FY2023 Annual Report

Neuronal Mechanism for Critical Period Unit (Yoko Yazaki-Sugiyama)
Professor Yoko Yazaki-Sugiyama

Abstract

Songbirds learn to sing vocalize intensively through social vocal communications during development as humans learn to speak. Our lab has been investigating the neuronal mechanism underlying how early auditory experiences shape neuronal circuits for song learning and auditory perception and how the time window for this neuronal circuits wiring is regulated by using zebra finch, one of premier model of songbirds. Interestingly, zebra finch juveniles learn efficiently through social interaction with a tutor, while they learn little from passive auditory song experiences. Recent years we also have worked on how social interaction regulate effective song learning and found the neuronal circuit from the attention control nucleus, Locus Cereleous (LC) to the higher auditory cortical area, NCM, authenticate social information for song learning via vocal communication. We have started to elucidate how this neuronal circuit change their activities during development regarding regulating the time window of developmental critical period. As we also found transient neuronal projections from NCM to the song motor control area which subserving song learning, we also have established the new project where we are trying to do genetic profiling of these neuronal subsets.

1 Staff

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2 Collaborations

Luke Ramegy-Healry (U Mass) for GABA inhibitory control of auditory activity in zebra finch higher auditory cortical neurons (Supported by NIH RO1 grant)

Jon Sakata and Sarah Woolley (McGill Univ) for innate restriction in bird song learning (Supported by CIHR grant)

Takao K Hensch (WPI-IRCN, the University of Tokyo) for regulation of the timing critical period by neuronal inhibitory function development (Supported by OIST KICKS grant)

Masafumi Kuroda and Daisuke Taniguchi (WPI-IRCN, the University of Tokyo) for the development of whole brain axonal tracing and annotations

3 Activities and Findings

3.1 Transient auditory-motor neuronal projections during developmental zebra finch song learning period

Memory recall and guidance is essential for motor skill acquisition. Like humans learning to speak, male zebra finches learn to sing by memorizing a tutor's song then vocally matching it in sequentially well-orchestrated auditory then sensorimotor developmental learning periods. Yet, the neuroanatomical substrate supporting auditory memory-guided sensorimotor learning has remained elusive. We identified a transient neuronal projection into the motor control region, HVC, from the neuronal ensembles responsive to the playback of tutor's song in the auditory forebrain area, caudomedial nidopallium (NCM). In turn, virally-induced cell death of neurons activated earlier by hearing their tutor's songs in the juvenile NCM impaired song learning, while the same deletion in adulthood had no such effect on faithful song production. Dynamic pruning of long-range axonal projections thus suggests regulating auditory memory-guided vocal learning during a specific juvenile period in zebra finches. Persistence of exuberant connections with enriched experience in the same period may increase the capacity of song circuits in adulthood, implicating similar underlying mechanisms in human bilingualism (Louder et al, in press). We have established the following project where we are trying to understand how the dynamic neuronal rewiring in the NCM-HVC circuit is regulated with experiences (collaboration with Kuhn Unit) and the underlying molecular mechanism.

3.2 Neuronal circuit for detecting individual difference encoded in sequential

variations of elements in zebra finch songs

Zebra finches recognize their own species song as well as individual identity in songs. However, the neuronal mechanisms allowing them to detect individual differences in parallel with species-specificity have yet to be elucidated. We found that various zebra finch songs share acoustically similar song elements but those differ in their sequential arrangement between individuals. With single unit electrophysiological recording in vivo we also found each neuron in a higher auditory area the caudal nidopallium (NCM) detected only a small subset of zebra finch songs, while NCM neuronal ensembles responded to all zebra finch songs presented. Notably each of 18 songs presented was responded by distinct combinations of neurons. Subsets of NCM neurons were sensitive to sequential arrangements of specific elements, which dramatically increase a capacity of song variations with limited numbers of species-specific elements. Taken together, our results suggest the mechanism for recognizing all specie-specific individually unique songs with sparse coding of individual NCM neurons. (Chang et al, in prep).

3.3 Effect of social interaction on brain functions sensing through wireless biosensing devices.

Social interaction, especially during development, has been suggested to have impacts on brain functional development and consequently behaviors. However, monitoring brain functions during animals/humans have natural social behaviors is almost impossible due to the needs of wired and/or heavy/big equipment sitting on the head. To overcome this problem, we are trying to develop biosensing devices to measure biophysical conditions such as, blood pressure, body temperature which change depending on internal conditions of animals, such as stress, attention or motivation. We then will develop mathematical modeling predicting brain functions from biophysical measurements (collaboration with Pao unit). This is a collation project with Seiko Instruments Ltd. and the Univ of Tokyo.

4 Publications

4.1 Journals

Nothing to report

4.2 Books and Other One-Time Publications

Nothing to report

4.3 Oral and Poster Presentations

Sarah Morson, Yuichi Morohashi & Yoko Yazaki-Sugiyama, Investigating the functions and connections of individual sub-regions in the zebra finch higher auditory cortex. the 45th Annual Meeting of the Japan Neuroscience Society, 2023 July, Sendai

Zhehao Cheng & Yoko Yazaki-Sugiyama, Neural mechanisms underlying complemental species and individual song discrimination in the zebra finch higher auditory cortex. the 45th Annual Meeting of the Japan Neuroscience Society, 2023 July, Seidai

Jelena Katic, Ryosuke Isogai, Minghao Nie, Yuidai Imano, Junya Nonaka, Shoji Takeuchi, Yoshifumi Yoshida & Yoko Yazaki-Sugiyama, Autonomic biomarkers correlate brain activity during social behaviors in zebra finches. the Annual Meeting of the Society for Neuroscience, 2023 November, Washington DC

Joanna A. Komorowska-Muller, Yuichi Morohashi & Yoko Yazaki-Sugiyama Transient connection from tutor-song-responsive neurons in NCM to HVC disappears at the end of the critical period. the Annual Meeting of the Society for Neuroscience, 2023 November, Washington DC

Yuichi Morohashi, Noriyuki Toji, Yasuhiro Go, Kazuhiro Wada & Yoko Yazaki-Sugiyama, Molecular profiles of auditory tutor song memory neurons, transiently projecting to song premotor area in zebra finches. the Annual Meeting of the Society for Neuroscience, 2023 November, Washington DC

Zhehao Cheng & Yoko Yazaki-Sugiyama, Neural mechanisms underlying complemental species and individual song discrimination in the zebra finch higher auditory cortex. the Annual Meeting of the Society for Neuroscience, 2023 November, Washington DC

Invited lectures at conferences

The 2023 Birdsong Symposium "Birdsong X: Welcome Back!" satellite event at SFN "Transient auditory to motor neuronal projection subserving developmental song learning in zebra finches", George Washington University, Washington DC, USA, Nov 2023

5 Intellectual Property Rights and Other Specific Achievements

Nothing to report

6 Meeting and Events

6.1 Symposium

Nothing to report

7 Others

Nothing to report