Supplementary information

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Preparation of playback tutorial songs

The background songs (Source 1) to which we later added the tutorial syllables (Source 2 and 3) were prepared by using our long-term archive of song recordings that were collected in the same area where the playback tests took place. These recordings have been processed by using established standards. Songs were cut from recordings and followed by the segmentation of syllables with the help of Ficedula Toolbox (Zsebők *et al*., 2018) by marking manually the start and end points and the minimum and maximum frequencies of the syllables. Afterwards, syllables were clustered manually based on the spectrographic representation of them within-individually, and then between-individually resulting a final syllable library. This clustering process was helped by the Ficedula program by ordering the syllables by their acoustic similarity (see Zsebők *et al*. 2018 in detail). This process resulted a syllable library containing 2264 unique syllable types of 91468 syllables from 319 birds. The sounds around the syllables were cleaned manually in Adobe Audition 3.0 (Adobe Systems Incorporated, USA) with the help of the "Lasso selection" tool in the spectrogram view.

Before adding them to the playback sequence, we verified that chosen tutorial syllable types from the Source 2 and 3 were unknown for the focal populations. We used the same method for checking if Source 2 and 3 syllables are absent from the population's repertoire, as for the later screening of potentially learnt syllables. In both cases a huge amount of syllables has to be screened effectively. With this method, we matched the focal syllables against syllables in the whole syllable library (that contained the syllable types that we detected in the last 20 years). To make this comparison, we first automatically selected those syllables that reached a certain criterion for template matching by using the monitoR R package (Hafner & Katz, 2018; R Core Team, 2019). Accordingly, we marked those syllable types in our library (i.e. already known syllables) that provided a spectrographic cross-correlation of at least $r = 0.55$ with the generated foreign and modified syllable templates (i.e. supposedly unknown syllables). Then, we visually inspected these marked syllables to verify true match. The visual inspection revealed that none of the templates used as unknown syllables in the experiment could be found previously in our population.

The above mentioned r = 0.55 criterion was first calculated by recording the playback that contained the tutorial syllables and then tested by our two-steps method. Our test showed that the cut-off value of 0.55 is sensitive enough to reveal all true matches but at the cost of detecting a large number of false positives, which we selected through the visual inspection. Later, during the recordings of the focal males, we often recorded the playback from different angles and distances resulting different quality of recorded syllables. In these recordings, the tutorial syllables were discovered by our program that convinced us about our screening routine and the defined cut-off score.

When preparing the playback sequences, first, we randomly selected the baseline sequence of songs from the population-specific recordings from a preceding year (Source 1). Then we inserted three foreign (Source 2) and three modified (Source 3) syllable types at specific parts of the baseline sequence. In particular, we randomly chose one frequent and two rare syllable types in the baseline songs to replace with a particular tutorial syllable. Then these selected syllables were systematically changed in the whole baseline song sequence into the tutorial syllable by using Adobe Audition. By this approach we assured that we left the overall syllable sequence intact and familiar to the species. We opted to replace both rare and common syllable types, because of no prior information with regard to their roles in syllable learning.

Each playback sequence of songs with the replaced syllables included 6-11 songs (7 ± 1.4 songs in average ± SD). We created 5 sequences by randomizing the order of songs within each of these sequences and inserted small pauses (1 - 4 sec) between the songs, resembling the natural situation. Finally, we added a longer pause (10-40 sec) in a specific order to the end of each sequence in order to model pauses of a singing male in nature. (**Error! Reference source not found.**b in the main text). In 2018, we used altogether eight, meanwhile in 2019 five different playback sequences, each containing three foreign (Source 2) and three artificially modified (Source 3) syllable types, thus we used 13 different playback sequence stimuli.

The playback sequences had a sample rate of 44100 Hz, 16 bit quality, and converted to mp3 files for the playback devices.

Fieldwork

The field tests were performed in April and May of 2018-2019. Males involved in the study were free-living individuals occupying natural tree holes that were identified as unpaired males by their conspicuous courtship behaviour (i.e. singing and displaying).

The playback sequences were played as mp3 files, from Sony NWZ-B183F digital music players, through amplified (M031N Kemo amplifier, Germany) loudspeakers (Bose SoundLink Color Bluetooth II). The sound level was set to match the loudness of a singing collared flycatcher male as much as possible what was checked by a human listener. The individuals were not banded but identified by the locality of their territories (based on extensive field experience we can reasonably assume that singing males rarely change territories if undisturbed). The identity of individuals was also verified by the individual specific song content as well. This also ensured us that the recordings at a particular tree hole always corresponded to the same individual.

Similar to our long term database, recordings were made at a ca. 20 m distance from the nest hole of the focal male from a hiding position and possibly also distant from the playback, that provided a good-quality recording with a minimal disturbance from the playback source. We used a Sennheiser ME62 microphone and a K6 preamplifier, attached to a Telinga parabolic dish and to a Zoom H4n digital sound recorder (sampling frequency: 48 Hz, quality: 16 bit). Each recording was tagged with information on date, time, and GPS position.

In our recent tests we did not use any controls, however in a parallel experiment, where the setup (distance, volume) of the playback was similar, we found that collared flycatcher males have reacted (moved closer to the playback) to the song of conspecifics, meanwhile ignored the song of the European robin (*Erithacus rubecula*) as a control. Therefore, we are sure that birds were aware of the conspecific neighbour. Additionally, we also have to highlight that we simulated neighbouring males and not intrusions, as in case of intrusion the focal male stops singing and actively search for the sound source. Therefore, we placed the speaker out of the territory, in a distance where the focal male still reacts to the neighbouring male and continues singing.

References

Hafner, S. D., & Katz, J. (2018). Acoustic template detection in R.

R Core Team. (2019). R: A language and Environment for Statistical Computing.

Zsebők, S., Blázi, G., Laczi, M., Nagy, G., Vaskuti, É., & Garamszegi, L. Z. (2018). "Ficedula": An open-source MATLAB toolbox for cutting, segmenting and computer-aided clustering of bird song. Journal of Ornithology, 159(4), 1105–1111.

Supplementary Table

Table S1. The sources of the recordings containing the tutoring syllable types from distant populations.

Country	Xeno-Canto ID	Recorder	Location	Distance (km)
Bosnia Herzegovina	XC411430	Aidan Place	Ilidža, Kanton Sarajevo, Federacija Bosne i Hercegovine	520
Croatia	XC176239	Franck Hidvegi	Jezerce, Općina Plitvička Jezera, Lika-Senj County	500
Czech Republic	XC317844	Stuart Fisher	Nové Mlýny middle reservoir, South Moravia	400
France	XC318880	Dries Van de Loock	Sommeilles, Meuse, Alsace-Champagne-Ardenne-Lorraine	1100
France	XC318880	Dries Van de Loock	Sommeilles, Meuse, Alsace-Champagne-Ardenne-Lorraine	1100
Germany	XC414731	Frank Holzapfel	Naturpark Stromberg-Heuchelberg, Baden-Württemberg	860
Italy	XC375479	Egidio Fulco	Marsicovetere, Provincia di Potenza, Basilicata	1000
Italy	XC106163	Francesco Sottile	Carlopoli, Province of Catanzaro, Calabria	1300
Netherlands	XC415371	Joost van Bruggen	Vierhouten, Nunspeet, Gelderland	1200
Poland	XC327764	Patrik Aberg	Bialowieza	700
Poland	XC132481	Tomek Tumiel	Czarna Białostocka (near Gmina Czarna Białostocka), białostocki, Podlaskie Voivodeship	800
Poland	XC327764	Patrik Aberg	Bialowieza	700
Poland	XC246000	Jarek Matusiak	Gmina Białowieża (near Teremiski), hajnowski, podlaskie	700
Poland	XC459871	Mats Rellmar	Gmina Białowieża (near Białowieża), hajnowski, podlaskie	700
Poland	XC179198	david m	Bialowieza Forest	700
Sweden	XC449056	Patrik Aberg	Horns kungsgard	1300
Sweden	XC376323	Peter Ericsson	Ottenby, Öland	1300
Ukraine	XC240471	Jarek Matusiak	Klesiv, Sarnens'kyi district, Rivnens'ka oblast	800

The recordings are originated from the Xeno-Canto library. The last column indicates the distances between the recording sites of the recordings and the playback area.