

The Behavioral Influence of Nonlinear Sound in Lincoln's Sparrows

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Abstract

Animals that experience fear or stress may produce alarm calls, fear screams and mobbing calls and by doing so communicate their current state to conspecifics. These sounds are created by often easily identified because they contain nonlinear acoustic attributes that are somewhat acoustically unpredictable and sound harsh. The unpredictability hypothesis explains that because the nonlinearities are so variable and unpredictable, the sounds are difficult to habituate to. Animals should have increased responses to sounds with nonlinearities in them compared to sounds that don't have nonlinearities. We studied Lincoln's Sparrows (*Melospiza lincolnii*) and found that there are small but non-significant effects of non-linear sounds on sparrow behavior. This could be a function that the sparrows are relatively unhabituated and were responding more to the presence of the human than to the experimental playbacks.

Introduction

In cases when individuals are under stress, fear, or even arousal, they may produce harsh, unpredictable, nonlinear sounds (Slaughter et al. 2012). These nonlinearities can arise when the sound production system in individuals becomes overblown in various stressful

or alarming situations (Fitch et al. 2002). A good example of this is a righteous, honest scream from somebody truly experiencing a fearful or stressful situation. When this happens, too much air is being forced through the vocal system, making a noisy sound containing nonlinear acoustic attributes (Fitch et al. 2002). Morton's (1977) motivation-structural rules, suggest an evolution of the sounds animals produce in specific social situations through natural selection. This nonlinear sound due to its unpredictability gets the attention of other individuals more so than regular linear sounds (Slaughter et al. 2002). Different types of nonlinearities are frequency shifts, subharmonics, biphonation, and deterministic chaos (Fitch et al. 2002). These complex sounds are called nonlinear phenomena (Wilden et al., 1998; Fitch et al., 2002). These nonlinearities are difficult to habituate to (Fitch et al. 2002). Nonlinear phenomena that is harder to habituate to should bring about more evocative behavior to receiving individuals (Blumstein and Récapet, 2009). Previous studies have shown that some of these types of nonlinearities modify the regular behavior of individuals hearing the sounds (Blumstein et al. 2009, 2010, 2012; Slaughter et al. 2012; Blesdoe & Blumstein in revision). To test the hypothesis that nonlinearities are generally evocative, we used 4 novel synthesized sounds and 6 novel tropical king bird calls to a population of Lincoln's Sparrows (*Melospiza lincolnii*). Three of the synthesized sounds encompassed a type of nonlinearity (noise, frequency shift up, frequency shift down) while the 4th synthesized sound is a pure tone to act as a procedural control along with the tropical kingbird calls which will serve as a novelty control.

Methods

A single observer conducted a total of 100 playback experiments (18 of the Tropical King Bird, 20 white noise and pure tone, and 21 frequency shift down and frequency shift up) between 23 June 2013 and 16 July 2013, from 0530 to 1130 at times when it was not raining and when the wind was < Beaufort Scale 3. The playback tracks were stored on an Apple iPhone (Apple Inc., Cupertino, CA) in AIF format. The stimuli were broadcasted from a PAL speaker (Tivoli Audio, Boston, MA) at an amplitude of 85 dB SPL measured 1 m from the speaker (peak response, weighting level A). Each trial began with 30 s of silence during which time a single observer quietly dictated baseline behavior into a cassette recorder (ethogram in Table 1). Once the 30 s baseline period had passed, the stimulus was broadcast and followed by 60 s of silence during which behavioral observation continued. GPS coordinates, percentage cloud cover, distance from observer (m), distance subject is from the ground, and the number of conspecific/heterospecific avian species within 10 m were also recorded. Each trial was done with > 40 m distance between target birds to avoid testing the same bird. The average ($\pm$ SD) distance between birds was 49.35 ($\pm$ 47.39 m, min = 16 m, max = 448 m).

Analysis

The time allocated to each behavior was scored using JWatcher (Blumstein & Daniel 2007). We then calculated the difference from the baseline in the time allocated to relaxed, vocalization, locomotion and vigilance. The birds spent a substantial proportion of time looking in their baseline period. Because of this apparently heightened response (potentially to the observer), we focused on comparing the difference in time allocation

between the last 30 s of the trial and the 30 s baseline period. Time budget data were arcsine transformed for analysis. We first calculated 95% confidence intervals to determine whether the sparrows responded to the playback (CIs that did not include zero would signify a response. To answer our question if nonlinear sound affects the sparrows, we fitted GLM models (in SPSS 21.0, IBM, New York, NY) and compared treatments to each other (using Fisher's PLSD tests) to determine whether they were significantly different.

Because sparrows apparently responded to the kingbird novelty control, we excluded the trials from analysis. This exclusion was justified because this was not a within-subjects design. Finally, we used GLMs and Chi-Square tests to determine if there was a potential for confounding effects of other variables. We did so by seeing if treatments were conducted at different distances between the bird and speaker, the distance between birds, the distance between the bird and the road, the distance between the bird and the Gothic town site, and the bird's sex.

Results

95% CIs

Sparrows spent much of their time looking in the baseline period (approx. 60% of their time was spent looking; (Figure 1), but there were no significant differences as a function of treatment. The proportion time spent in locomotion increased slightly, but not significantly when birds were exposed to the frequency shift up and frequency shift down stimuli (Figure 2). The rate of looking was slightly, but not significantly, increased with

frequency shift up. The rate in locomotion was slightly increased with frequency shift up and frequency shift down. Vocalization was slightly suppressed, but not significantly, with noise and frequency shift up stimuli.

GLMs Including Tropical Kingbird

Few significant differences in bird response to playbacks were detected among our treatments including Tropical Kingbird calls. Arcsine transformed difference from baseline proportion time spent looking showed no significant treatment effects ($p = 0.278$). Pairwise comparisons in difference from baseline proportion time looking showed no difference with the Tropical Kingbird (noise $p = 0.480$, pure $p = 0.408$, shift down $p = 0.909$, shift up $p = 0.195$). Arcsine transformed difference from baseline proportion spent in locomotion showed no significant treatment effects ($p = 0.168$). Pairwise comparisons in difference from baseline in proportion time locomotion shows no difference with Tropical Kingbird (noise $p = 0.075$, pure $p = 0.765$, shift down $p = 0.189$, shift up $p = 0.279$), however, there was a difference between noise and pure tone ($p = 0.034$). Arcsine difference from baseline in proportion time spent in relaxed behaviors showed no significant treatment effects ($p = 0.440$). Pairwise comparisons showed no difference with Tropical Kingbird (noise $p = 0.074$, pure $p = 0.453$, shift down $p = 0.184$, shift up $p = 0.195$). Arcsine difference from baseline in rate of looking had no significant treatment effects ($p = 0.229$). Pairwise comparisons in difference from baseline of rate in looking behaviors showed no difference with Tropical Kingbird (noise $p = 0.559$, pure $p = 0.273$, shift down $p = 0.519$, shift up $p = 0.143$).

GLMs Excluding Tropical Kingbird

There were few significant differences in bird responses to playbacks excluding the Tropical Kingbird calls. Arcsine difference from baseline in proportion time spent in vigilance had no significant treatment effect ($p=0.174$). Pairwise comparisons showed no difference with the pure tone (noise $p = 0.111$, shift down $p = 0.450$, shift up $p = 0.211$), however there was a significant difference between noise and shift up ($p = 0.038$).

Arcsine transformed difference from baseline in proportion time spent in locomotion behaviors had no significant treatment effect ($p = 0.224$). Pairwise comparisons showed no difference with pure tone with shift down and shift up ($p = 0.124$ and $p = 0.186$ respectively), but there was a difference with pure tone and noise ($p = 0.047$). Arcsine difference from baseline in proportion time spent in relaxed behaviors had no significant treatment effects ($p = 0.661$). Pairwise comparisons showed no difference with pure tone (noise $p = 0.210$, shift down $p = 0.491$, shift up $p = 0.517$). Arcsine difference from baseline in the rate for vigilance had no significant treatment effects ($p = 0.185$). Pairwise comparisons showed no significant differences with the pure tone (noise $p = 0.093$, shift down $p = 0.635$, shift up $p = 0.517$), however, there was a significant difference in noise and frequency shift up ($p = 0.040$).

Confounding Variables

Our analyses of potentially confounding variables did not reveal any potential confounding variables (distance from road $p = 0.397$, distance from town $p = 0.671$, distance from speaker $p = 0.084$, distance between birds $p = 0.298$, sex $p = 0.943$).

Discussion

The sparrows did not deviate much from their baseline behaviors. This was likely because the initial time allocated to vigilance was around 60%. This could have been because we were too close to the sparrows. We are not sure why this is because in previous years similar experiments found significant effects using identical methods on different species (Blesdoe & Blumstein in revision). There could have been some other factor that influenced our ability to detect a response to our experiment. For instance distance to Gothic or distance to the road could have influenced the ability to detect a response. Gunther's dik-diks (*Madoqua guentheri*) and mule deer (*Odocoileus hemionus*) both were better able to discriminate threatening and non-threatening sounds when they were studied closer to people than farther away from people. This finding suggests that habituation is important if we are to study the response to threatening acoustic stimuli (Carrasco et al. 2011; Coleman et al. 2008). However, a previous study with white-crowned sparrows (*Zonotrichia leucophrys*) at the RMBL was able to detect some differences in birds studied throughout the valley (Blesdoe & Blumstein in revision). Overall, it seems that a larger sample size will be required to detect relatively small effect of this playback experiment.

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Literature Cited

- Blesdoe, E. K. & Blumstein, D. T. In Revision: What is the sound of fear?: behavioral responses of white-crowned sparrows (*Zonotrichia leucophrys*) to synthesized nonlinear acoustic phenomena. *Cur. Zool.*
- Blumstein & Daniel 2007: Quantifying Behavior The JWatcher Way. Sinauer Associates, Inc.
- Blumstein, D. T. & Recapet, C. 2009: The sound of arousal: the addition of novel nonlinearities increases responsiveness in marmot alarm calls. *Ethology* 115, 1074-1081.
- Blumstein, D. T., Davitian, R. & Kaye, P. D. 2010: Do film soundtracks contain nonlinear analogues to influence emotion? *Biol. Lett.* 6, 751-754.
- Blumstein, D. T., Bryant, G. A., & Kaye, P. 2012: The sound of arousal in music is context-dependent. *Biol. Lett.* 8, 744-747.
- Carrasco, M. F. & Blumstein D. T. 2008: Mule deer (*Odocoileus hemionus*) respond to yellow-bellied marmot (*Marmota flaviventris*) alarm calls. *Ethology* 118 1-8.
- Coleman, A., Richardson, D., Schechter R., & Blumstein, D. T. 2008: Does habituation to humans influence predator discrimination in Gunther's dik-diks (*Madoqua guentheri*)?. *Biol. Lett.* 4, 250-252.
- Fitch, W. T., Neubauer, J & Herzel, H. 2002: Calls out of chaos: the adaptive significance of nonlinear phenomena in mammalian vocal production. *Anim. Behav.* 63, 407-418.
- Morton E. S., 1977. Occurrence and significance of motivation structural rules in some bird and mammal sounds. *Am. Nat.* 111:855-869
- Slaughter, E. I., Berlin E. R., Brower J. T., & Blumstein, D. T. 2013: A test of the nonlinearity hypothesis in great-tailed grackles (*Quiscalus mexicanus*). *Ethology* 119, 309-315

Wilden, I., Herzel H., Peters G., Tembrock G., 1998. Subharmonics, biphonation, and deterministic chaos in mammal vocalization. Bioacoustics 9: 171-196

Table 1: Ethogram of behaviors being recorded during playbacks (From Slaughter et. al 2012)

Behavior	Description
Stand and look	Standing or perching, scored each time head moved and fixated
Forage	Moving head towards the ground to forage or having food in beak
Preen	Moving beak through feathers
Walk	Taking steps, moving legs individually
Hop	Jumping from one location to another, scored by each discrete hop
Flutter	A quick flapping or vibrating motion without flight
Vocalization	Singing or non-song vocalization, excluding chinking
Flight	Flying, but not out of sight
Out of sight	No longer in sight

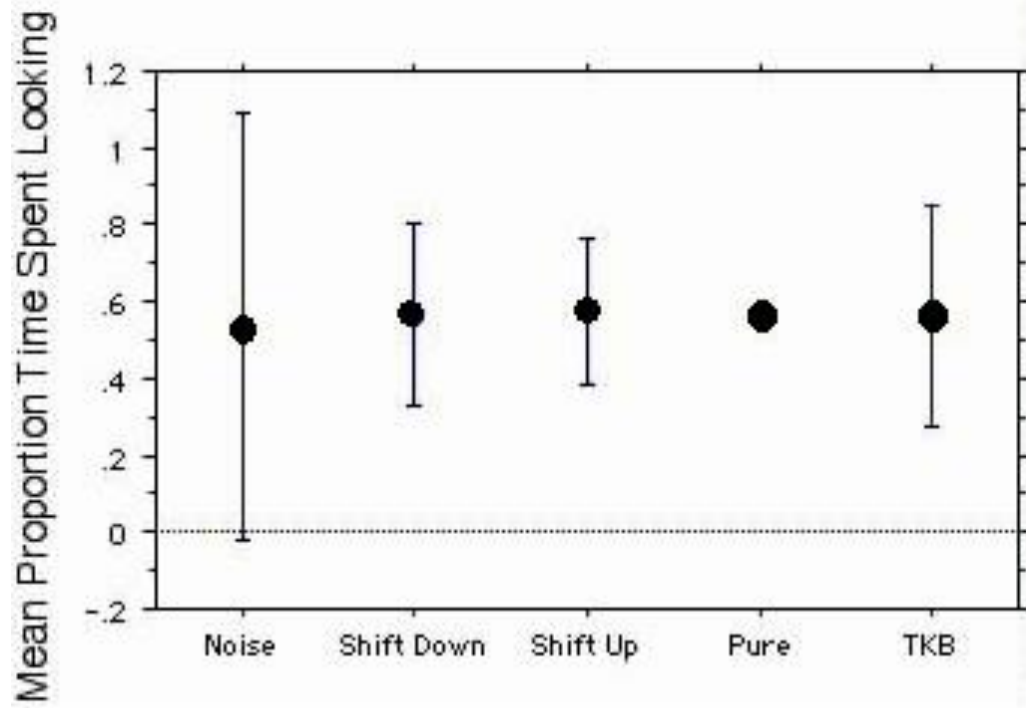


Figure 1. Mean proportion time in sight ($\pm$ 95% CI) allocated to looking in the baseline time period.

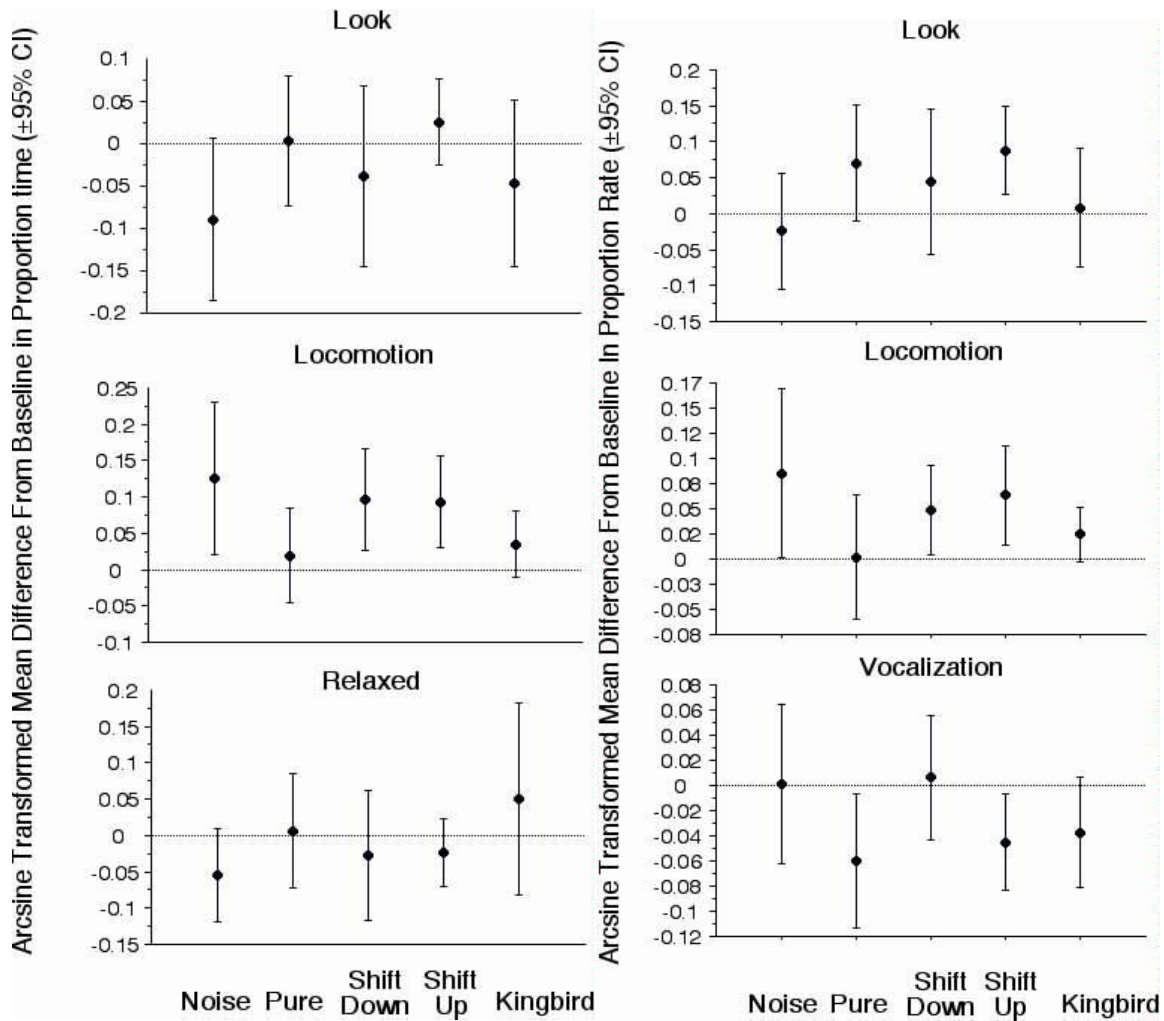
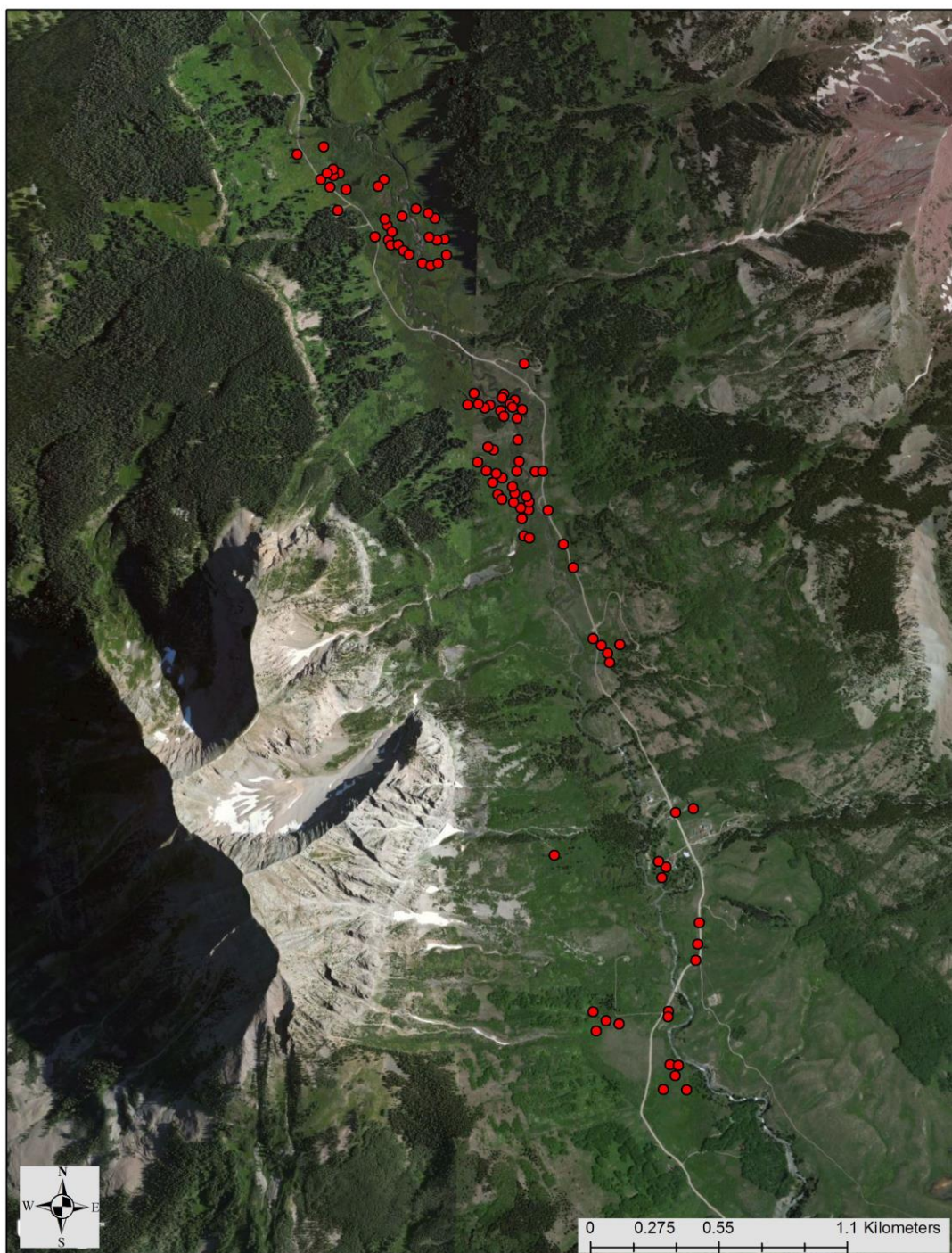


Figure 2: Change from baseline in the mean (± 95% CI) in the proportion of time allocated to behaviors (on the left graphs) change from baseline in the mean (± 95% CI) in the rate of behaviors (right graphs) after hearing one of the five experimental playbacks.



Map of the research site. Each dot represents one Playback Experiment.