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Like Music to our Ears: The Complexity of Bird Vocalizations as a Key Factor of Attractiveness

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ABSTRACT

It is known that bird vocalizations and music share acoustic similarities. Unsurprisingly, bird sounds inspired a number of music composers. In music, complexity plays an important role in auditory attractiveness. Would sound complexity also be important to explain the attractiveness of bird vocalizations to humans? In our study, we experimentally assessed the preference for vocalizations according to their level of complexity, indicated by objective measurements. Further, given that men and women enjoy music similarly, we verified whether the taste for the sound of birds differs between the sexes. The study was conducted on 114 adults living in a rural district in the northeast of Brazil. The results showed a significant and linear preference for sounds, with the most complex ones being preferred. Moreover, both men and women were attracted to the songs of these animals. For the first time, the importance of complexity in humans' appreciation for bird vocalizations has been objectively demonstrated. Our results stress the relationship between bird vocalizations and music for people. In addition to its theoretical nature, this study might be useful to predict, based on the sound complexity, which birds would be subject to a higher risk of capture, information that would help in reducing the loss of biodiversity. Moreover, giving the apparently universal aspect of bird song attraction to humans, it would be advisable in terms of conservation efforts to elect singing birds as flagship species. We hope that our research will serve as a motivation for further efforts in this area, as it clearly brings important insights into ethnozoology and other interdisciplinary fields.

KEYWORDS
Aesthetics; birdsong; conservation; ethnobiology; human–animal interaction; zoomusicology

Among the sounds that nature offers to human ears, bird vocalizations seem to have gained special interest over time. In fact, records of this interest date back to ancient Rome and Greece (Kleczkowska, 2015). The vocalizations of these animals also inspired great artists of the fine arts, such as European poets and composers (Catchpole &

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Slater, 2008, p. 3, 9, 247). This fascination seems to be common among human cultures, as the use of bird sounds in music and healing rituals has been documented in several tribes (Baptista & Keister, 2005).

From a scientific perspective, efforts have been made to understand the reasons why we like to hear the vocalizations of these animals. To date, research suggests that acoustic features such as tone variation, rhythms, time pattern similarity, call duration, and repertoire size affect the attractiveness of bird vocalizations to humans (e.g., Baptista & Keister, 2005; Bjerke & Østdahl, 2004; Blackburn et al., 2014). Importantly, it is suggested that sound complexity plays a role in human appreciation for bird vocalizations (Catchpole & Slater, 2008, p. ix). In a more recent study, a pleasant experience was associated with complex bird vocalizations, with sounds subjectively and remotely classified by the participants themselves (Ratcliffe et al., 2018). Because the perception of complexity may change from person to person, a question arises: Would the objective physical properties of bird vocalizations, denoting high complexity, be a key factor in the appreciation of bird vocal sounds? At this point, it should be noted that the acoustic features of music are considered similar to those of bird vocalization (Baptista & Keister, 2005; Doolittle et al., 2014; Doolittle & Gingras, 2015; Janney et al., 2016). Moreover, complexity plays a key role in music appreciation (for a review, see Chmiel & Schubert, 2017). Thus, we have strong evidence that objective complexity would be an important aspect to explain the attractiveness of bird vocalizations to humans. Unfortunately, to date, no experimental study has been conducted to test this hypothesis.

An additional question of interest is whether there would be a difference between men and women in the attraction to bird vocalizations. An analysis from this angle would allow us to better assess the degree of proximity between birds' vocalization and human music. With music, regarding short-term preferences, there seems to be no difference between the sexes (North & Hargreaves, 2008, p. 114). Accordingly, given the general similarities between music and a number of bird vocalizations (Baptista & Keister, 2005; Doolittle et al., 2014; Doolittle & Gingras, 2015; Janney et al., 2016), we assume that there would be no significant differences between men and women in their short-term appreciation for bird vocalizations. Thus, our aim was two-fold: (1) experimentally evaluate human attraction to bird vocalizations, according to their level of complexity; (2) test the difference between the sexes in appreciating bird vocalizations. In addition, as human appreciation for singing birds is a factor that leads to the illegal capture and trade of these birds (e.g., Alves et al., 2009; Nijman & Nekaris, 2017), we also discuss our findings in terms of conservation.

Methods

Ethics

All participants accepted and signed the Free and Informed Consent Form, authorizing their participation in the study. In addition, this research was approved by the Human Ethics Committee of the University of Pernambuco (CEP / UPE), Resolution 466/2012 (Written Opinion No. 2.968).

Study Site and Inclusion/Exclusion Criteria

The study was conducted in Ribeira, a rural district of the municipality of Cabaceiras (S 7° 29′ 21′′, W 36° 17′ 18′′) in the state of Paraíba, Brazil, from February to September, 2019. The main economic activities in the Ribeira District are leather handicraft and subsistence farming.

Initial contact with the community of the Ribeira District occurred through the Family Health Clinic (PSF) of the District, where initial information was collected, such as the number of people and the age range of the population. Participants were randomly selected either to take part in the experimental survey or to be interviewed on bird song. The same person did not participate in both parts of the study. People with cognitive difficulties (reported by the family), total or partial hearing impairment (acknowledged by the interviewee), or were under 18 years old or over 60 years old did not participate in our study. The experimental part of our study (complexity and preference for bird vocalizations) was restricted to persons aged above 18 years as youth sometimes represent a challenge regarding attention in research (Poole & Peyton, 2013). Restriction was adopted to persons above 60 years old as hearing loss due to aging (for a review on the subject, see Van Eyken et al., 2007) could be a confounding factor. Also, people who at the time of data collection had an infection, such as otitis or flu, were excluded owing to the possible impact of these conditions on their hearing. For the interviews on sex and attractiveness to bird vocalizations, we also restricted it to persons aged 18–60 years. This was done to avoid age discrepancies between the two selected groups of participants (those for the experiment and for the interviews).

A total of 114 people took part in this study. Research participants were randomly assigned. Before data collection, we developed a randomization procedure using the *sample* function (Random Samples and Permutations) in the basic R package (R Core Team, 2019).

We used vocalizations of birds exotic to Brazil in order to avoid a potential emotional effect on the participants (e.g., Salimpoor et al., 2013). The sounds, all tonal, were chosen from a pool of 198 vocalizations, whose use was kindly authorized by The Sound Approach (UK).

We divided the audio selection for the complexity experiment into five phases. In phase 1 or disposal phase, 132 out of a total of 198 sounds (sample rate: 44.1 kHz; bit depth: 16; uncompressed) were discarded for reasons such as files with multiple sounds of different birds at the same time, sounds of nonpasseriform birds, and the presence of mechanical sounds produced by birds.

In phase 2, two of the authors (da Silva & Souto) subjectively categorized the 66 most suitable sounds for the study according to their perceived complexity (through variation in pitch, variation in the intensity of sounds and intervals or "gaps" between the phrases). The higher the variation in the frequency and intensity of the sounds, the higher the perception of complexity (e.g., Farina, 2019). Shorter gaps between varying vocalizations were also perceived as complex sounds (e.g., Catchpole & Slater, 2008, p. 226). The 66 sounds were classified into sounds with low, medium, and high perceived complexity. In this phase, we used headphones as support equipment for listening to the sounds, and sonograms visualization was accomplished with the software Raven Pro 1.4 (Cornell Labs, NY).

In phase 3, the cutting, cleaning, and normalization phase, the first 35 s of each sound selected in the previous step were extracted with the help of the open-source software Audacity 2.3.0 (Audacity, USA). The duration of each sound file comprised 35 s. There was a slight length variation between the actual sounds in each file owing to the natural presence of gaps in the vocalizations. The mean sound duration was 32.8 s (*SD* = 2.2). Sound files longer than 35 s were cut to match the adopted length. The cut occurred when there was an adequate interval between phrases, so that the end of the bird vocalization would sound natural to the listener. Recordings of bird calls shorter than 35 s were edited as follows: the initial portion of the call was smoothly pasted at the end of the vocalization (as if the bird restarted or kept vocalizing). Both procedures were adopted to avoid having markedly different durations in the sounds, which could represent a confounding factor in our research. It should be noted that both situations can occur in nature; that is, a bird may produce a shorter version of a call, and calls may also be repeated over time (Farrell et al., 2012; Oberweger & Goller, 2001). Background noise was removed from the vocalizations with the Spectral De-noise module in the Izotope RX software (Sound on Sound, UK). After this step, all sounds were normalized for intensity using the Sound Forge Pro 11 (Magix Software GmbH, Germany).

In phase 4, the 66 sounds were analyzed in the public domain software Luscinia version 1.0.11.12.30 (Lachlan, 2007) to test if our subjective distinctions were objectively distinguishable, representing a clear cut in terms of sound complexity (i.e., our subjective distinction between sounds with perceived high, medium, and low complexity). In the analyses conducted in this software, we used the following parameters: "gap" (acoustic element interval), fundamental frequency change (variations in the first harmonic), and harmony (based on an evaluation of the acoustic signal under analysis, by comparing it with a harmonic sound model; that is, a pure tone whose frequency is an integer multiple of another frequency as defined by McDermott and Oxenham (2008); the closer to the model, the more harmonious the sound). By confirming our initial subjective selection using three parameters, acting as a whole, we intended to provide a picture closer to reality, given that acoustic components do not act separately on human perception (e.g., Bradbury & Vehrencamp, 2011, p. 98; To et al., 2009). To assist in sound selection, Luscinia generated dendograms and nonmetric multidimensional scaling functions. This software has supported a number of new investigations in the field of bioacoustics (e.g., Araya-Salas et al., 2017; Lachlan et al., 2018; Roper et al., 2018; Van Els & Norambuena, 2017). For details about the program, see http://rflachlan.github.io/Luscinia/. The 66 vocalizations were reduced to nine sounds in this phase. The nine vocalizations were arranged into three groups, each containing a sound with high, medium, and low complexity. The vocalizations in each group were clearly distinguishable between them both subjectively (via listening to the sounds and visual inspection of sonograms) and objectively (via software analysis, using Luscinia).

Lastly, in phase 5 we employed the public domain software ImageJ (v. 1.46r; Schneider et al., 2012) with the plugin FracLac (v. 2.5wb126; Box Count function) to objectively evaluate our complexity ranking (i.e., low, medium, and high complex sounds) through fractal analysis. Measuring complexity is not an easy task, and there have been different metrics used for this purpose regarding bird vocalizations (Benedict & Najar, 2019). Fractal analysis has been successfully employed in a number of fields that requires the evaluation of complexity (e.g., Karperien & Jelinek, 2016, pp. 13-43; Milosevic et al., 2017; Namazi et al., 2018), including sound investigations (e.g., Bigerelle & Iost, 2000; Das & Das, 2010; Hsu & Hsu, 1990). The program is able to analyze the visual representation of sounds (the sonograms were generated in our case by the Raven Pro 1.4 with a window size of 512, Hann type, brightness and contrast at 57). The grayscale, white background images from the Raven Pro were saved as 8-bit, tiff format. Chosen module in FracLac to analyze the images: "Box Count" (type of image was set to grayscale with a white background color; plus 1 was the type of scan; all other setting to default); in "Actions" the plugin was set to "Scan Image/Roi" (box sizes: 250).

From the three groups of sounds subjectively categorized in relation to the order of complexity, the ImageJ detected one group with an incorrect categorization. This group was discarded from the study. As a consequence, six sounds in two groups were selected for our study (see next paragraph for details). With the use of the software programs Luscinia and Image J, we ascertained that the three sounds in each group were objectively and clearly distinguishable, and they were also objectively ranked regarding the three different levels of sound complexity. Both programs covered a number of important factors for this study, including precision, objectivity, and processing capacity.

The two groups of bird species, with their common names, whose sounds were chosen were the following (sound complexity level – low, medium, and high – in parentheses; numbers represent the Mean Fractal Dimension, MFD; higher numbers represent higher complexity): First group (see Figure 1 for sonograms) = *Phylloscopus proregulus*, Pallas's leaf warbler (low; MFD = 2.61), *Cettia cetti*, Cetti's warbler (medium; MFD = 2.66), *Acrocephalus palustris*, Marsh warbler (high; MFD = 2.74); second group (see Figure 2 for sonograms) = *Phylloscopus ibericus*, Iberian chiffchaff (low; MFD = 2.56), *Carpodacus erythrinus*, common rosefinch (medium; MFD = 2.64), *Acrocephalus dumetorum*, Blyth's reed warbler (high; MFD = 2.73) (species names following Constantine & The Sound Approach, 2006).

For the sake of a point of reference, we analyzed in terms of complexity the initial 35 s of two renowned music compositions from Beethoven: "Moonlight" Sonata Op. 27/2 in C sharp minor (Beethoven 1801/1989) (MFD = 2.66) and Symphony Nr. 5 Op. 68 in C minor (Allegro con brio) (Beethoven 1804/1989) (MFD = 2.78). In the two cases, sonograms and images were generated and analyzed with the same adjustments used for the bird vocalizations (see previous paragraph). Recording quality: 44.1 kHz, 16-bit, uncompressed. The vocalizations comprised non-noisy, tonal sounds (as commonly found in birds; e.g., Jančovič, & Köküer, 2011; Slabbekoorn, 2004, pp. 5–6). However, the Marsh warbler (*Acrocephalus palustris*) had two short, harsher sound elements as part of its otherwise well-defined vocalization.

A total of 53 participants (25 women and 28 men; mean age = 37.28 years, *SD* = 15.29) listened to the bird sounds through a pair of Sennheiser HD 280 Pro headphones (Sennheiser electronic GmbH & Co., Germany) or JBL headphones, model C300S1 (Samsung Electronics, South Korea), both having a frequency response of 20-20.000 Hz. For sound reproduction, we used an iPod Touch (model A1574; Apple Inc, USA) (frequency response: 20-20.000 Hz).

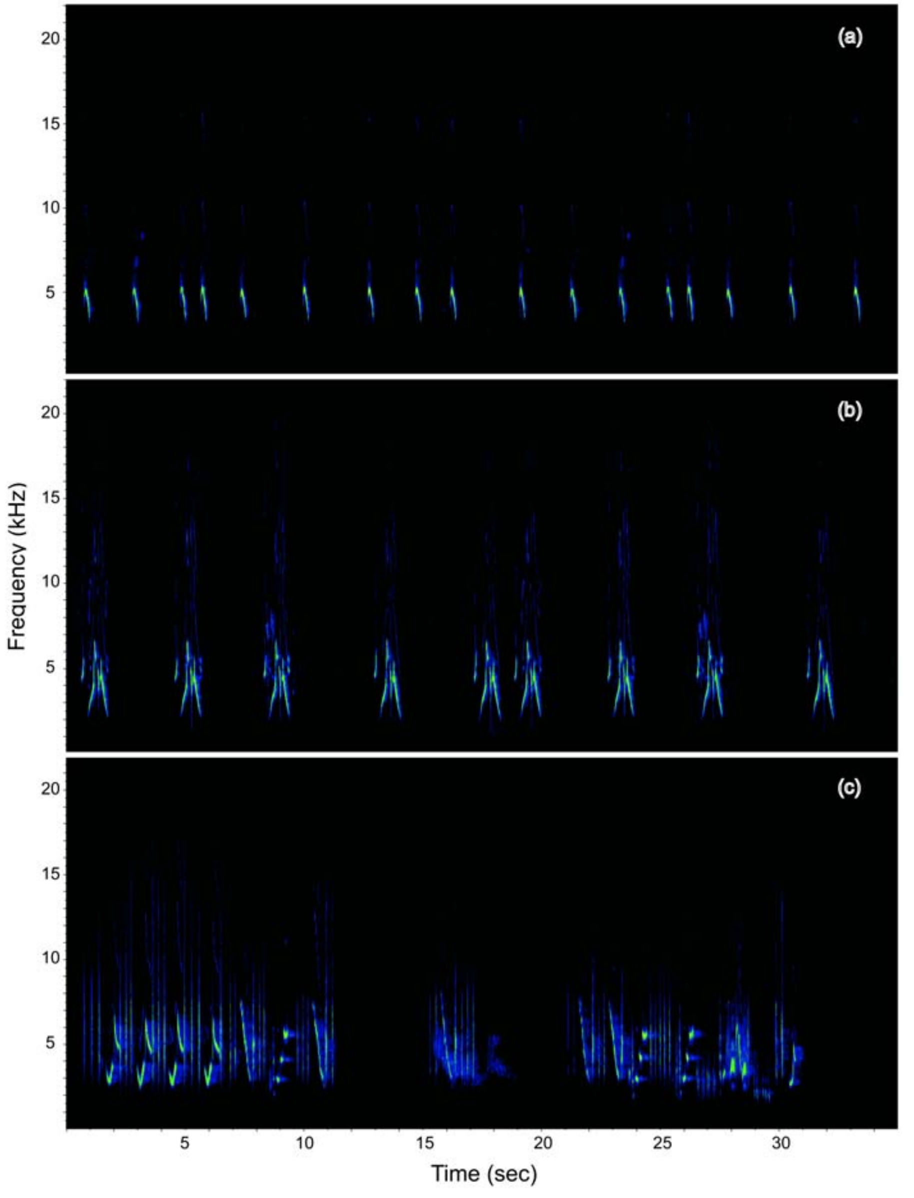

Figure 1. Sonograms of the first group of bird vocalizations with different levels of complexity: (a) low (from *Phylloscopus proregulus*, Pallas's leaf warbler); (b) medium (from *Cettia cetti*, Cetti's warbler); (c) high (from *Acrocephalus palustris*, Marsh warbler). Sonograms created in Raven 1.4 (window size: 512; window type: Hann; brightness and contrast: 50 (default)). Brighter parts of the image represent sounds with higher intensity.

The *sample* function was used to randomize the two sets of bird sounds, as well as the order of the three sounds within each set. The randomization procedure (Random Samples and Permutations) was accomplished using the basic R package (R Core Team,

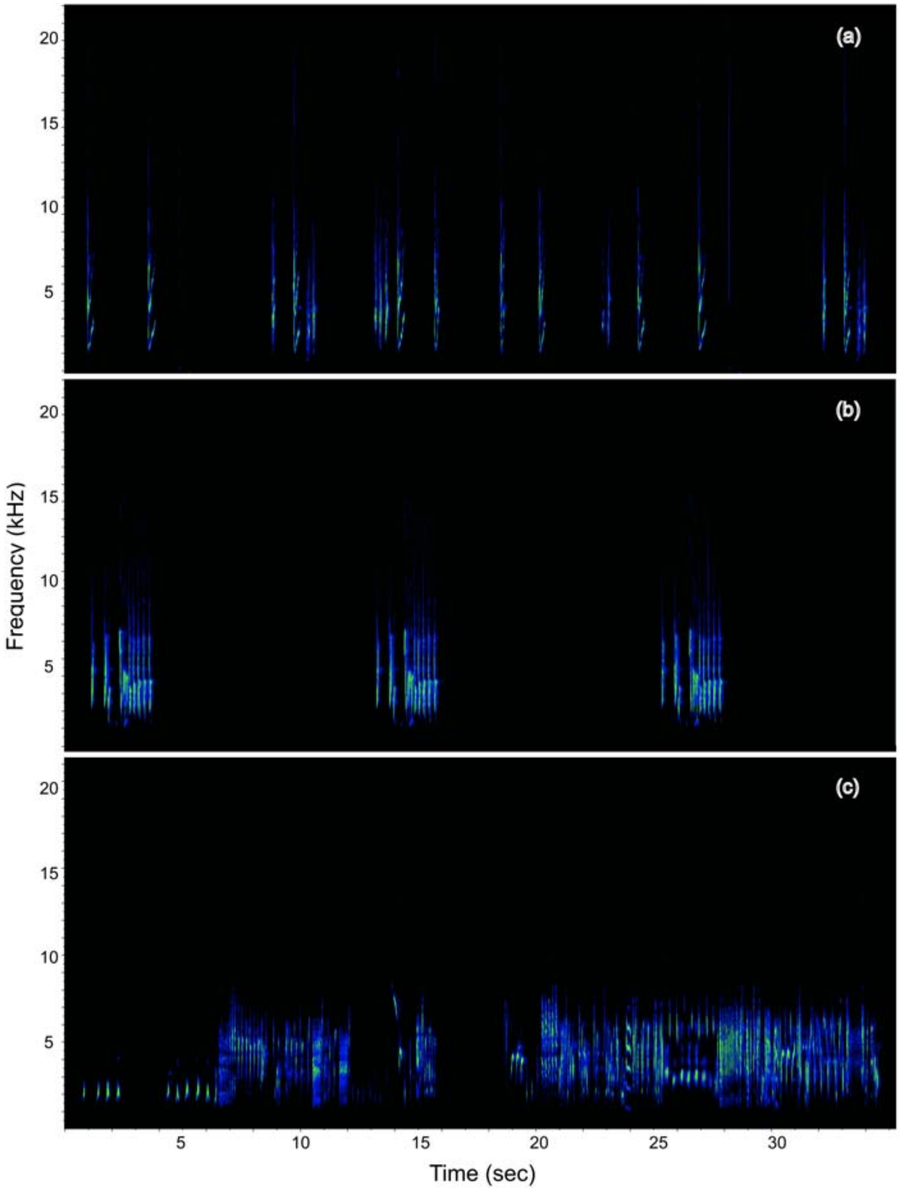

Figure 2. Sonograms of the second group of bird vocalizations with different levels of complexity: (a) low (from *Phylloscopus ibericus*, Iberian chiffchaff); (b) medium (from *Carpodacus erythrinus*, common rosefinch); (c) high (from *Acrocephalus dumetorum*, Blyth's reed warbler). Sonograms created in Raven 1.4 (window size: 512; window type: Hann; brightness and contrast: 50 (default)). Brighter parts of the image represent sounds with higher intensity.

2019). During collection, each set of randomized experiments was unavailable to the next participant. Both sexes had equal chances to participate in one of the research phases. Participants could listen to the sounds more than once if they wanted to. After listening to the three sounds, each participant was asked their order of preference.

Sound intensity was the same for all participants. The participants did not receive information about the birds and their vocalizations used in this study, as this could be a confounding factor.

A total of 61 participants were interviewed about their preference for bird vocalizations (35 women and 26 men; mean age = 38.42 years; $SD = 12.2$). Importantly, none of these individuals took part in the complexity experiment and vice-versa. In order to avoid misinterpretation, the participants were approached with a concise and simple question: "Do you like bird songs?" The answer options to that question were "not at all," "a little," or "a lot."

Data Analysis

We used the Wilcoxon *T*-test for repeated measures to test for significant differences between men and women with regards to bird sound choices, according to their complexity. An alpha correction was performed using the Bonferroni sequential test (Lamprecht, 1999, p. 57; Rice, 1989). If all the results of a certain family of tests were characterized by $p \leq 0.05$, then we regarded the differences as significant without the need for correction (Lamprecht, 1999, p. 57). Moreover, we calculated the effect size (r) following Field (2005, p. 541). The Fisher exact test was used to examine men's and women's answers about their appreciation for bird sounds (a lot; a little; not at all). For this test, we combined the options "not at all" and "a little" into one category, owing to the small number of individuals who chose them. Effect size (ES_{OR}) for the Fisher exact test was calculated based on Berben et al. (2012). The InStat 3.0 software (GraphPad Software Inc., San Diego, CA) was used both for the Wilcoxon *T*-test and the Fisher exact test. We used the public domain statistical package Past 4.03 (Hammer et al., 2001) to obtain *z*-values, given that InStat 3.0 does not provide this information. Significance was set at $p \leq 0.05$ (two-tailed).

Results

With regard to the experimental test on the appreciation for bird vocalizations and their complexity, there was a significant difference for men: sounds with high complexity being the most preferred, and sounds with low complexity the least preferred (high vs. medium): $n = 28$, $T = 95$, $p = 0.0066$, $r = 0.36$; high vs. low: $n = 28$, $T = 21$, $p < 0.0001$, $r = 0.58$; medium vs. low: $n = 28$, $T = 25$, $p < 0.0001$, $r = 0.58$; see Figure 3. Similarly, women showed a higher preference for sounds with high complexity and a lower preference for sounds with low complexity (high vs. medium): $n = 25$, $T = 89$, $p = 0.0483$, $r = 0.29$; high vs. low: $n = 25$, $T = 9$, $p < 0.0001$, $r = 0.36$; medium vs. low: $n = 25$, $T = 72$, $p < 0.0136$, $r = 0.61$; see Figure 3.

When we asked the interviewees about their appreciation for bird vocalization, 96% (25) of men said they liked it a lot, while 4% (1) said they liked it a little or they did not like it at all. On the other hand, 80% (28) of women stated that they enjoyed listening to bird vocalizations very much, while 20% (7) answered that they did not like it very much or at all. There was no significant difference between men and women ($n = 61$, $p = 0.1222$, $ES_{OR} = 0.16$).

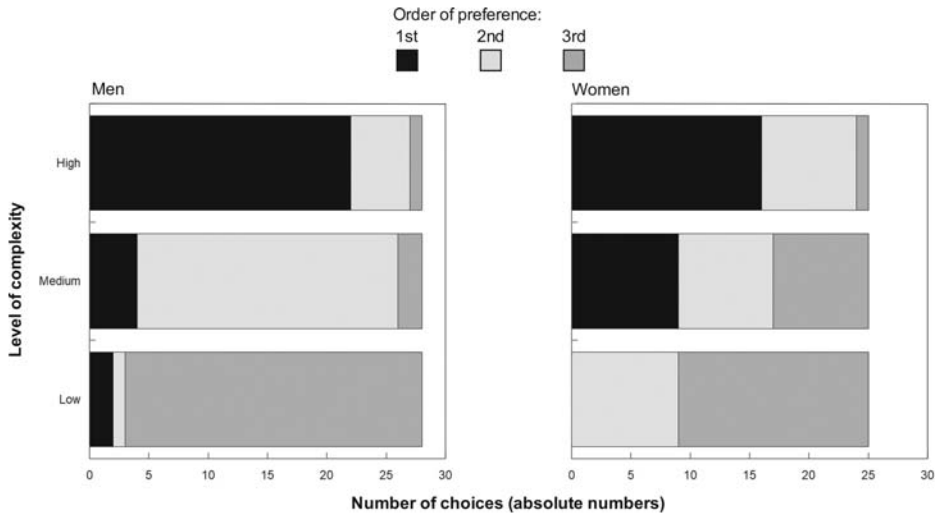

Figure 3. The preferred sound for both men and women was a highly complex bird vocalization, followed by sounds with medium and low complexities, in this order. See text for statistical results.

Discussion

Our results show that the objectively measured, highly complex sounds of birds were significantly more attractive to both men and women. This finding is even more compelling when we take into account that we used sounds with three different levels of complexity (low, medium, high), showing a linear preference in both sexes. Also, with the aid of software programs we performed the important final acoustic procedures (differentiation and ranking) of the sounds in an automated way, making the procedure objective, more easily replicable, and fast. Thus, our results emphasize the importance of complexity in human preference for bird vocalizations, an aspect that had not been objectively evaluated until the present study.

The clear interrelationship between the complexity of bird sounds and their attractiveness to humans would explain the inspiring role of bird vocalizations for the composition of baroque and classical music. As a matter of fact, several composers, such as Vivaldi, Mozart, and Beethoven, were inspired by bird vocalizations when composing their music (Castelões, 2007; Doolittle & Gingras, 2015; West & King, 1990). This explanation also applies to a number of tribal societies (Baptista & Keister, 2005). For example, a whole musical scale from an isolated community on Palawan Island, in the Philippines, was conceived around bird vocalizations and the sounds of nature (Roulon-Doko, 1993). It is equally important to stress that we did not document a distinction between men's and women's short-term appreciation for bird vocalizations. This finding is similar to that obtained in studies with human music (North & Hargreaves, 2008, p. 114), which reinforces the importance of bird sounds for human societies and communities throughout history.

It is interesting to note that the appreciation of bird vocalizations presented a linear and ascending response in relation to sound complexity. Although this is congruent with a number of studies on music, there seems to be a tendency to accept that the aesthetic preference of highly complex, unfamiliar music (like the bird vocalizations of our study), is associated with an inverted U-shaped curve (for a review, see Chmiel & Schubert, 2017; see also Van Geert & Wagemans, 2020). That is, an increasing complexity would promote an increased sound appreciation up to a certain point, after which it would have a decreasing effect, reverting the upward appreciation trend. Thus, if an inverted U-shape curve is what is expected when complexity increases in terms of music appreciation, our results suggest that bird vocalizations do not follow this pattern, as also seen in other structures like snowflakes (Adkins & Norman, 2016). This would be somehow unexpected, given the general similarities between bird vocalizations and music (e.g., Baptista & Keister, 2005; Doolittle et al., 2014; Doolittle & Gringas 2015; Janney et al., 2016). On the other hand, it is also possible that bird vocalizations may not reach the level of complexity that can be found in music. As a matter of fact, for the sake of comparison we analyzed two compositions (Beethoven: "Moonlight" Sonata and Symphony Nr. 5). Viewed as possessing a calm beginning (e.g., Cooper, 2008, p. 177), "Moonlight" Sonata's initial section – used for comparison – reaches or surpasses our bird vocalizations with medium complexity. On the other extreme, Symphony Nr. 5, which is described as a "dramatic fire" (Cooper, 2008, p. 177), reveals a complexity level that is above that shown by the two most complex bird vocalizations of our study (see methods for details about their complexity levels). Importantly, both vocalizations are from *Acrocephalus* warblers (*A. palustris* and *A. dumetorum*), which are considered birds with "songs of bewildering variety and complexity" (Catchpole, 1980, p. 149). It is possible, then, that bird vocalizations do not reach the point at which highly complex music is perceived as less pleasant than music with moderate complexity. Therefore, while complexity undoubtedly plays a key role in the appreciation of bird vocalizations, similarly as in music, bird vocalizations may not reach levels that would negatively affect the appreciation of these sounds. It seems of great interest for future studies to conduct a broad comparison between the levels of complexity of bird vocal sounds (including harsh vocalizations) and those found in music.

Apart from the theoretical contribution, the findings of this study may also be relevant from an application point of view, especially in the field of conservation and animal welfare. In fact, the production of sounds by songbirds is known to be an important reason for the capture and/or illegal trade of these animals – which are major reasons for the loss of biodiversity (Alves et al., 2009; Burivalova et al., 2017; Collar et al. 1997; Lowen, 2020; Nijman & Nekaris, 2018; Paddock, 2020), especially in developing countries (e.g., Alves et al., 2010; Jepson & Ladle, 2009; Nijman et al., 2018). Sadly, a high number of birds die in transit, and many others do not survive the first days of captivity (Alves et al., 2012). Hence, acknowledging the complexity of bird songs as a potential attraction would help to predict the impact on the singing birds of a given region in terms of trade and capture. Importantly, this information could be used to promote protective measurements in favor of the target birds, ultimately helping to reduce biodiversity loss and suffering. Moreover, due to the appeal of the vocalizations of some birds to people, it might be convenient to use selected birds that produce complex sounds as flagship species; that is, species that promote a greater awareness in the field of environmental protection (Caro, 2010, pp. 245–246). Currently, vocal production is not a feature considered in the selection of flagship species, as other characteristics, such as large size and bright colors are privileged (Clucas et al., 2008). As singing birds generally do not have these attributes, their use as a symbol may promote the protection not only of singing birds but also of similarly sized animals with dull colors.

Conclusions

Our study revealed that the complexity of bird vocalizations is a major aspect responsible for attractiveness to people. In addition, there was no difference between men's and women's short-term appreciation for bird sounds. Both findings reinforce the relationship between bird song and music for humans and open up the possibility of new and exciting investigations on the bioacoustics of bird vocalization, aesthetics, and conservation. Another point to highlight is the clear importance of the software solutions in sound analysis that requires intense and complex calculations. Without them, accomplishing the objectives of this study would have been much harder. We hope that our study will encourage further research, as this will provide a theoretical and applied contribution to the fields of ethnozoology and anthrozoology, as well as other interdisciplinary areas.

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Disclosure Statement

No potential conflict of interest was reported by the authors.

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