# Hour-scale slow changes in songs might reflect motivation and arousal in songbirds

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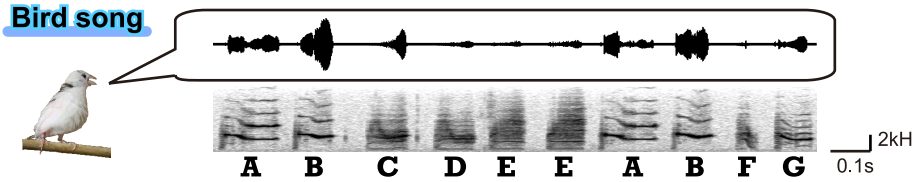
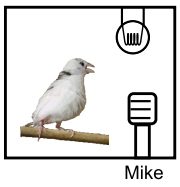
**Conclusions** Classified notes in the songs with as little human intervention as possible. ⟶ Worked well.
Characterized hour-scale change in the note sequence pattern. ⟶ Found periodic patterns.

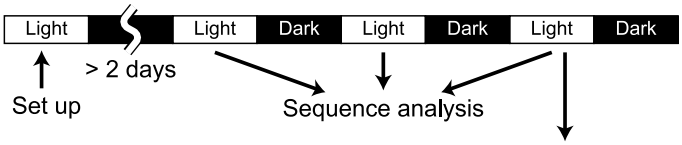
## Bird song




Complex temporal & spectral structure.
Multiple elements (notes) in a sequence.

## Song Recording




3 birds

20523±5992 notes
44.6±6.9 minutes in a day

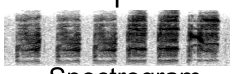
## Goal

Output label sequence

A A A B B C

Viterbi algorithm

Artificial neural network



Spectrogram

## Training

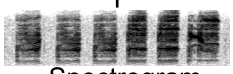
Correct label sequence

A A A B B C

Error backpropagation

Viterbi algorithm

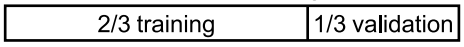
Artificial neural network



Spectrogram

(LeCun, et al., 1998)

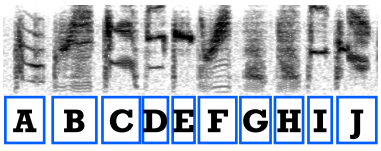
## Evaluation




With or Without note boundaries specified in training data
transition probability taken into account

A A → B 80%
C 20%

## Tipical result




Detected note labels & boundaries

## Validation score

$$\text{Error ratio} = \frac{\text{Levenshtein distance between correct \& output sequences}}{\text{Length of correct sequence}}$$

Transition scores

| Note positions | + | − |
|---|---|---|
| + | 0.21±0.14% | 0.28±0.19% |
| − | 0.33±0.15% | 0.36±0.11% |

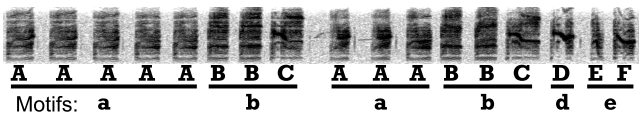
(Ave.±sd over 3 birds)

A A A B B C  A A A B B C
A A B B B C  A A  B B C
Error ratio = 1/6

Better with transition scores
note boundaries

## Motif-to-motif transition probabilities

**Motif: frequently appearing sequence pattern**

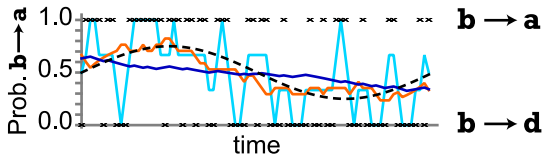



**Branch points in motif sequences**

b → a $P(x_t = \mathbf{a})$
b → d $P(x_t = \mathbf{d})$

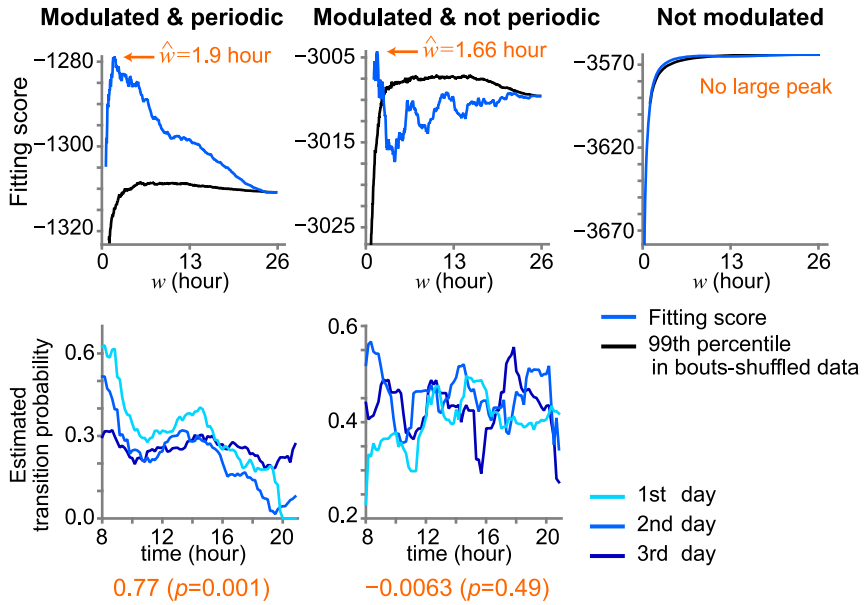
**Determination of the most suitable window width**

to best predict the observed data




Real probability (unobservable)
x Actual transition
Short window
Middle window
Long window

## Transition probabilities




0.77 ($p$=0.001)  −0.0063 ($p$=0.49)
Ave. correlation coefficients