

Do birds differentiate white noise and deterministic chaos? A playback experiment

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Abstract

Evocative sounds are known to elicit heightened responses from receivers across animal taxa. Many species of caregivers specifically have been shown to have increased arousal from infant baboon screams providing a unique conspecific identification for baboon mothers to discriminate their young from nearby infants (Rendall et al. 2009) to women decreasing their parasympathetic drive after exposure to infants crying, impelling them to react and care for the infants (Tkaczyszyn et al. 2012) to infant giant pandas (*Ailuropoda melaneuca*). Despite them being relatively common, the function of these nonlinearities is less well-understood. One hypothesis suggests that non-linearities function to increase fear and arousal in receivers (Blumstein and Recapet 2009; Slaughter et al., 2013). Playback experiments have been very useful in evaluation of this nonlinearity and fear hypothesis. In them, investigators have used white noise as a substitute for deterministic chaos. Deterministic chaos contains irregular oscillations with patterns of energy that are irregular and widely distributed over frequency bands (Beckers and Cate 2006). In acoustic spectrographs, chaos and noise appear superficially similar, but structurally they are different. We designed two experiments to clarify whether American robins (*Turdus migratorius*) and warbling vireos (*Vireo gilvus*) discriminate between white noise and deterministic chaos. Playback experiments consisted of broadcasting one of four types of stimuli at a time to a relaxed bird: white noise or deterministic chaos created from either logistic wave form or a Chua oscillator, and one control stimulus, one of four exemplars of Tropical Kingbird (*Tyrannus melancholicus*) vocalizations. Robins engaged in significantly less relaxed behavior after hearing noise compared to the kingbird treatment, and all noise/non-linearity treatments led to significantly less relaxed behavior than the kingbird treatment (pair-wise comparisons between kingbird and chua chaos. Pairwise comparisons did show that after hearing chua chaos, warbling vireos decreased locomotion significantly compared to kingbird. Our results suggest that American robins and Warbling vireos do not discriminate noise from at least two types of deterministic chaos: chua chaos and logistic chaos, thus indicating that future playback studies can continue to use white noise as a nonlinear stimulus.

Introduction

When extremely scared, individuals may scream or produce other sounds that overblow their vocal production system. These sounds have remarkably similar acoustic characteristics and may contain a variety of non-linear acoustic attributes. Non-linear acoustic attributes include frequency jumps, subharmonics, biphonation, and deterministic chaos (Figure 1). The nonlinearity and fear hypothesis suggests that nonlinearities, specifically the addition of ‘noise’, functions to increase fear and arousal in receivers (Blumstein and Recapet 2009). Playback experiments have evaluated this hypothesis in some birds and mammals (e.g., Slaughter et al. 2013; Blumstein & Recapet 2009; Blumstein et al.), but most of the studies have used white noise as a substitute for deterministic chaos. Is this a problem?

In audio spectrograms, chaos and noise appear superficially similar, but structurally they are different (Tokuda et al., 2002). Deterministic chaos contains irregular oscillations with patterns of energy that are irregular and widely distributed over frequency bands (Beckers and Cate 2006). Chaos is produced by vibrating vocal chords (Fitch et al. 2002) while white noise is produced by vocal tract constriction that creates airflow turbulence (Stevens, 1998).

The objective of this study was to determine whether noise and deterministic chaos elicits the same responses in receivers.

Methods

Study Site and Species

From 2 June 2015 to 10 July 2015, we conducted playback experiments on American Robins (*Turdus migratorius*) and Warbling Vireos (*Vireo gilvus*) near the Rocky Mountain Biological Laboratory in Gothic, Colorado (N 38.9592°, W 106.9898°). The goal was to expand the sample size collected in 2013 by Jessica Whitaker. Experiments were conducted from sunrise until mid-morning when it was not precipitating or windy (< 3 on the Beaufort Scale).

Playback Experiment

Playback experiments consisted of broadcasting one of four types of stimuli at a time to a relaxed bird: white noise or deterministic chaos created from either logistic wave form or a Chua oscillator, and one control stimulus, one of four exemplars of Tropical Kingbird

(*Tyrannus melancholicus*) vocalizations. The Tropical Kingbird playback provides a control for stimulus novelty that was necessary given that all the synthesized stimuli were novel.

We began playback experiments by observing the bird and quantifying its behavior for a 30s baseline period, followed by a brief playback, and 60 further seconds of behavioral quantification. Experiments were conducted 10-15 m from a relaxed subject (indicated by foraging, walking, or preening), from an iPod (Apple, Cupertino, CA), through a PAL Speaker (Tivoli Audio, Boston, MA) at a peak amplitude of 85 dB SPL (measured 1 m away). All behavioral transitions were quietly dictated into a digital audio recorder based on an ethogram consisting of the following behaviors: stand look, forage, preen, walk, hop, vocalization, flight, out of sight, and other (Table 1). Following the focal sample, the observer marked the GPS location, recorded wind speed, percentage of cloud cover, distance from observer (in m), distance from ground (in m), number of conspecifics within 10 m, number of heterospecifics within 10 m, distance from a road (< 20 or > 20), sex (if sexually dimorphism was obvious), and age (if obvious from plumage). Playback stimuli were broadcasted in a rota and with >100 m between successive playbacks to reduce the likelihood that the same subject is exposed to more than a single playback. Subsequently, trials were conducted a minimum of 5 minutes apart (Warbling vireo average 51 minutes, 6.9 seconds, stdev=0.0326, range =48, 11 minimum time apart, 59 maximum time apart & American robin average of 23 minutes 3.7 seconds, st dev=0.8977, range=7 hours 53 mintes, minimum apart 7 minutes, maximum 8 hours) and all stimuli were broadcast in a predetermined rota to avoid carryover effects on subjects that may have been previously exposed to a stimulus.

Data Analysis

Combining data collected in 2013 with data collected this summer, we conducted a total of, 114 playback experiments on American Robins (33 for the tropical kingbird stimulus, 28 for noise, 28 for logistic waveform, and 25 for Chua chaos), and a total of 91 playback experiments on warbling vireos (20 tropical kingbird, 24 noise, 24 logistic chaos, and 23 Chua chaos).

Focal recordings were scored in JWatcher (v1.0 Blumstein & Daniel, 2007), and we calculated the proportion of time in sight for allocated behaviors. We later defined

two additional behaviors by combining time allocations. For robins, relaxed behavior included time allocated to foraging, preening, and walking. For vireos, we also added time allocated to vocalizing. For both species, total locomotion was defined as hopping, flying, and walking.

Because responses were transient, we focused on the first 30s following playback. We calculated the change in time allocated to looking, relaxed behavior, and total locomotion in the first 30 s after hearing the playback compared to the 30 s baseline time allocation by subtracting the after minus the baseline times. We then arcsine transformed these differences to normalize variation. We constructed 95% CI to determine if the change in time allocation was significantly different from baseline for each treatment which would be inferred if the CIs included 0. We then fitted general linear models in SPSS v. 21 to compare response to the treatments and to calculate the planned comparisons between the response to the kingbird and the other three treatments and to see if noise and the two types of deterministic chaos led to similar responses. Throughout, our alpha was set to 0.05, we did not correct for the planned multiple comparisons, and we calculated Cohen's d-scores to compare the responses.

Results

Playback Experiments

We conducted several covariate analyses to determine if any confounding variables affected our results, and sex ($p = 0.583$), heterospecifics ($p = 0.413$), conspecifics ($p = 0.242$), height in trees (average = 1.15 m, $p = 0.512$), wind ($p = 0.817$) distance from observer (average distance = 11.6 m, $p = 0.171$), and distance from road ($p = 0.548$) did not have any significant results for American robins; for time between stimuli, there was an average of 23 minutes 3.7 seconds between playbacks with a standard deviation of 0.8977, range of 7 hours 53 minutes, minimum of 7 minutes apart, and a maximum of 8 hours apart, thus successfully avoiding carryover effects on subjects that may have been previously exposed to a stimulus.

The time robins allocated to relaxed behavior was the most sensitive variable measured. Examination of 95% CI revealed that there was no highly significant effect of playback type on relaxed behavior ($p=0.077$); however, robins engaged in significantly less relaxed behavior after hearing noise compared to the kingbird treatment ($p=0.031$),

and all noise/non-linearity treatments led to significantly less relaxed behavior than the kingbird treatment (pair-wise comparisons between kingbird and chua chaos ($p=0.034$), logistic chaos ($p=0.049$), and noise ($p=0.031$). Robin time allocation was also significantly modified as a function of the playback heard ($p = 0.022$). Examination of 95% CI revealed that after hearing chua chaos, robins looked significantly less ($p= 0.004$) compared to logistic chaos. Examination of 95% CI revealed that kingbird playback led to significant differences ($p = 0.048$) compared to noise ($p = 0.052$), chua chaos ($p = 0.055$), or logistic chaos ($p = 0.052$) when examining the time allocated to looking. After hearing the noise playback, decreased looking compared to logistic chaos ($p = 0.018$). Robin locomotion was unaffected by any playback ($p=0.358$).

Covariate analyses for Warbling vireos revealed that heterospecifics ($p = 0.204$), conspecifics ($p = 0.333$), height in trees (average = 8.73 m, $p = 0.758$), wind ($p = 0.702$), and distance from road ($p = 0.553$) did not have significant, confounding results; however, distance from observer (average distance = 12.19 m, $p = 0.034$) did significantly affect treatments, so distance from observer was therefore factored in for the analyses.

Overall, vireo behavior was not differentially effected by playback type (relaxed behavior $p = 0.517$), locomotion $p = 0.098$), looking $p = 0.627$). Likewise, pairwise comparisons did not reveal significant differences in looking or relaxed behavior. However, pairwise comparisons did show that after hearing chua chaos, warbling vireos decreased locomotion significantly compared to kingbird ($p=0.022$), and after hearing kingbird, noise led to significantly decreased locomotion ($p=0.049$).

Discussion

Our results suggest that American robins and Warbling vireos do not discriminate noise from at least two types of deterministic chaos: chua chaos and logistic chaos. In fact, American robins responded to the nonlinear chua chaos, logistic chaos, and noise similarly with less relaxed behavior compared to the linear, novel tropical kingbird stimuli, and Warbling vireos similarly reacted to noise and chua chaos after the kingbird stimulus with less locomotion with no discrimination between the two different types of nonlinearities.

Deterministic chaos has a variety of ways that it can be produced; with synthetically produced deterministic chaos, there is room for parameter manipulation, thus a wide variation. Chua's oscillator is an example that is produced on an electronic circuit by varying parameters (α , β , $-\gamma$, a , b , k) (Pivka et al. 1994, Chua 1995).

While Chua and logistic chaos we used differed structurally, and both are structurally different from white noise, they seem to elicit similar responses in at least two species of birds. Importantly, these similar responses are not because these sounds were novel; our kingbird stimulus permitted us to control for novelty. These results suggest that white noise may be a valid surrogate with which to evaluate the nonlinearity and fear hypothesis. However, the results also suggest that deterministic chaos can be quite variable in its acoustic structure and our results strictly hold for the specific exemplars that we used.

Literature Cited

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Table 1. Ethogram of behaviors recorded during playbacks, modified from Slaughter et al. 2013.

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
Other	Other behaviors such as shaking, feather ruffling, scratching, etc.
Vocalization	Singing or non-song vocalization,

excluding chinking

Flight

Flying, but not out of sight

Out of sight

No longer in sight

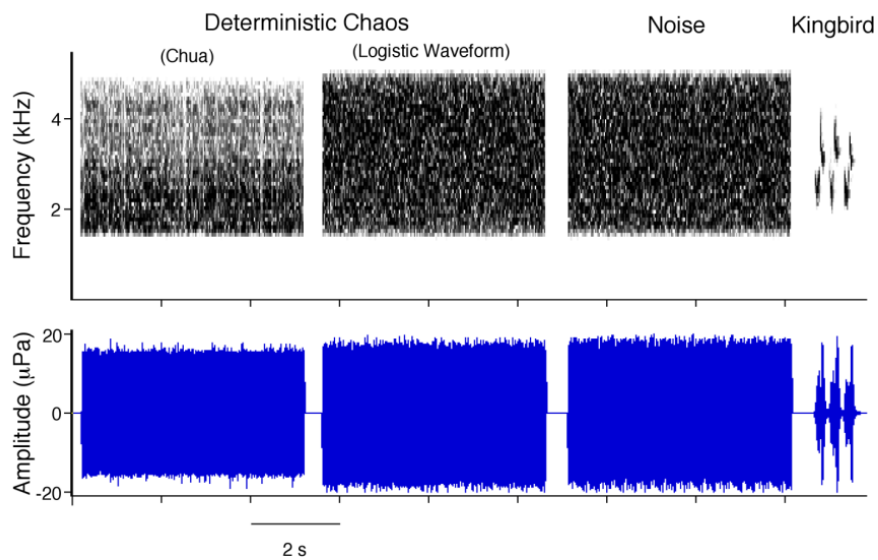


Figure 1. Spectrogram and amplitude plot of three experimental stimuli (Chua, logistic waveform, white noise) and exemplar of kingbird vocalization used in playback experiments.

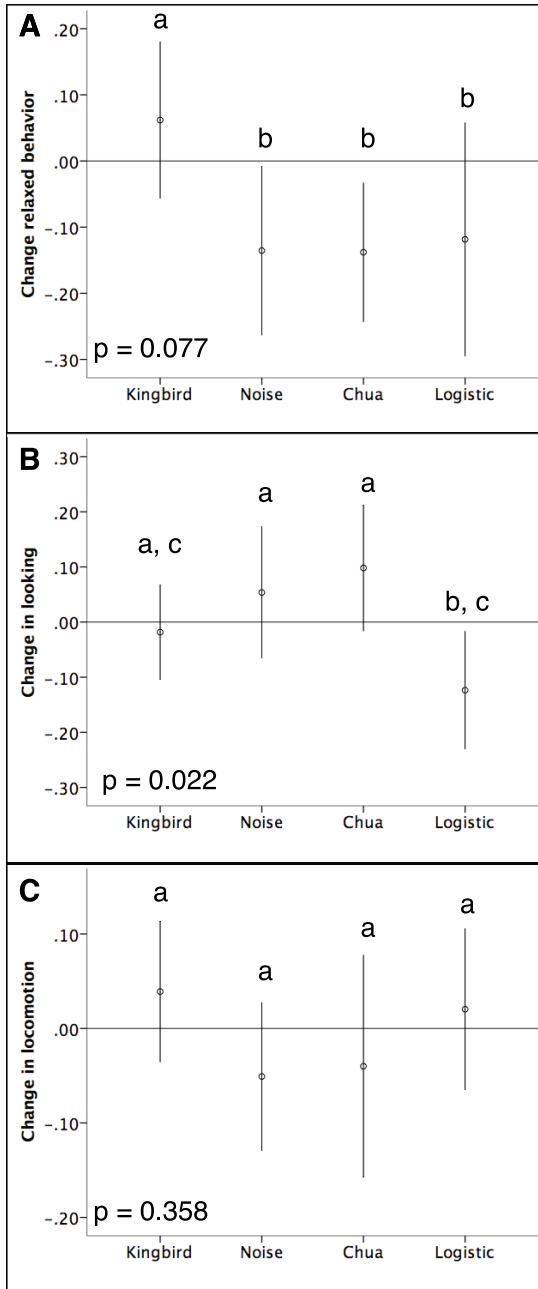


Figure 2. Arcsine transformed mean differences from baseline ($\pm$ 95% CI) in relaxed (preen, walk, forage), look, locomotion (walk, hop, flight) for American robins.

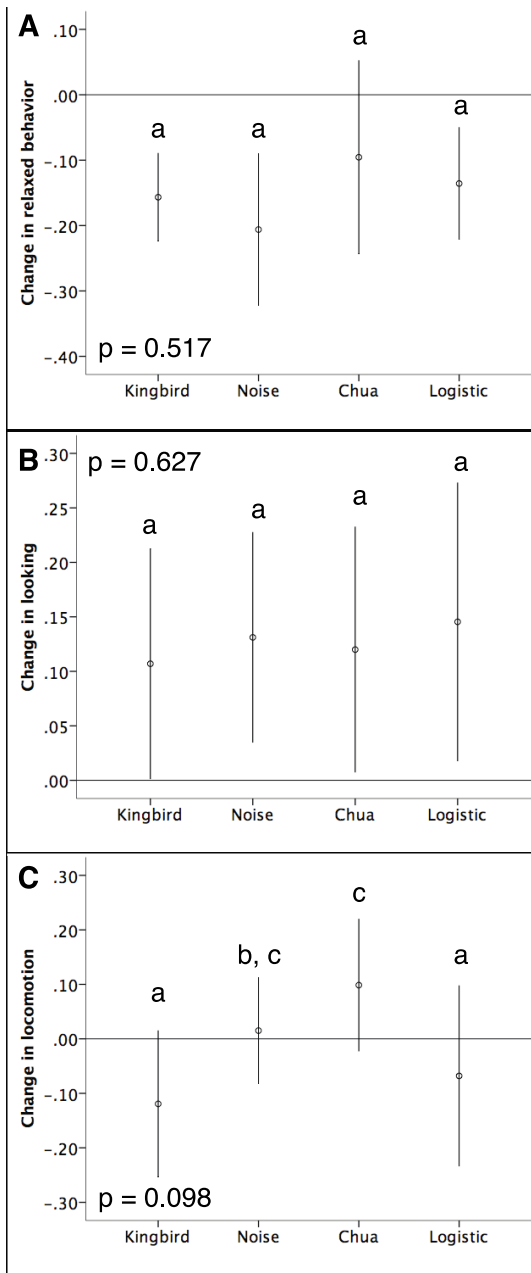


Figure 3. Arcsine transformed mean differences from baseline ($\pm$ 95% CI) in relaxed (preen, walk, forage), look, locomotion (walk, hop, flight) for warbling vireos.