbil with peripheral hearing loss.

## **Sensitivity shift of auditory periphery in Mongolian gerbil: the comparison between communicating and single-animal**

*Hiroyuki Miyawaki, Ayako Nakayama, Kohta I. Kobayasi, & Hiroshi Riquimaroux*

Our auditory nervous system is specialized to analyze speech signals, and the tight coupling between auditory and vocal system could be a physiological basis of our vocal communication. Mongolian gerbil, *Meriones unguiculatus*, communicate with others by various sounds. About 80 percentage of those sounds range over 20 kHz. A threshold of hearing in this range, however, was about 20 dB higher than their most sensitive frequency (1 to 16 kHz). We proposed a hypothesis that the auditory sensitivity heightened when gerbils communicated with others. This study tested the hypothesis by recording cochlear microphonics (CM) as a measure of auditory sensitivity under various behavioral conditions. In paired condition, subject was set with other anesthetized conspecific. The power spectrum analysis of CM, evoked by pseud communication sound showed that CM response in paired condition was higher by 2 to 4 dB than in single condition. Then, we further investigated if the CM increase was communication specific. Subject was trained to pay attention to sound stimuli using an electric shock as a positive punishment. After training, CM increased by at most 1.9 dB while animals were paying attention to the sound. Those results suggest that the sensitivity of auditory periphery increase while gerbils communicate with others, and that the increase could not be explained only by auditory attention.



## A comparative study of temporal pattern development in vocal learners

*Miki Takahashi, Kazuo Okanoya, & Reiko Mazuka*

Humans and songbirds are both vocal learners, a skill that requires the control of respiration. We analyzed three temporal features of sequential vocalizations in human infants and in Bengalese finches; 1) Note duration (ND); vocalizations with expirations, 2) Inter-onset-interval (IOI); between the onset of the preceding note and the onset of the following note, and 3) Inter-note-interval (INI); the silent period without any vocalization. Our goal was to determine whether developmental characteristics of the temporal parameters were shared in humans and songbirds.

In human infants, the distribution of IOI became diverse prior to the onset of babblings and then the distribution converged to the same range as in earlier phases. In Bengalese finches, frequency distributions of temporal parameters were widely distributed initially. But through development, these distributions gradually converged. Their developmental pattern of temporal parameters followed a different trajectory from that in humans. Babbling had been considered to be analogues to the subsong in birds (Doupe & Khuls 1999). However, our results suggested that the human infants and songbirds might be different in their strategy to control both respiration and vocalization.

Doupe, A. J., & Kuhl, P. K. (1999). Birdsong and human speech: common themes and mechanisms. *Annual review of neuroscience*, 22(1), 567-631.

## Bipolarity Hypothesis of Language

*Minoru Ohtsuki*

A language does not exist in isolation but in relationship with other linguistic counterparts, primarily with other variants of the same language, and secondarily with other individual languages. Variants of a language include its former stages (in time) as well as its regional and social dialects (in space).

We propose the Bipolarity Hypothesis of Language: the existence of two competing but unequal linguistic variants, one of which is the stronger and the other the weaker, is a requisite for the existence of an individual language.

It is neither monopolarity (only one variant) nor mere pluripolarity (existence of scattered monopoles, lacking a unifying power) but bipolarity that allows dynamic historical change and dialectal variation (cf. n-bipolarity). Linguistic poles are of the following types: (a) styles (e.g. written French / spoken French), (b) social dialects (e.g. aristocratic Japanese / vulgar Japanese in ancient Kyoto), and (c) regional dialects (e.g. British English / American English). Shifts could take place between poles or different types of poles. The history of Japanese observed shifts in this order : (a) > (b) > (c) (Kindaichi et al. 1988, Hida et al. 2007).

A monopolar language could become endangered or cease to be alive (even if change should be possible, it would only be a passive and external one). On the other hand, a “dead language” could be revived through the introduction of bipolarity, as happened in the case of Classical Hebrew (St. John 1952). Similar phenomena of bipolarity can also be found in such fields as topology and astrophysics.

## Recent brain-related gene mutations and the emergence of our language-ready brain

*Antonio Bentez-Burraco, Constantina Theofanopoulou, & Cedric Boeckx*

The sequencing of the genomes from extinct hominins has revealed that the coding regions of several dozens of genes have changed after our split from Neanderthals/Denisovans. The latter species were certainly able to communicate and had rich conceptual representations, but some human-specific traits still distinguish our mode of cognition and of communication from theirs. We claim that most of the brain-related genes selected in our species are functionally interconnected. They are involved in skull and brain morphology, neural connectivity, and sensorimotor learning. We focus on three subsets of genes here.

The first subset is centered around RUNX2, involved in skull and brain development. The evolutionary modification of this network may account for our more globular head shape and for the concomitant rewiring of different connections between cortical and sub-cortical structures, which provide the scaffolding for our species-specific mode of cognition. The second subset is centered around the ROBO1 and FOXP2, two gene sets that have been repeatedly associated to speech disorders, and which emerge from the literature as prominent molecular signatures of vocal learning and motor control. The third set is clustered around PAX6 and AUTS2 and provides additional robust links between the two main networks we have uncovered.

## Quantifying the Strength of Evidence for Common Ancestry in Historical Linguistics

*Emi Okayasu*

While much of traditional historical linguistics is concerned with reconstructing the characters of ancestral languages on the basis of extant or attested characters in daughter languages via the Comparative Method or internal reconstruction, much of this research either requires or presupposes knowledge about the genealogy and evolutionary history of various languages.

Here I propose a model (based on Sober and Steele's 2015 model for evolutionary biology) that uses the law of likelihood to quantify the relative strength of two genealogical hypotheses: that two languages are daughter languages of a common ancestral language, or that they descend from separate ancestors. The relative strength of each hypothesis on this model depends not just on the quantity of shared characteristics between two daughter languages, but also on the quality of those shared characteristics, most saliently, whether the shared characters are shared retentions (synapomorphies) from the ancestral language or whether they are shared innovations (symplesiomorphies). Following Brugmann's foundational observation (1884) that shared innovations are evidentially more significant than shared retentions in judgments of linguistic subgroupings, my model clarifies this observation by quantifying the relative strength of synapomorphic character similarities to symplesiomorphic character similarities.

## Communication increases the expressivity of emergent languages in an open-ended meaning space

*Jon W. Carr, Hannah Cornish, Kenny Smith, & Simon Kirby*

The meaning spaces typically used in iterated learning experiments (e.g. Kirby, Cornish, & Smith, 2008) are unlike natural language, which is characterized by open-ended structure. Some recent experiments have used continuous spaces (e.g. Perfors & Navarro, 2014; Silvey, Kirby, & Smith, 2013), but these do not fully address the open-ended nature of meaning. We have constructed a meaning space based on randomly generated triangles that is continuous, high-dimensional, open-ended, and not pre-determined by the experimenter. Participants in our experiments learned an artificial language describing these triangles. The first participant in a transmission chain was taught words that were generated from a finite set of syllables. Subsequent participants were trained on the output of the previous participant in the chain. The set of stimuli that participants were tested on was different at every iteration. This experimental paradigm models discrete infinity (see Studdert-Kennedy, 2005 for some discussion), since a finite set of symbols is used to describe an infinite and ever-changing set of meanings. In our first experiment, the emergent languages arbitrarily divided the meaning space into a small number of categories based on the size and shape of the triangle stimuli. Our second experiment added dyadic communication to the paradigm which greatly increased the expressivity of the languages. These more expressive languages made more nuanced distinctions by making use of compositional structure. This suggests that communicative pressures are required for compositionality to arise in more complex, higher-dimensional meaning spaces.

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Perfors, A., & Navarro, D. J. (2014). Language evolution can be shaped by the structure of the world. *Cognitive Science*, 38(4), 775–793. doi:10.1111/cogs.12102

Silvey, C., Kirby, S., & Smith, K. (2013). Communication leads to the emergence of sub-optimal category structures. In M. Knauff, M. Pauen, N. Sebanz, & I. Wachsmuth, *Proceedings of the 35th annual conference of the Cognitive Science Society* (pp. 1312–1317). Austin, TX: Cognitive Science Society.

Studdert-Kennedy, M. (2005). How did language go discrete? In M. Tallerman, *Language origins: Perspectives on evolution* (pp. 48–67). Oxford, UK: Oxford University Press.

## **Preference for complex songs might emerge from peak shift in female songbirds: a demonstration by operant discrimination.**

*Giorgia Caspani, Tucker Gilman, & Kazuo Okanoya*

In Bengalese finches (BF), the main criterion for mate choice is song evaluation, with complex vocalisations being an indicator of male quality (Soma & Okanoya, 2013). Since mating to a complex singer indirectly increases female fitness, a bias in female preference will be expected. We predicted that peak shift (Spence, 1937) - a behavioural phenomenon by which animals tend to maximise their response to extreme versions of a known advantageous stimulus - will occur in BFs after song discrimination, and that this mechanism accelerated the emergence of a preference for complexity.

We performed operant conditioning to train five females to discriminate between a complex (Go) song and a simple (NoGo) song, varying in the number of trill repetitions. During testing, the birds were presented with six songs of different levels of complexity and their response to each stimulus was quantified. Trend analysis showed a systematic rise in the strength of the response as the trill repetitions increased. Direct comparison between the training Go stimulus and the successive, more complex probe stimulus demonstrated a significant difference in the response evoked, with a response bias towards the exaggerated version of the Go stimulus. We concluded that the peak shift effect is observable in female BFs. Such gradual shift in female preference towards more and more complex songs, by means of sexual selection, could explain the fast development of BF songs into more complex vocalisations.