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Predicting the perceived restorative potential of bird sounds through acoustics and aesthetics

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Abstract

Some, but not all, bird sounds are associated with perceptions of restoration from stress and cognitive fatigue. The perceptual properties that might underpin these differences are understudied. In this online study, ratings of perceived restorative potential (PRP) and aesthetic properties of 50 bird sounds were provided by 174 residents of the United Kingdom. These were merged with data on objectively measured acoustic properties of the sounds. Regression analyses demonstrated that sound level, harmonics, and frequency, and perceptions of complexity, familiarity, and pattern, were significant predictors of PRP and cognitive and affective appraisals of bird sounds. These findings shed light on the structural and perceptual properties that may influence restorative potential of acoustic natural stimuli. Finally, through their potential associations with meaning, these findings highlight the importance of further study of semantic or meaning-based properties within the restorative environments literature.

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Predicting the Perceived Restorative Potential of Bird Sounds Through Acoustics and Aesthetics

Spending time in or with non-threatening nature can generate cognitive and affective benefits, particularly after stress or mental fatigue (Berto, 2014; Hartig, Mitchell, de Vries, & Frumkin, 2014). Attention towards psychologically beneficial soundscapes in nature has grown in recent years, with birdsong as a common choice in such experimental studies, but there is limited understanding of why these sounds may afford positive outcomes. This paper examines how the perceptual properties of bird sounds relate to their perceived restorative potential, and cognitive and affective appraisals of the sounds.

Restorative Environments

Current theoretical frameworks of restorative environments focus on cognitive and affective processes as mechanisms responsible for attention restoration, recovery of positive mood, and reductions in arousal observed after exposure to natural environments (Kaplan, 1995; Kaplan & Kaplan, 1989; Ulrich, 1983; Ulrich et al., 1991). In attention restoration theory (ART; Kaplan, 1995; Kaplan & Kaplan, 1989), natural environments are proposed to aid the recovery of voluntary or directed attention, and subsequent improvements in mood, by engaging attention yet still offering opportunities for reflection. This may be achieved by certain qualities of person-environment transactions; that is, those that offer fascination or effortless attentional engagement, a sense of being away or escape, physical or perceptual extent, and compatibility with one's aims and desires.

Ulrich's (1983; Ulrich et al., 1991) stress recovery theory (SRT) offers a different perspective, in which the benefits of nature following stress are framed in terms of affective appraisals of valence and arousal, as well as changes in physiological responses. SRT is sited in a psycho-evolutionary context, with aesthetic and semantic properties such as moderate levels of complexity, high levels of structure, even surface texture, the presence of water, and the absence of threat argued to contribute to environmental appraisals of positive valence and low arousal due to their adaptive, psycho-evolutionary significance. Recently, researchers such as Joye and van den Berg (2011) have argued that there is relatively little evidence for primarily psycho-evolutionary perspectives on positive appraisals of potentially beneficial aspects of nature, instead suggesting that nature might be beneficial for attention because its perceptual properties tend to be easily processed by the visual system. However, these theoretical approaches consider experience of nature as a primarily visuo-spatial event.

Natural Sounds and Restoration: The Case for Bird Sounds

While receiving less attention than visuo-spatial experience in theoretical frameworks, the sounds of nature can be perceived and experienced as restorative. Bird sounds are almost always present in such soundscapes, which can reduce psychophysiological arousal faster, and improve mood to a greater extent, than certain sounds from the built or manmade environment (e.g., Alvarsson, Wiens, & Nilsson, 2010; Benfield, Taff, Newman, & Smyth, 2014; Jahncke, Eriksson, & Naula, 2015; Krzywicka & Byrka, 2017; Largo-Wight, O'Hara, & Chen, 2016; Medvedev, Shepherd, & Hautus, 2015; Payne, 2013; Ratcliffe, Gatersleben, & Sowden, 2013). These sounds may also improve self-reported motivation to work following fatigue (Jahncke, Hygge, Halin, Green, & Dimberg, 2011).

Ratcliffe et al. (2013) observed bird sounds as the type of natural sound most commonly associated with perceived restoration (that is, self-reported perceptions of recovery from stress and mental fatigue), with affective appraisals of valence and arousal, and with cognitive appraisals that mirror two concepts from attention restoration theory – fascination and a sense of being away. Notably, these two factors from attention restoration theory do not rely on visuo-spatial judgments. The extent to which bird sounds were considered restorative, and the ways in which they were affectively and cognitively appraised in such ways, varied depending on the species mentioned by participants and the perceived acoustic and aesthetic properties of their sounds: the sounds of crows and magpies were perceived to be unhelpful for restoration, for example, due to their “raucous” and “squawking” acoustic properties (Ratcliffe et al., 2013, p. 225).

As in studies that compare natural and man-made scenes, natural sounds, and particularly bird sounds, are often more positively affectively appraised than those from the built environment (e.g., Alvarsson et al., 2010; Anderson, Mulligan, Goodman, & Regen, 1983; Kariel, 1980; Kumar, Forster, Bailey, & Griffiths, 2008; Medvedev et al., 2015). Perceptions of pleasure also vary depending on the type of bird. For example, Björk (1985) noted that the sounds of songbirds were considered pleasant and sounds made by gulls less so, while Cox and Gaston (2015) identified songbirds as more preferred than calling, non-songbirds. Research in the visuo-spatial domain has forged ahead in recent years in understanding the specific perceptual properties that might contribute to restoration in natural environments (see Joye & van den Berg, 2011). However, there is little evidence about how variation in the perceived restorative potential of natural sounds (PRP; i.e., the judged likelihood that a stimulus can encourage restoration) might vary as a function of their perceptual properties; that is, acoustic properties and aesthetic appraisals. Since birds occur frequently in restorative soundscapes (e.g., Alvarsson et al., 2010; Benfield et al., 2014; Medvedev et al., 2015; Payne, 2013), they are a highly appropriate type of stimulus to use in order to examine relationships between specific acoustic and aesthetic properties of natural sounds and judgments of restorative value as measured via PRP, affective appraisals, and cognitive appraisals. By examining the relative contributions of these properties to such perceptions, it may be possible to better understand the mechanisms through which evaluations of the PRP of natural sounds can occur.

The following two sections outline the main acoustic and aesthetic properties that may relate to PRP of bird sounds. Acoustic properties of sound level, harmonics, and frequency, and aesthetic properties of novelty, complexity, and pattern, are perceived as important in affective appraisals of bird sounds and perceptions of their restorative value (Ratcliffe et al., 2013). While there is a lack of research that quantitatively examines relationships between these properties and such appraisals in the context of bird sounds, evidence for these potential relationships that draws on wider literature regarding acoustics and aesthetics is discussed below.

Acoustic Properties of Bird Sounds

Sound level. Existing research suggests a link between loud sound levels and appraisals of natural sounds arousing, dominating, or symbolic of animal aggression (Björk, 1985; Morton, 1977; Tsai et al., 2010). Based on this, it is possible that loud bird sounds may be perceived as more arousing and negatively valenced than quiet bird sounds due to their associations with dominance and threat. However, understanding of relationships between bird sound level and PRP, as well as cognitive appraisals of fascination and being away, is limited.

Frequency. The frequency of a bird sound is related to its perceived pitch, and may also relate to affective appraisals and judgments of its restorative potential. Sounds with low frequencies are rated as less unpleasant than those with high frequencies (Kumar et al., 2008), which may be attributable to associations between high-frequency sounds and attack or distress calls (Halpern, Blake, & Hillenbrand, 1986). However, Thorpe (1961) indicated that high-frequency sounds of songbirds are considered positively valenced by human listeners. Björk (1985) noted that unpleasant natural sounds, including bird sounds, tend to have low fundamental frequencies, whereas perceptions of activation or arousal are related to higher-frequency sounds. As such, there is mixed evidence for a directional relationship between frequency of bird sounds and affective appraisals, and as yet limited understanding of how frequency might relate to PRP or cognitive appraisals such as fascination and being away.

Harmonics. The harmonicity of a sound relates to its acoustic periodicity or regularity; harmonic sounds are experienced as a clear signal, while unharmonic sounds are experienced as noise. Existing research on perceptions of natural or animal sounds suggests that low levels of sound harmonicity may be associated with negative valence (Björk, 1985; Juslin & Laukka, 2003; Tsai et al., 2010) and with arousal through association with low frequencies and dominant or aggressive animal behavior (Blumstein & Récapet, 2009; Fitch et al., 2002; Leinonen et al., 2003). As such, harmonic bird sounds may be positively related to valence and negatively related to arousal ratings, although again, possible relationships with PRP and cognitive appraisals such as fascination and being away are unclear.

Aesthetic Properties of Bird Sounds

Familiarity. There is mixed evidence for associations between familiarity and restorative value of natural stimuli, with some research suggesting that the two are positively, although not always closely, related (e.g., Hartig & Staats, 2006; Purcell, Person, & Berto, 2001). Medvedev et al. (2015) linked perceived familiarity of bird sounds with its ability to generate stress recovery outcomes. In contrast, Ratcliffe et al. (2013) observed that the perceived novelty of bird sounds could provide feelings of escape, which is similar to the concept of being away outlined in attention restoration theory (ART; Kaplan, 1995; Kaplan & Kaplan, 1989), although perceptual novelty is not directly comparable to being away (Laumann, Gärling, & Stormark, 2001). Berlyne (1960, 1970) observed that both novelty of and familiarity with a stimulus have been associated with preference, pleasure, and interest. As such, the direction of any role of familiarity in PRP and affective and cognitive appraisals of bird sounds is unclear.

Complexity. Moderate levels of environmental complexity may contribute to perceptions and/or experiences of nature as restorative (Kaplan & Kaplan, 1989; Ulrich, 1983), and it seems likely that the aesthetic property of complexity relates both to affective appraisals such as pleasure and arousal (see Berlyne, 1960, 1970) and cognitive appraisals such as fascination (Kaplan & Kaplan, 1989). However, there has been little study of such relationships in the context of restorative acoustic environments and stimuli. Ulrich (1983) discusses the role of visual complexity in preferences for and restorative experiences in nature, and while Berlyne's (1971) work on aesthetics does consider acoustic stimuli, his studies focused more on interest and affective appraisals than specifically on restoration from stress or cognitive fatigue. As such, there is a need to examine connections between complexity and evaluations such as PRP in the context of specific natural sounds.

Pattern. Patterned or structured environments can aid cognitive and affective restoration through affordances of safe, coherent spaces (Joye & van den Berg, 2011; Kaplan, 1995; Kaplan & Kaplan, 1989; Ulrich, 1983), whereas a moderate level of unpredictability or randomness among stimuli encourages interest and arousal (Berlyne, 1960). However, this focus on pattern versus randomness in restorative environments and aesthetics is centered on visual experiences. There is a lack of research on whether perceptions of pattern are related to evaluations of acoustic stimuli as potentially restorative, and in particular specific stimuli such as bird sounds that possess patterned structures in their own right (Thorpe, 1961).

The literature reviewed above suggests that certain acoustic and aesthetic properties of bird sounds may relate to perceptions of their restorative potential (PRP) in situations of stress and cognitive fatigue, affective appraisals of valence and arousal in response to the sounds, and cognitive appraisals of the sounds as generating fascination and a sense of being away, as noted in Ratcliffe et al. (2013). These affective and cognitive appraisals represent different constructs that are proposed to contribute to PRP within affectively- (Ulrich, 1983) and cognitively-focused (Kaplan & Kaplan, 1989) theories respectively. It is therefore important to examine each of these outcomes individually in order to understand how acoustic and aesthetic properties of bird sounds relate not just to overall PRP, but the appraisals that inform that PRP.

Aims and Hypotheses

The present study sought to: a) quantify perceptions of bird sounds as potentially restorative, as measured via ratings of PRP and affective and cognitive appraisals of 50 10-second bird sound clips under states of imagined stress and mental fatigue; and b) examine how these ratings may be predicted by the objectively measured acoustic and subjectively measured aesthetic properties of the sounds; that is, their objectively measured sound level, harmonics, and frequency, and their subjectively measured familiarity, complexity, and pattern. Objective familiarity was also captured by identifying country of origin of the bird sound; i.e., native to the UK (familiar) or Australia (novel). Based on existing literature, sound level and harmonics were expected to be negative and positive predictors of restorative perceptions, respectively. With regard to other predictor variables, the mixed nature of the evidence meant that directional hypotheses were not set, and potential relationships were explored.

The aim of this study was not to study in-depth the inter-relationships between ratings of the overall PRP of the bird sounds and affective and cognitive appraisals. Rather, the aim of this study was to establish whether, and to what extent, acoustic and aesthetic variables directly predict ratings of PRP, affective appraisals, and cognitive appraisals. This study follows the procedure put forward in Ratcliffe, Gatersleben, and Sowden (2016), in which qualitative data regarding associations with bird sounds were captured and related to quantitatively measured PRP scores. In this paper we reiterate the procedure undertaken but focus instead on the perceptual properties of acoustics and aesthetics, and their relationships to PRP and cognitive and affective appraisals of bird sounds.

Method

Participants and Design

One hundred and seventy-four adult residents (123 female) of the United Kingdom took part in a predictive correlational study advertized as ‘responses to environmental sounds’. Participants were invited to take part online via adverts placed on social media, mailing lists, email-based snowball sampling, and posters located in London and the South East of England. All were aged between 18 and 68 (*M* = 35.52 years, *SD* = 13.22). No remuneration in cash or kind was provided in exchange for participation. Due to its non-sensitive nature the study was exempt from requiring ethical approval by the authors' institutional ethics committee, but appropriate ethical guidelines were followed.

Materials and Stimuli

Dependent variables. Bird sounds were evaluated using three sets of measures, as follows:

Perceived restorative potential (PRP). The PRP of each bird sound was evaluated in terms of how helpful it would be for participants in need of recovery from cognitive fatigue and stress. The following vignette detailing such a scenario was provided, based on those used by Staats, Kieviet, and Hartig (2003) and Staats and Hartig (2004): "You've been working very hard recently. Now, after a long day, you really have had it. You have difficulty concentrating and are very irritable. To top it all off, you have had an upsetting argument with a friend and are feeling very stressed out about it. You sit down somewhere to take a break. To what extent would listening to this sound help you to recover in this scenario?" Participants rated agreement with the question per bird sound on a scale of 1 to 7 (not at all – completely). A more detailed discussion of this vignette and its development is contained in Ratcliffe et al., (2016).

Affective appraisals. The valence and arousal dimensions of the pictorial Self Assessment Manikin scale (SAM; Bradley & Lang, 1994) were used to measure affective appraisals in response to each sound. Each single-item scale measured affective response to a stimulus on a 9-point scale, from sad (1) to happy (9) and calm (1) to activated (9). Appraisals of affect and arousal have been implicated in perceptions and experiences of restorative environments, and particularly natural sounds (Benfield et al., 2014; Ratcliffe et al., 2013; Ulrich, 1983).

Cognitive appraisals. Ratings of fascination and being away were measured using single items in response to each sound. The items used here are derived from items in scales in published papers. Items for being away ("Listening to this sound is an escape experience") and fascination ("This sound has fascinating qualities") were adapted from the highest-loading items on being away and fascination factors in Hartig, Kaiser, and Bowler's (1997) Perceived Restorativeness Scale (PRS).

Each item was rated in terms of agreement on a scale from 0 (not at all) to 6 (completely), as in the PRS.

Independent variables. The aim of this study was to examine the absolute acoustic properties that might predict ratings of PRP and affective and cognitive appraisals. As such, objective measures of acoustic properties of bird sounds were utilized. These were computed using the bioacoustics software Praat (Boersma & Weenink, 2012). Self-report measures of aesthetic properties (familiarity, complexity, and pattern) were used due to the more subjective nature of these variables, particularly familiarity (see McDermott, 2012).

Objective properties. Sound level was measured via A-weighted equivalent sound pressure level in decibels (dB L_{Aeq}) as used by Björk (1985), with higher values corresponding to louder sounds. Since measurement of L_{Aeq} as heard by participants was not possible due to the online nature of this study, these data were gathered by proxy using a sound pressure level meter and closed-back headphones. Participants were asked to calibrate their computer's audio output to a certain level using a loudness matching task, in order to increase standardization of presentation of the audio clips and their sound intensity across participants. The matching task is described further in the Procedure section.

Harmonics were measured using the harmonics-to-noise ratio (HNR), expressed in decibels (dB). This measure expresses the ratio of harmonic components of an acoustic signal to its noise components. HNR has been used with bioacoustic signals such as the human voice and dog barks, with low values representing harsh, rough sounds and high values representing smooth, clear sounds (Riede, Herzel, Brunnberg, & Tembrock, 2001).

Frequency was measured using the mean fundamental frequency (F_0) value, expressed in Hertz (Hz), for each bird sound, with increasing values corresponding to higher frequency. Björk (1985) reported that mean fundamental frequency was positively correlated with subjective perception of pitch (ρ = .95).

Country of origin of the bird sound (UK or Australia) was also included as an objective measure of familiarity, where 1 = UK and 2 = Australia. In a post-hoc check, participants rated UK birds as significantly more familiar ($M = 5.42$, $SD = .95$) than Australian birds ($M = 3.75$, $SD = 1.20$), $t(48) = 5.44$, $p < .001$.

Subjective aesthetic appraisals. Familiarity, complexity, and pattern were measured using self-report semantic differential scales based on those used by Björk (1985). These were three items on a seven-point scale (1 – 7): very unfamiliar – very familiar; very simple – very complex; and very random – very patterned.

Stimuli. Fifty 10-second sound clips were used in the study, comprising sounds made by 25 common birds in the South East of England and 25 common birds in New South Wales in Australia. The sounds were presented in isolation with no species names or other information provided. The bird sounds were either songs or calls depending on the type of bird and its typical sound. Sound clips were collected from high-quality archives, with permission where necessary, and were evaluated for accuracy by two ornithologists. Sounds were randomly assigned to five groups of 10 sounds each (consisting of five UK bird sounds, and five Australian) using a random number generator corresponding to each sound clip. Via the online survey software, participants were randomly assigned to rate the sounds in one of these groups (participant *N*s ranged from 30 to 39 per group), and the order of sound presentation was also randomized within each group.

Procedure

In the online survey setting, participants provided electronic informed consent to participate in the study and for their data to be used in subsequent analyses. They calibrated their computer's sound output level via a loudness matching task. This involved listening to a test audio clip of a ballpoint pen being clicked up and down, and matching the perceived loudness of that audio clip to the clicking of a ballpoint pen of their own. For more details of this task, please see Ratcliffe et al. (2016; Appendix A). After this, participants completed a brief measure of demographic data and then rated 10 bird sounds on familiarity, complexity, pattern, affective and cognitive appraisals, PRP, and qualitative associations (see Ratcliffe et al., 2016). All measures were completed for each bird sound before moving onto the next sound. Participants were asked to complete the measures for a test sound before beginning. At the end of the study, participants rated how comfortable they found the sound level of the audio clips (1 = very uncomfortable, 5 = very comfortable), before being thanked and debriefed online.

Results

Data Screening

Data from 25 participants were excluded due to procedural issues: 23 because participants rated the sounds as uncomfortably loud, and two due to physiological hearing difficulties. This resulted in data from 149 participants being retained for analysis.

Since not all participants rated all bird sounds, the possibility that scores on dependent variables varied by group was investigated. However, relevant intraclass correlation coefficients (ICC1) per dependent variable ranged from .01 to .03; i.e., only 1 to 3% of variance in the dependent variables was attributable to group membership. Schoemann, Rhemtulla, and Little (2014) indicate that in cases where less than 5% of variance is attributable to such a factor, multilevel modelling techniques may be inappropriate. As such, mean scores per bird sound on the DVs and subjective IVs were calculated and merged with objectively measured acoustic properties. Hierarchical multiple regression analyses were conducted using these data (i.e., individual bird sounds were treated as the unit of analyses, $N = 50$), with group assignment per sound (1 to 5) entered in the form of four dummy-coded predictors at Step 1; these variables accounted for a non-significant amount of variance (between <.01% and 4%, $ps > .05$) in each of the DVs.

Multiple Regression Analyses

Five sets of hierarchical multiple linear regression analyses were conducted, with PRP, valence, arousal, fascination, and being away scores as respective dependent variables (DVs), and sound level, harmonics, frequency, country of origin, familiarity, complexity, and pattern as independent variables (IVs). No multivariate outliers were identified, using Mahalanobis Distance values at 12 *df*, $p = .001$.

As shown in Table 1, frequency was significantly correlated with all DVs, and with two other IVs (familiarity and complexity). However, in multiple regression analyses (see Tables 2 to 6) where acoustic and aesthetic variables were entered together as predictors, the predictive role of frequency was consistently non-significant. This suggests that direct relationships between frequency and the dependent variables might be obscured by the presence of either familiarity or complexity, or both. As such, the regression analyses presented below outline steps in hierarchical regression models, with group membership entered in Step 1 (not shown in Tables for brevity), acoustic predictors in Step 2, and subjective aesthetic predictors entered thereafter (first individually in Steps 3a, b, and c, and then together in Step 3d), in order to better understand the unique predictive roles of each of these properties.

As can also be seen in Table 1, valence and arousal scores were significantly negatively correlated. Given that valence and arousal as measured by the SAM are intended to be uncorrelated (Bradley & Lang, 1994), regression analyses with arousal/valence as DV included valence/arousal, respectively, as control variables in Step 1 alongside group membership. This was done in order to provide a more informative model of predictive relationships between acoustic and aesthetic properties and each affective appraisal, independent of variance associated with the other.

[TABLE 1 ABOUT HERE]

Regressing PRP score on acoustic and aesthetic variables. Together, acoustic and aesthetic properties predicted a significant 71% of variance in PRP score, over and above group membership. Step 2 indicated that approximately 43% of this variance was predicted by acoustic properties of the bird sounds. As shown in Table 2, bird sounds highest in PRP were those that were harmonic, high-frequency, and of a low sound level. Country of origin did not significantly predict PRP score.

In Steps 3a and 3b, familiarity and complexity were positive, significant predictors of PRP score, over and above acoustic properties. In Step 3c, pattern was not a significant predictor and its inclusion in the model did not significantly add to the explained variance in PRP score. However, in the full model listed under Step 3d, all aesthetic properties emerged as individually significant positive predictors of PRP, and explained a significant 28% of variance in PRP score.

The predictive role of frequency was reduced in the presence of both familiarity and complexity, but only became non-significant as a predictor when both aesthetic properties were present in the model, suggesting that indirect relationships between frequency and PRP score may be mediated through both familiarity and complexity.

[TABLE 2 ABOUT HERE]

Regressing valence on acoustic and aesthetic variables. Together, acoustic and aesthetic properties predicted a significant 29% of variance in valence score, over and above variance associated with group membership and arousal. Step 2 indicated that approximately 12% of this variance was predicted by acoustic properties of the bird sounds. As shown in Table 3, bird sounds rated as more likely to make participants happy were those that were high in frequency. Sound level, harmonics, and country of origin did not significantly predict valence score.

In Steps 3a and 3c, familiarity and pattern were not significant predictors of valence score, over and above acoustic properties, and their addition to the models did not significantly explain any more variance in valence score. However, in Step 3b, complexity was a significant positive predictor. In the full model listed under Step 3d, both complexity and pattern emerged as individually significant positive predictors and explained a significant 17% of variance in valence score.

[TABLE 3 ABOUT HERE]

Regressing arousal on acoustic and aesthetic variables. Together, acoustic and aesthetic properties predicted a significant 20% of variance in arousal score, over and above variance associated with group membership and valence. Step 2 indicated that approximately 14% of that variance was predicted by acoustic properties of the bird sounds. As shown in Table 2, bird sounds rated as more arousing were those that had high sound levels and low harmonicity. Country of origin and frequency did not significantly predict arousal score.

In Step 3a and 3b, familiarity and complexity were significant negative and positive predictors of arousal score, respectively, over and above acoustic properties. However, in Step 3c, pattern was not a significant predictor and addition of this variable to the model did not significantly explain any more variance in arousal score.

In the full model listed under Step 3d, the three aesthetic variables explained a significant 6% of variance in arousal score, but complexity emerged as the only significant, positive aesthetic predictor. In the presence of all three aesthetic variables together, harmonics became a non-significant predictor, suggesting a possible mediating role for a combination of aesthetic properties in the relationship between harmonics and arousal.

[TABLE 4 ABOUT HERE]

Regressing fascination on acoustic and aesthetic variables. Together, acoustic and aesthetic properties predicted a significant 74% of variance in fascination score, over and above group membership. Step 2 indicated that approximately 23% of the variance in fascination was predicted by acoustic properties of the bird sounds. Harmonics emerged as a significant, positive predictor of fascination score, while sound level, frequency, and country of origin were not significant predictors.

In Step 3a, familiarity was not a significant predictor of fascination score, over and above acoustic properties, and addition of this variable to the model did not significantly increase explained variance in fascination score. However, in Steps 3b and 3c, complexity emerged as a significant positive predictor and pattern as a significant negative predictor of fascination. In the presence of these aesthetic variables, sound level became a significant negative predictor.

In the full model shown under Step 3d, complexity and harmonics remained as significant positive predictors, while pattern and sound level became non-significant. Altogether, the three aesthetic variables explained a significant 51% of variance in fascination score.

[TABLE 5 ABOUT HERE]

Regressing being away on acoustic and aesthetic variables. Together, acoustic and aesthetic properties predicted a significant 70% of variance in being away score, over and above group membership. Approximately 40% of that variance was predicted by acoustic properties of the bird sounds. Harmonics and frequency were significant, positive predictors, and sound level was a significant negative predictor of being away. Country of origin was not a significant predictor.

In Steps 3a and 3c, familiarity and pattern were not significant predictors of being away score, over and above acoustic properties, and inclusion of these variables did not result in a significant change to the amount of variance explained by the model. In Step 3b, complexity emerged as a significant positive predictor of being away. Frequency became a non-significant predictor in the presence of complexity, suggesting a potential mediating effect of this aesthetic variable on the relationship between frequency and being away. In the full model shown in Step 3d, harmonics was the only remaining significant acoustic predictor, while familiarity, complexity, and pattern were significant aesthetic predictors. Altogether, the three aesthetic variables explained a significant 30% of variance in being away score.

[TABLE 6 ABOUT HERE]

Discussion

Acoustic properties of sound level, frequency, and harmonics, and aesthetic properties of familiarity, pattern, and complexity, were significant predictors of perceptions of bird sounds as potentially restorative, positively valenced, and generating a sense of being away. To a lesser extent, these variables also predicted perceptions of arousal and fascination. Together, acoustic and aesthetic factors predicted 70 - 74% of variance in PRP, fascination, and being away scores, and 20 - 29% of variance in arousal and valence scores. Potential explanations for the low level of explained variance in arousal include: a limited range of certain acoustic properties such as sound level utilized in this study; possible roles of other unmeasured acoustic or aesthetic properties such as sound brightness, as well as semantic associations with the sounds; or the possibility of curvilinear relationships between acoustic and aesthetic properties and perceptions of arousal, which was not explored in this linear regression study.

Hierarchical regression analyses also revealed that inclusion of subjective aesthetic properties of complexity and familiarity within the models reduced the predictive roles of acoustic properties such as frequency and harmonics. This provides an initial indication that subjective evaluations of the way bird sounds are structured may mediate relationships between the objective acoustic properties of these sounds and ratings of their perceived restorative potential.

Dependent Variables

Acoustic properties explained a total of 40 to 45% of variance in PRP and being away score, 23% of variance in fascination score, 14% of variance in arousal score (when cleared of variance associated with valence), and 12% of variance in valence score (when cleared of variance associated with arousal). This suggests that acoustic properties of sound level, harmonics, and frequency may be most relevant to measures that capture both cognitive and affective appraisals, such as PRP score. In contrast, subjective aesthetic properties explained a total of 51% of variance in fascination score, 25 to 30% of variance in PRP and being away scores, 17% of variance in valence score, and only 6% of variance in arousal score. As such, aesthetic properties appear more relevant to measures that focus on cognitive appraisals.

PRP, valence, fascination, and being away scores were highly positively correlated (see Table 1), but arousal score was more highly correlated with PRP and valence scores than with cognitive variables of fascination and being away. Despite the strong correlations between PRP, valence, fascination, and being away, conducting separate regression analyses per dependent variables was important given that affective appraisals are not strongly integrated into ART constructs, and similarly cognitive processes are not emphasized in SRT. Therefore, this study examined whether acoustic and aesthetic properties might present different patterns of prediction for each of these dependent variables, and indeed despite being strongly correlated with PRP, valence, and being away scores, fascination did show a different pattern of prediction by acoustic and aesthetic variables, which may relate to its greater emphasis on cognitive rather than affective appraisal of stimuli.

Despite the differences in regression models observed for the dependent variables, we acknowledge the presence of strong positive correlations between several of these variables. Positive correlations between PRP and valence, and negative correlations between valence and arousal, may be explained by the need for restoration elicited in the stress and cognitive fatigue vignette provided to participants; for example, preference for natural environments is known to be influenced by need for restoration (Hartig & Staats, 2006; van den Berg, Koole, & van der Wulp, 2003), and participants in this study may have rated certain bird sounds as positively valenced (a similar concept to preference) because they also perceived them as high in restorative potential (and, conversely, low on arousal).

Correlations between PRP, fascination, and being away scores are not unexpected given that the latter two constructs are proposed by ART to be constituent processes within the wider experience of attention restoration. Correlations between these variables and valence are also to be expected given that, in their initial presentation of ART, Kaplan and Kaplan (1989, p. 189) suggest that “a preferred environment is thus more likely to be a restorative environment” (although notably this proposes a different direction of relationship to that discussed by Hartig & Staats, 2006, and van den Berg et al., 2003).

Acoustics

Acoustic properties of sound level, frequency, and harmonics were significant predictors of PRP and being away scores. Harmonics and sound level were significant predictors of arousal, while harmonics alone significantly predicted fascination and frequency alone predicted valence.

Sound level. These findings confirm existing evidence that sound level may primarily be associated with appraisals of affective arousal in response to natural sounds (Björk, 1985; Tsai et al., 2010), and extends this by linking it to perceptions of restorative potential, supporting findings from Ratcliffe et al. (2013) that loud bird sounds were not considered restorative.

Harmonics. The broadly consistent relationship between harmonics and all dependent variables bar valence supports evidence suggesting that harmonic sounds are preferred over those that are unharmonic or evaluated as rough-sounding (e.g., Berlyne, 1971; Kumar et al., 2008). The fact that valence was not significantly predicted by harmonics may be related to shared variance between valence and arousal, and suggests that harmonicity may act more on affective appraisals of arousal than pleasure. This, again, corresponds with links between unharmonic animals sounds and their threatening semantic value (Tsai et al., 2010). The fact that harmonic sounds possess inherent structure may also explain their positive prediction of attention restoration constructs of fascination and being away, in that they can be easily processed.

Frequency. When considered separately from aesthetic variables, frequency was a positive predictor of PRP, valence, and being away scores. This supports previous findings of associations between pleasantness and higher-frequency natural sounds, and especially bird sounds (Björk, 1985; Thorpe, 1961). In contrast to findings by Björk (1985) that such sounds relate positively to arousal, however, this study found no such predictive relationship for frequency. Frequency was also not implicated in ratings of fascination; rather, aesthetic variables bore greater relation to this outcome, and are discussed below.

Aesthetics

Subjective sound familiarity was a significant predictor of PRP, arousal, and being away scores. Complexity was a significant predictor of all dependent variables. Pattern was a significant predictor of PRP, valence, fascination, and being away scores, although in the case of fascination pattern was a negative, rather than positive, predictor.

Familiarity. All dependent variables, with the exception of fascination, were significantly predicted by subjective familiarity ratings. In the case of PRP and being away scores, familiarity was a positive predictor, while it was a negative predictor of arousal. In Ratcliffe et al. (2013), some participants felt that the novelty of certain bird sounds would be helpful for restoration, but findings from this study contradict this position and suggest that, when measured quantitatively, familiar bird sounds are perceived as potentially restorative, low in arousal, and generating a sense of being away. Notably, familiarity was not predictive of valence score, which contradicts findings from literature on music perception, where familiarity has been found to be related to intensity of emotional responses such as liking (McDermott, 2012). Participants' imagined need for restoration in this study may have made ratings of familiarity more relevant for arousal score than for valence.

Kaplan and Kaplan (1989) suggest that being away from one's everyday concerns can aid recovery from cognitive fatigue, but Laumann et al. (2001) note that being among novel stimuli is conceptually different from achieving psychological escape or awayness. In the context of this study, the observation that familiar birds are perceived to be more restorative than novel bird sounds suggests that listeners may not need to travel far to find this kind of psychological escape. It is also notable that this relationship was based on perceived, rather than absolute, novelty, since country of origin was not a significant predictor of any of the dependent variables, despite being significantly related itself to perceived familiarity (see Table 1). Future studies may wish to investigate whether explicitly stating whether or not a bird is native influences restorative perceptions of its sound, as well as exploring whether reciprocal relationships between familiarity and restorative potential might be found among a sample of Australian participants.

Complexity. All dependent variables were significantly and positively predicted by complexity ratings. Complex bird sounds were rated as higher in PRP, more pleasant, more fascinating, and generated higher being away ratings than bird sounds that were simple, yet they were also rated as more arousing. This extends existing findings that (moderately) complex visuo-spatial elements of nature can also be perceived as restorative (Kaplan & Kaplan, 1989; Ulrich, 1983). An explanation that balances positive relationships between complexity and both PRP and arousal (which are theoretically negatively correlated) might be that bird sounds offer a moderate range of complexity that is neither over- nor under-stimulating. This study also demonstrates that complexity is predictive of a sense of being away, which might be related to the distraction offered by complex, rather than simple, bird sounds.

Pattern. Pattern was a significant, positive predictor of PRP, valence, and being away scores. It was also a significant negative predictor of fascination when added into the regression model alone. Ulrich (1983) theorized that structured natural environments are more likely to be restorative than chaotic ones due to their ease of navigability, and similarly Kaplan and Kaplan (1989) proposed that an environment that is coherent will also be easier to process, and is therefore more likely to be restorative. This perspective is echoed in Joye and van den Berg's (2011) processing fluency account (PFA). Findings regarding pattern in this study suggest that these theoretical constructs may be applicable to bird sounds as well as visuo-spatial stimuli.

The observation that more patterned bird sounds were rated as less fascinating may relate to the proposed distinction between 'soft' and 'hard' types of fascination (Kaplan & Kaplan, 1989); i.e., more patterned bird sounds may be more moderately or 'softly' fascinating than those that are less predictable and therefore engage more of one's attention. It is notable that pattern was not significantly related to arousal, of which familiarity was a better aesthetic predictor. A speculative explanation for the predictive role of pattern in ratings of being away may be that patterned bird sounds required less focus and thereby provided greater opportunity to escape the need for concentration, in comparison to more unpredictable bird sounds.

Aesthetic properties as potential mediators of relationships between acoustics and perceptions of bird sounds. When regressing PRP and being away score on acoustic and aesthetic variables together, the predictive role of frequency was reduced in the presence of familiarity and complexity. A similar reduction was found in relation to sound harmonics as a predictor of arousal, in the presence of all three aesthetic properties. Such effects were not hypothesized based on the paucity of research on this topic in the context of restorative environments. However, these findings suggest potential mediating effects of complexity, pattern, and/or familiarity on relationships between certain acoustic properties of bird sounds and judgments regarding their perceived restorativeness. Future research involving a larger sample of bird sounds may wish to examine this via formal mediated regression analyses.

When fascination was regressed on acoustic and aesthetic variables, sound level only became a significant negative predictor when in the presence of complexity or pattern variables alone. Pattern was moderately negatively correlated with sound level (see Table 1), and as such inclusion in the model may have revealed a unique contribution of this acoustic variable to fascination; despite this, the predictive role was not strong enough to remain significant in the full model.

Study Limitations

Contributions of semantic and individual differences to ratings. The regression models above predicted between 20 and 74% of variance in PRP, affective appraisal, and cognitive appraisal variables. However, given that scores were averaged per bird rather than per participant, some data regarding individual participant responses to the bird sounds is inevitably lost. This may be of particular relevance to the familiarity variable. Additionally, use of the 50 bird sounds as units of analysis meant that sample sizes per regression were small ($N = 50$).

Furthermore, associations with bird sounds were not captured in this study (although see Ratcliffe et al., 2016, for a treatment on this topic) and may contribute to unexplained variance. As other authors on perceptions of and responses to nature have noted (e.g., Cox & Gaston, 2015; Kumar et al., 2008; Pretty, 2004; Ulrich, 1983), the semantic value of such stimuli is likely to contribute to perceptions of their restorative value. A speculative interpretation of this study's findings is that certain acoustic properties, such as sound level and harmonics, may be associated with the intention behind the sound, and particularly with aggressive or threatening behavior on the part of the animal making the sound (see Morton, 1977; Tsai et al., 2010). Individuals may also have personal or cultural associations with bird sounds independent of their perceptual properties; for example, certain birds may be associated with memories of a place or time (e.g., Mynott, 2009).

Assumed need for restoration through use of vignettes. This study utilized a vignette that detailed the need for affective and attentional restoration (PRP), requiring participants to rate the likelihood that each bird sound would help them recover from such a scenario as well as provide ratings of affective and cognitive appraisals of each sound. The vignette approach has been utilized in previous restorative environments literature, in which such a scenario was rated as familiar and conceivable (Staats et al., 2003; Staats & Hartig, 2004). The scenario used in this study was rated as less familiar to participants than that used in the work of Staats and colleagues, but it was similarly conceivable (see Ratcliffe et al., 2016, for details). As such, it is presented as a valid and reliable way of subjectively assessing the perceived restorative potential of a range of brief auditory stimuli, particularly since other subjective measures of restorative potential focus on visuo-spatial experience (e.g., PRS, Hartig et al., 1997) or broader soundscapes (see Payne, 2013).

This study examined multiple facets of restorative perceptions of bird sounds by measuring a set of dependent variables known to relate to perceived restorative potential of natural environments, and affective and cognitive appraisals of such environments. These variables were identified by Ratcliffe et al. (2013) as being particularly relevant to evaluations of bird sounds as potentially restorative. Single-item measures were deemed most appropriate so as not to exhaust participants during the procedure. However, it is acknowledged that this type of dependent variable may lead to a lack of reliability. Future research may wish to induce affective and attentional fatigue, rather than ask participants to imagine it, and to measure responses to a smaller range of bird sounds using multiple-item instruments measuring subjective restorative and/or affective outcomes; e.g., the Restoration Outcome Scale (ROS; Korpela, Ylén, Tyrväinen, & Silvennoinen, 2008) as well as performance and/or psychophysiological measures.

Online nature of the study. Given that this study was conducted in an online setting, certain factors were beyond experimental control; namely, the equipment that participants used to listen to the sounds and the acoustic setting that they conducted the study in. Participants were asked to participate in the study at a time when they were free from interruptions in order to minimize interference from extraneous stimuli. Participants were also asked to complete a short audio calibration task before listening to the sounds, in order to maintain approximately the same sound level across the sample, and to familiarize themselves with the questions through use of a practice task. However, future research may benefit from being conducted in a laboratory using standardized equipment and headphones in order to further control for error variance associated with differences in procedure.

Sounds isolated from the wider soundscape. The purpose of this study was to examine the relative contributions of acoustic and aesthetic properties of bird sounds to ratings of their perceived restorative potential, in order to better understand the perceptual mechanisms through which cognitive, affective, and restorative appraisals of these common stimuli might occur. In order to do this accurately, it was necessary to isolate the bird sounds from their acoustic context as far as possible. This was done by presenting the bird sounds in short clips, free of extraneous sounds made by other birds and animals, water, and wind. Ratings and measurements of aesthetic and acoustic properties were therefore made in response to the bird sounds alone rather than any accompanying sounds. However, it is acknowledged that bird sounds are rarely heard in isolation in the natural world, and are usually experienced in the context of a wider natural soundscape. Therefore, this study does not seek to extend its conclusions to the predictive role of acoustics and aesthetics in the perceived restorative potential of other natural sounds, soundscapes, or environments; rather, these findings serve as a first step in showing how acoustics and aesthetics play a role in restorative perceptions of bird sounds.

Conclusions and Implications

This study explored predictive relationships between acoustic and aesthetic properties and restorative perceptions relating to 50 bird sounds. Through an online study conducted with 174 participants, a number of acoustic and aesthetic properties were found to significantly predict ratings of variables related to restoration in the context of British and Australian bird sounds; that is, their perceived restorative potential (PRP), and ratings of valence, arousal, fascination, and being away. Harmonics, sound level, frequency, familiarity, complexity, and pattern each had significant predictive roles, depending on the DV in question.

Each bird sound is a product of a combination of acoustic and aesthetic properties that are not, in practice, always easily dissociable from each other (as shown by the possible mediating relationships between acoustic and aesthetic variables identified in this study). However, different patterns of prediction were especially apparent between arousal and fascination. Acoustic properties were more relevant for the former, while aesthetic properties were more relevant for the latter. As such, researchers studying cognitive responses to natural sounds may wish to attend to aesthetic properties of complexity and pattern when choosing stimuli, whereas those with more emphasis on affective responses may wish to prioritise acoustic properties and familiarity when making such choices. For an exhaustive ranking of the 50 bird sounds according to their PRP scores, please see Ratcliffe et al. (2016), which may be of use to researchers who wish to choose bird sounds likely to be perceived as restorative in their work.

Building on findings from Ratcliffe et al. (2016) regarding associations with bird sounds and their links to restorative perceptions, the results presented here indicate that certain perceptual and aesthetic properties of bird sounds are also related to how restorative they are considered to be and how they are cognitively and affectively appraised. Given that the majority of literature in the field has focused on visuo-spatial experience of nature, this study provides novel insights into restorative nature as experienced through sound, and specifically a type of sound that individuals perceive to be particularly restorative (Ratcliffe et al., 2013). In so doing it highlights the need for further study of the role of perceptual properties of auditory environments in restoration as well as those that are experienced visuo-spatially. Such research may be of benefit not only to academic environmental psychologists, but also conservation practitioners who wish to encourage positive experiences in natural places through the different sensory experiences afforded therein.

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Table 1. Matrix of correlations between acoustic and aesthetic properties, cognitive and affective appraisals, and perceived restorative potential (PRP) per bird sound.

Variables	PRP	Valence	Arousal	Fascination	Being away	Sound level (dB L_{Aeq})	Harmonics (HNR Hz)	Frequency (Hz)	Country of origin	Familiarity	Complexity	Pattern
Valence	.95***											
Arousal	-.78***	-.71***										
Fascination	.87***	.84***	-.50***									
Being away	.97***	.96***	-.68***	.92***								
Sound level (dB L_{Aeq})	-0.25*	-0.20	0.45***	-0.12	-0.19							
Harmonics (HNR Hz)	0.43***	0.46***	-0.36**	0.39**	0.46***	0.27*						
Frequency (Hz)	0.55***	0.59***	-0.34**	0.46***	0.55***	-0.14	0.31*					
Country of origin	-0.20	-0.21	0.18	-0.08	-0.16	0.12	0.08	-0.09				
Familiarity	0.45***	0.47***	-0.46***	0.56	0.37**	-0.26*	-0.05	0.30**	-0.62***			
Complexity	0.46***	0.43***	-0.05	0.74***	0.55***	0.06	0.13	0.34***	-0.01	-0.03		
Pattern	0.22	0.28*	-0.35**	-0.09	0.15	-0.22*	0.14	0.05	-0.20	0.29*	-0.50***	
Min.	1.50	3.52	3.19	2.40	1.63	47.00	-.23	294.35	-	1.90	3.00	3.16
Max.	5.26	7.52	5.62	5.28	5.13	62.70	28.00	6336.53	-	6.71	6.24	6.00
Mean	3.29	5.87	4.44	4.09	3.54	55.48	13.28	2922.00	-	4.59	4.62	4.60
Standard deviation	1.04	1.02	0.56	0.72	0.89	3.93	7.18	1708.67	-	1.36	0.86	0.75

N = 50. * $p < .05$, ** $p < .01$, *** $p < .001$. Country of origin = categorical variable (1 = UK, 2 = Australia). Ratings scales: PRP = 1 (not at all) to 7 (completely); valence and arousal = 1 (sad/calm) to 9 (happy/activated); fascination and being away = 0 (not at all) to 6 (completely); familiarity, complexity, and pattern = 1 (very unfamiliar/simple/random) to 7 (very familiar/complex/patterned).

Table 2. Hierarchical linear regression statistics for predictor variables (acoustic and aesthetic properties) with perceived restorative potential (PRP) as dependent variable.

	IV	*t*	*B*	*SE B*	*β*
Step 2	Sound level	-2.60**	-.08	.03	-.31
$R^2_{Adj}Chg$ = .43	Harmonics	3.35**	.06	.02	.41
FChg (4, 41) = 9.90***	Frequency	2.92**	< .001	< .001	.35
	Country	-1.50 ^{ns}	-.34	.23	-.16
Step 3a	Sound level	-2.30*	-.07	.03	-.26
$R^2_{Adj}Chg$ = .06	Harmonics	3.69***	.06	.02	.43
FChg (1, 40) = 5.96*	Frequency	2.21*	< .001	< .001	.27
	Country	.25 ^{ns}	.07	.27	.03
	Familiarity	2.44*	.26	.11	.34
Step 3b	Sound level	-3.17*	-.09	.03	-.33
$R^2_{Adj}Chg$ = .12	Harmonics	3.70***	.06	.02	.41
FChg (1, 40) = 11.70***	Frequency	2.04*	< .001	< .001	.23
	Country	-1.71 ^{ns}	-.34	.20	-.17
	Complexity	3.42***	.44	.13	.36
Step 3c	Sound level	-2.37*	-.08	.03	-.30
$R^2_{Adj}Chg$ < .001	Harmonics	3.14**	.06	.02	.41
FChg (1,40) = .02 ^{ns}	Frequency	2.88**	< .001	< .001	.36
	Country	-1.41 ^{ns}	-.33	.23	-.16
	Pattern	.15 ^{ns}	.03	.17	.02
Step 3d	Sound level	-2.02*	-.05	.02	-.18
$R^2_{Adj}Chg$ = .28	Harmonics	3.55***	.05	.01	.33
FChg (3, 38) = 14.37***	Frequency	1.00 ^{ns}	< .001	< .001	.10
	Country	1.17 ^{ns}	.24	.21	.12
	Familiarity	3.61***	.28	.08	.39
	Complexity	5.70***	.72	.13	.60
	Pattern	2.97**	.44	.15	.32

N = 50. *** $p \leq .001$, ** $p \leq .01$, * $p \leq .05$, ^{ns} Not significant. Country = categorical variable (1 = UK, 2 = Australia). Ratings scales: PRP = 1 (not at all) to 7 (completely); familiarity, complexity, and pattern = 1 (very unfamiliar/simple/random) to 7 (very familiar/complex/patterned).

Table 3. Hierarchical linear regression statistics and significance values for predictor variables (acoustic and aesthetic properties) with valence score as dependent variable.

	IV	*t*	*B*	*SE B*	*β*
Step 2	Sound level	.96 ^{ns}	.03	.03	.12
$R^2_{Adj}Chg$ = .12	Harmonics	.85 ^{ns}	.01	.02	.10
FChg (4, 40) = 4.63**	Frequency	3.32**	< .001	< .001	.32
	Country	-1.02 ^{ns}	-.18	.18	-.09
Step 3a	Sound level	.74 ^{ns}	.02	.03	.09
$R^2_{Adj}Chg$ < .001	Harmonics	1.16 ^{ns}	.02	.02	.14
FChg (1, 39) = 1.11 ^{ns}	Frequency	2.92**	< .001	< .001	.29
	Country	-.19 ^{ns}	-.04	.22	-.02
	Familiarity	1.05 ^{ns}	.10	.10	.14
Step 3b	Sound level	1.01 ^{ns}	.03	.03	.11
$R^2_{Adj}Chg$ = .09	Harmonics	.83 ^{ns}	.01	.01	.08
FChg (1, 39) = 14.72***	Frequency	2.45*	< .001	< .001	.21
	Country	-1.18 ^{ns}	-.18	.15	-.09
	Complexity	3.84***	.37	.10	.31
Step 3c	Sound level	.99 ^{ns}	.03	.03	.12
$R^2_{Adj}Chg$ < .001	Harmonics	.78 ^{ns}	.01	.02	.09
FChg (1, 39) = .07 ^{ns}	Frequency	3.28*	< .001	< .001	.32
	Country	-.94 ^{ns}	-.17	.18	-.09
	Pattern	.27 ^{ns}	.04	.13	.03
Step 3d	Sound level	1.56 ^{ns}	.04	.02	.14
$R^2_{Adj}Chg$ = .17	Harmonics	.79 ^{ns}	.01	.01	.07
FChg (3, 37) = 13.16***	Frequency	2.01*	< .001	< .001	.16
	Country	.74 ^{ns}	.12	.16	.06
	Familiarity	1.96 ^{ns}	.14	.07	.19
	Complexity	6.11***	.61	.10	.51
	Pattern	3.69***	.43	.12	.32

N = 50. *** $p \leq .001$, ** $p \leq .01$, * $p \leq .05$, ^{ns} Not significant. Country = categorical variable (1 = UK, 2 = Australia). Ratings scales: valence = 1 (sad) to 9 (happy); familiarity, complexity, and pattern = 1 (very unfamiliar/simple/random) to 7 (very familiar/complex/patterned). Arousal was controlled for along with group membership in Step 1.

Table 4. Hierarchical linear regression statistics and significance values for predictor variables (acoustic and aesthetic properties) with arousal score as dependent variable.

	IV	*t*	*B*	*SE B*	*β*
Step 2	Sound level	4.77***	.06	.01	.44
$R^2_{Adj}Chg$ = .14	Harmonics	-2.54*	-.02	.01	-.27
FChg (4, 40) = 5.95***	Frequency	1.10 ^{ns}	< .001	< .001	.11
	Country	.51 ^{ns}	.05	.09	.04
Step 3a	Sound level	4.88***	.06	.01	.43
$R^2_{Adj}Chg$ = .03	Harmonics	-3.12**	-.03	.01	-.32
FChg (1, 39) = 4.70*	Frequency	1.38 ^{ns}	< .001	< .001	.14
	Country	-.83 ^{ns}	-.09	.11	-.08
	Familiarity	-2.17*	-.10	-.05	-.25
Step 3b	Sound level	4.45***	.06	.01	.40
$R^2_{Adj}Chg$ = .04	Harmonics	-2.20*	-.02	.01	-.23
FChg (1, 39) = 6.38*	Frequency	.86 ^{ns}	< .001	< .001	.08
	Country	.24 ^{ns}	.02	.09	.02
	Complexity	2.53*	.15	.06	.23
Step 3c	Sound level	4.36***	.06	.01	.43
$R^2_{Adj}Chg$ < .001	Harmonics	-2.37*	-.02	.01	-.26
FChg (1, 39) = .26 ^{ns}	Frequency	.99 ^{ns}	< .001	< .001	.10
	Country	.40 ^{ns}	.04	.10	.04
	Pattern	-.51 ^{ns}	-.04	.07	-.05
Step 3d	Sound level	4.85***	-.39	.01	.43
$R^2_{Adj}Chg$ = .06	Harmonics	-2.65 ^{ns}	-.02	.01	-.27
FChg (3, 37) = 3.70*	Frequency	1.25 ^{ns}	< .001	< .001	.12
	Country	-.29 ^{ns}	-.03	.11	-.03
	Familiarity	-1.13 ^{ns}	-.06	.05	-.14
	Complexity	2.43*	.21	.09	.32
	Pattern	1.56 ^{ns}	.14	.09	.18

N = 50. *** $p \leq .001$, ** $p \leq .01$, * $p \leq .05$, ^{ns} Not significant. Country = categorical variable (1 = UK, 2 = Australia). Ratings scales: arousal = 1 (calm) to 9 (activated); familiarity, complexity, and pattern = 1 (very unfamiliar/simple/random) to 7 (very familiar/complex/patterned). Valence was controlled for along with group membership in Step 1.

Table 5. Hierarchical linear regression statistics and significance values for predictor variables (acoustic and aesthetic properties) with fascination score as dependent variable.

	IV	*t*	*B*	*SE B*	*β*
Step 2	Sound level	-1.35 ^{ns}	-.03	.03	-.18
$R^2_{Adj}Chg$ = .23	Harmonics	2.59*	.04	.01	.37
FChg (4, 41) = 4.49**	Frequency	1.96 ^{ns}	< .001	< .001	.28
	Country	-.50 ^{ns}	-.09	.18	-.06
Step 3a	Sound level	-1.29 ^{ns}	-.03	.03	-.18
$R^2_{Adj}Chg$ < .001	Harmonics	2.56*	.04	.01	.37
FChg (1, 40) = .01 ^{ns}	Frequency	1.81 ^{ns}	< .001	< .001	.27
	Country	-.32 ^{ns}	-.07	.23	-.05
	Familiarity	.10 ^{ns}	.01	.09	.02
Step 3b	Sound level	-2.85**	-.04	.02	-.23
$R^2_{Adj}Chg$ = .47	Harmonics	4.14***	.04	.01	.36
FChg (1, 40) = 72.23***	Frequency	.41 ^{ns}	< .001	< .001	.04
	Country	-.89 ^{ns}	-.10	.11	-.07
	Complexity	8.50***	.59	.07	.70
Step 3c	Sound level	-2.06*	-.05	.03	-.29
$R^2_{Adj}Chg$ = .05	Harmonics	3.18**	.05	.01	.45
FChg (1, 40) = 4.67*	Frequency	1.72 ^{ns}	< .001	< .001	.23
	Country	-.96 ^{ns}	-.17	.18	-.12
	Pattern	-2.16*	-.27	.13	-.29
Step 3d	Sound level	-1.85 ^{ns}	-.03	.02	-.16
$R^2_{Adj}Chg$ = .51	Harmonics	3.52***	.03	.01	.31
FChg (3, 38) = 28.93***	Frequency	-.19 ^{ns}	< .001	< .001	-.02
	Country	.54 ^{ns}	.07	.13	.05
	Familiarity	1.42 ^{ns}	.08	.05	.14
	Complexity	8.54***	.70	.08	.84
	Pattern	1.92 ^{ns}	.18	.10	.19

N = 50. *** $p \leq .001$, ** $p \leq .01$, * $p \leq .05$, ^{ns} Not significant. Country = categorical variable (1 = UK, 2 = Australia). Ratings scales: fascination = 0 (not at all) to 6 (completely); familiarity, complexity, and pattern = 1 (very unfamiliar/simple/random) to 7 (very familiar/complex/patterned).

Table 6. Hierarchical linear regression statistics and significance values for predictor variables (acoustic and aesthetic properties) with being away score as dependent variable.

	IV	*t*	*B*	*SE B*	β
Step 2	Sound level	-2.12*	-.06	.03	-.26
$R^2_{Adj}Chg$ = .40	Harmonics	3.36**	.05	.02	.43
FChg (4, 41) = 8.69***	Frequency	2.74**	< .001	< .001	.34
	Country	-1.18 ^{ns}	-.23	.20	-.13
Step 3a	Sound level	-1.84 ^{ns}	-.05	.03	-.22
$R^2_{Adj}Chg$ = .03	Harmonics	3.55***	.05	.02	.44
FChg (1, 40) = 3.04 ^{ns}	Frequency	2.16*	< .001	< .001	.28
	Country	.11 ^{ns}	.03	.25	.02
	Familiarity	1.74 ^{ns}	17	.10	.26
Step 3b	Sound level	-2.85**	-.07	.02	-.29
$R^2_{Adj}Chg$ = .18	Harmonics	3.96***	.05	.01	.42
FChg (1, 40) = 18.89***	Frequency	1.76 ^{ns}	< .001	< .001	.19
	Country	-1.46 ^{ns}	-.24	.17	-.14
	Complexity	4.35***	.46	.11	.44
Step 3c	Sound level	-2.14*	-.06	.03	-.28
$R^2_{Adj}Chg$ < .001	Harmonics	3.34**	.06	.02	.44
FChg (1, 40) = .24 ^{ns}	Frequency	2.62**	< .001	< .001	.33
	Country	-1.25 ^{ns}	-.26	.20	-.14
	Pattern	-.49 ^{ns}	-.07	.15	-.06
Step 3d	Sound level	-1.71 ^{ns}	-.04	.02	-.16
$R^2_{Adj}Chg$ = .30	Harmonics	3.67***	.04	.01	.35
FChg (3, 38) = 14.34***	Frequency	.80 ^{ns}	< .001	< .001	.08
	Country	1.01 ^{ns}	.18	.18	.10
	Familiarity	2.94**	.21	.07	.33
	Complexity	5.99***	.70	.11	.65
	Pattern	2.52*	.33	.13	.28

$N = 50$. *** $p \leq .001$, ** $p \leq .01$, * $p \leq .05$, ^{ns} Not significant. Country = categorical variable (1 = UK, 2 = Australia). Ratings scales: being away = 0 (not at all) to 6 (completely); familiarity, complexity, and pattern = 1 (very unfamiliar/simple/random) to 7 (very familiar/complex/patterned).