Journal of Avian Biology

JAV-00383
Ota, N. and Soma, M. 2014. Age-dependent song changes in a closed-ended vocal learner: elevation of song performance after song crystallization. – J. Avian Biol. doi: 10.1111/jav.00383

Supplementary material

Appendix 1

To determine when note structure is stabilized and the song-learning period finishes, we calculated "Kullback-Leibler distance" following the method of Wu et al. (2008). The K-L distance analysis allows us to compare the probability density function from two large sets of notes and quantify the difference. To calculate it, we recorded the songs of five sons at least four times until birds were 234 days old. Then, we measured each note's duration and peak frequency. We analyzed 300–500 notes per recording. We calculated the K-L distance between data from the latest song and other songs for each individual. Larger K-L distance values indicate that two patterns are more dissimilar, and a K-L distance of 0 indicates a perfect match. The formula of K-L distance is as follows:

$$D_{kl}(Q_l \,\|\, Q_k) = \sum_{m=1}^{M}\sum_{n=1}^{N} q_l(m,n)\log_2\frac{q_l(m,n)}{q_k(m,n)}$$

where Q_l is estimated probability density functions at the latest song used in this analysis, Q_k is estimated probability density functions at k-days-old song, $q_l(m,n)$ is estimated probability for bin (m,n) for the latest song. We partition the two-dimensional scatter plot into an m by n array of bins and $q_k(m,n)$ is estimated probability for bin (m,n) for k days old song. In this analysis, syllable duration is partitioned into 22 equally-spaced bins and peak frequency is partitioned into 15 equally-spaced bins. Values of m and n were kept constant throughout all days of singing.

In this analysis, we found that song phonology seemed to stabilize around 150 to 180 days (Fig. A1). This result is consistent with our prediction based on visual inspection.

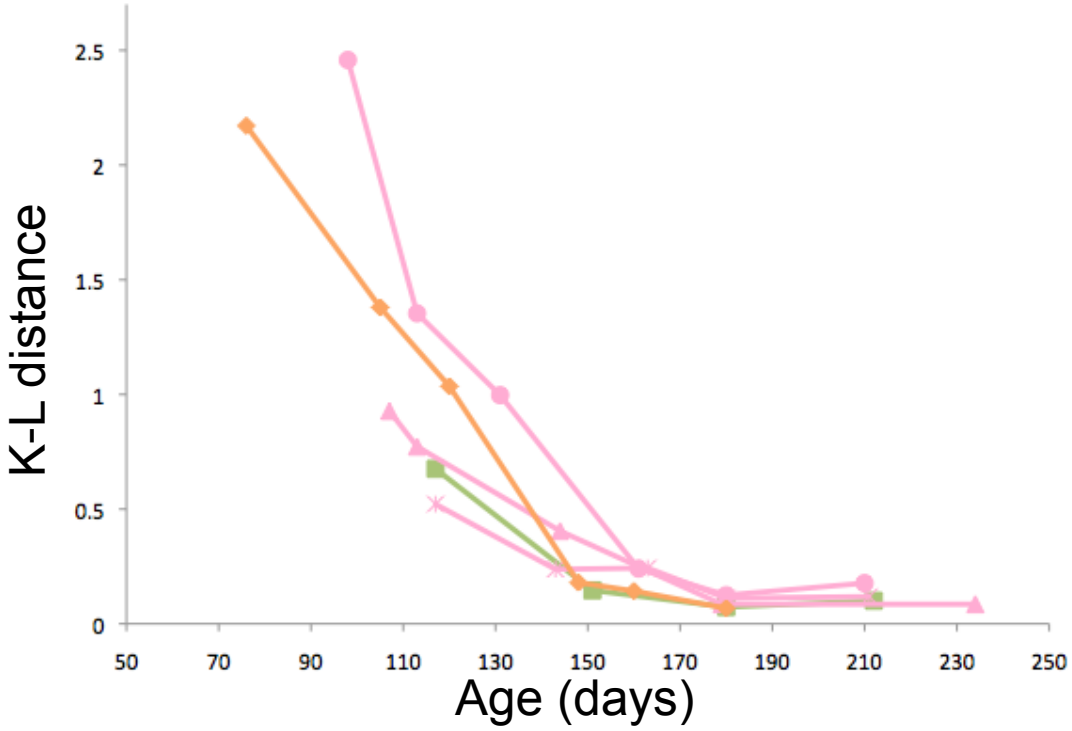

Figure A1. Age-dependent K-L distance changes.

Reference

Wei, W., Thompson, J. A., Bertram, R. and Johnson, F. 2008. A statistical method for quantifying songbird phonology and syntax. – J. Neurosci. Meth. 174: 147 – 154.

Appendix 2

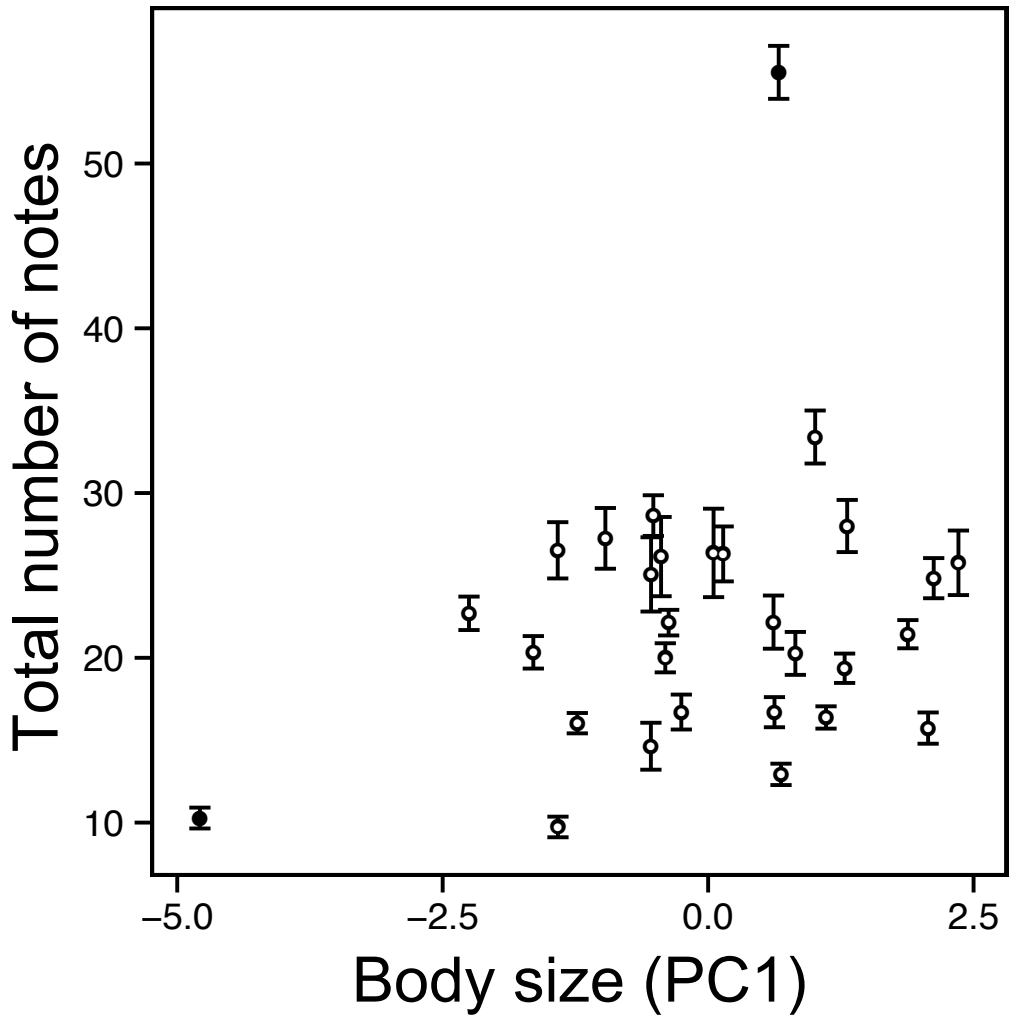

Figure A2. Effect of body size on total number of notes (± SE). There are two outliers (filled circles).

Table A1. GLMM analysis (random effect: song lineage/family lineage/bird ID) of the effects of early rearing condition and body size on song length soon after song crystallization. This analysis used 801 songs from 29 sons. The significant effect of body size on total number of notes disappeared when removing two outliers (p = 0.149, fig. A2).

Response variable	Fixed effect	Total number of data points	Estimate	SE	t/z	p	
Song duration	Intercept	801	3.434	2.466	t=1.393	0.164	LME, gaussian
	Age		<0.001	0.006	t=0.021	0.983	
	Brood size		-0.284	0.679	t=-0.419	0.685	
	Sex ratio		1.018	2.483	t=0.410	0.691	
	Brood size × sex ratio		0.178	0.826	t=0.215	0.835	
	Brood order		-0.036	0.550	t=-0.066	0.949	
	Body size (PC1)		0.279	0.149	t=1.876	0.093	
Total number of notes	Intercept	801	1.984	0.740	z=2.683	0.007	GLMM, poisson
	Age		0.002	0.002	z=1.327	0.184	
	Brood size		0.096	0.205	z=0.763	0.638	
	Sex ratio		0.831	0.778	z=1.512	0.285	
	Brood size × sex ratio		-0.151	0.246	z=-1.007	0.541	
	Brood order		-0.013	0.176	z=0.472	0.942	
	Body size (PC1)		0.110	0.050	z=2.950	**0.027**	