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Author(s)	Imai, Raimu; Sawai, Azusa; Hayase, Shin et al.
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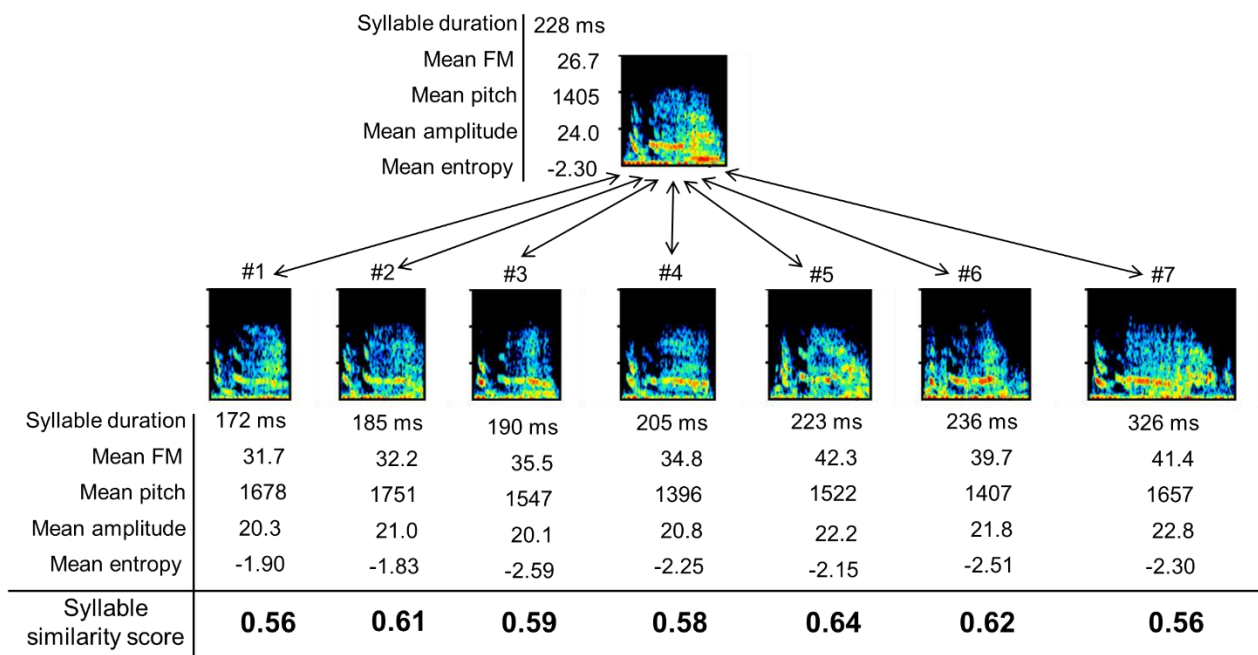


Supplementary materials

A quantitative method for analyzing species-specific vocal sequence pattern and its developmental dynamics

Raimu Imai¹, Azusa Sawai¹, Shin Hayase¹, Hiroyuki Furukawa¹, Chinweike Norman Asogwa¹, Miguel Sanchez¹, Hongdi Wang¹, Chihiro Mori¹, and Kazuhiro Wada^{1, 2, 3 #}

¹Graduate School of Life Science, ²Department of Biological Sciences, and ³Faculty of Science, Hokkaido University, Sapporo, Hokkaido, Japan, 060-810



Supplementary material 1

An example of comparisons of syllable similarity scores between syllables with a variety of durations and other acoustic features taken from a plastic song at the juvenile stage

a	b
c	d

$\sigma = 0.86$ (as the mean value of same/syllables syllables)

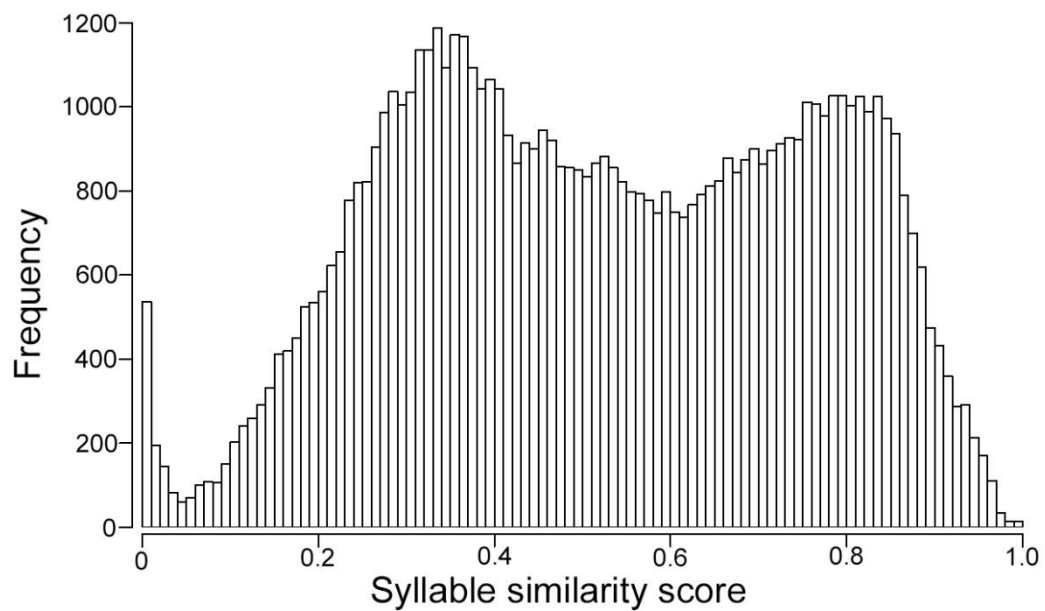
$\rho = 0.33$ (as the mean value of different syllables)

Possible syllable transition type

Type I		$t1 = ((a - \rho)^2 + (b - \sigma)^2 + (c - \sigma)^2 + (d - \rho)^2)$
Type II		$t2 = ((a - \sigma)^2 + (b - \sigma)^2 + (c - \sigma)^2 + (d - \sigma)^2)$
Type III		$t3 = ((a - \rho)^2 + (b - \rho)^2 + (c - \rho)^2 + (d - \rho)^2)$
Type IV		$t4 = ((a - \sigma)^2 + (b - \rho)^2 + (c - \rho)^2 + (d - \sigma)^2)$
Type V		$t5 = ((a - \rho)^2 + (b - \rho)^2 + (c - \sigma)^2 + (d - \rho)^2)$
Type VI		$t6 = ((a - \sigma)^2 + (b - \rho)^2 + (c - \rho)^2 + (d - \rho)^2)$
Type VII		$t7 = ((a - \rho)^2 + (b - \sigma)^2 + (c - \rho)^2 + (d - \rho)^2)$
Type VIII		$t8 = ((a - \rho)^2 + (b - \rho)^2 + (c - \rho)^2 + (d - \sigma)^2)$
Type IX		$t9 = ((a - \sigma)^2 + (b - \rho)^2 + (c - \sigma)^2 + (d - \rho)^2)$
Type X		$t10 = ((a - \rho)^2 + (b - \sigma)^2 + (c - \rho)^2 + (d - \sigma)^2)$
Type XI		$t11 = ((a - \rho)^2 + (b - \rho)^2 + (c - \sigma)^2 + (d - \sigma)^2)$
Type XII		$t12 = ((a - \sigma)^2 + (b - \sigma)^2 + (c - \rho)^2 + (d - \rho)^2)$

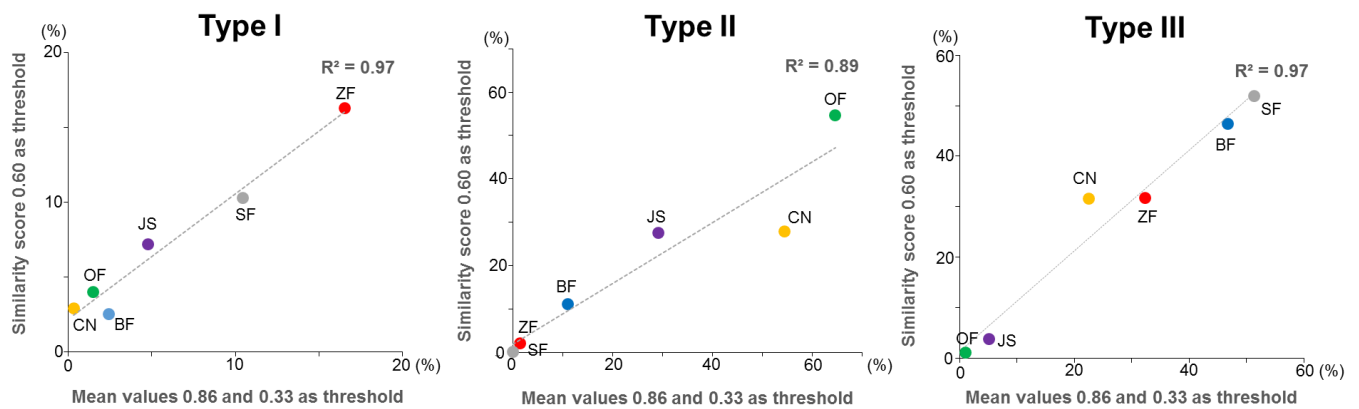
Supplementary material 2

Matching calculation was performed to find the most similar binarized pattern from 12 possible patterns of 2 x 2 cells. Sum of distances from the mean values of similar/same (colored with black, σ) or different (colored with white, ρ) syllables were calculated. A pattern type shown with the smallest value in the 12 patterns (t1–12) was determined as the most similar binarized pattern for the 2 x 2 cell.



Supplementary material 3

The distribution of syllable similarity scores of 240,000 syllables from six songbird species at the adult stage (ZF, OF, SF, BF, JS, and CN; $n = 4$ birds/each species, 1000 syllables/bird)



Supplementary material 4

Two different threshold settings for cell binarization - the mean value of 0.86 and 0.33 (as used in this study) or the similarity score 0.60 threshold (as boundary similar and different) - resulted in consistent calculations of the occurrence rates of the syllable transition types I, II, and III. These two threshold settings represented similar values of the occurrence rates of the syllable transition types for individuals of the six species shown in Figure 2.