The Acoustic and Auditory Contexts of Human Behavior

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Sound is a crucial component of the human communicative toolkit; however, as a topic of research, it has been relatively neglected in archaeological method and theory. We propose that a framework requires to be developed in which inferences can be made about the significance of sound in the past that are not bounded by the particularities of current cultural contexts. Such a framework should be multidisciplinary and draw on what is known scientifically about human sensitivities to and uses of sound, including nonverbal vocalizations, speech and music, ethological studies that offer insight into how sound perception and environment affect sociality and survival, and the effects of environment on socially significant human sound.

Human sociality involves complex and dynamic relationships with sound. Not only does sound provide information about the environments in which people live (Truax 1999), but its construction, perception, and socially ascribed meanings influence how people interact with each other (Cross and Woodruff 2009). Both intentional and unintentional sounds affect how people engage with, transform, and create environments or places. This is true for communicating through spoken language, dancing, music-making, and signaling, in addition to the everyday sounds of preparing and eating food, creating tools, and moving through spaces. The social values that are ascribed to sound involve intricate and diverse worldviews that are integral to modern-day societies (Atkinson 2007) and were undoubtedly significant in prehistoric and evolutionary time frames (Bannan 2012; Conard, Malina, and Münzel 2009; d'Errico et al. 2003; Mithen 2005; Morley 2013; Scarre and Lawson 2006; Wallin, Merker, and Brown 2000).

However, research in this area has largely remained underdeveloped in the discipline of archaeology relative, at least, to the study of other aspects of culture, structure, and practice. In part, this has been due to the perceived ephemerality of sound and the concomitant inaccessibility of its social significance, and because there is no single discipline that can be drawn upon to understand the acoustic and auditory aspects of human behavior. Additionally, there has been a tendency to focus on the particularities of cultural "complexity," with less emphasis on biocultural characteristics that arise from interaction between the dynamics of enculturation and cultural enaction, and the physical, physiological, neural, and evolutionary factors that shape the human perception and production of sound. Furthermore, outside archaeology, many of the approaches to studying sound and sociality have been constructed around modern conceptualizations of culturally meaningful sound, which may not be appropriate when applied to historic and prehistoric populations.

The ways in which sound has come to be measured in contemporary Western societies reflect the specific types of locations in which sound is held to be socially significant, and tend to focus on the aesthetic value of sound or on managing noise mitigation. Many of the measures that have been developed are intended to characterize sound in enclosed spaces that are used for particular—generally presentational—functions, involving speech or music, or sometimes both. Others have been developed so as to enable evaluation of environmental sounds that are generally considered to be undesirable, which typically includes what is referred to as noise pollution.

The first category of measure is intended to encapsulate information about the effects of indirect—reflected—sound within enclosed spaces. In such spaces, sound reflections will render a listener's perception of the sound different from that which would occur in a free field, where only the direct energy from the sound source would contribute to their perceptions. Reflections in the enclosed space will: (i) increase the integrated energy reaching a listener from a sound source, (ii) increase the perceived duration of the sound, and (iii) change

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the cues upon which a listener may rely in locating the source of a sound (see Rasch and Plomp 1982). Into this first category fall measures such as: *strength*, the increase in time-integrated sound energy reaching the listener over the free-field measure (e.g., Aretz and Orlowski 2009); *reverberation time*, or the time taken for sound to decay to a level that is 60 decibels (dB) lower than at the end of the direct sound; *early decay time*, or the time taken for the sound to decay by 10 dB from the end of the direct sound (e.g., Barron 1995); the *early lateral energy fraction* (LF), reflecting the "spatial impression" of a space perceived by a listener in terms of the proportion of early sound energy arriving from the side as opposed to energy arriving from all other directions (e.g., Barron 2000); and *clarity*, the extent to which successive sounds overlap with each other in time and thus render speech or music more or less intelligible, measured as the level of the direct sound reaching a listener (in dB) minus the level of all indirect sound.[1]

Into the second category fall measures based around aspects of the long-term average spectra (LTAS) of sounds in a given environment (e.g., Ge et al. 2009), typically expressed in terms of metrics such as L_{eq}, the continuous sound that would contain the same sound energy as a time-varying sound over a given time period, expressed as a single value in dB, or LA_{eq}, which takes into account the differential sensitivities of the human auditory system to different frequency ranges (i.e., lower frequency sounds are required to be at a higher physical intensity in order to be perceived as equally loud as sounds of a higher frequency, and hence lower frequency sounds would be differently weighted in measuring LA_{eq} and in L_{eq}). Other measures might include *modulation transfer function* (a measure of how well the temporal envelope of a sound signal is preserved in a given acoustical environment: see Houtgast, Steeneken, and Plomp 1980), and *attenuation* (the sound pressure level in a particular environment at a distance from a sound source, corrected for air absorption: see Naguib and Wiley 2001). Most of these measures have been developed in respect of, and have been applied to, contemporary built environments and are concerned with speech or music audibility and intelligibility, aesthetics, or minimization of noise-based social disruption, though some have been adapted for application in nonurban contexts or in the context of ethological research.

Rather than conceiving of the relevance of sound in terms, effectively, of aesthetics or of nuisance value, we propose that a framework for considering human relationships with sound should draw on large areas of research that have greatly expanded what is culturally and scientifically known about (1) human uses of, sensitivities, and responses to sound, including nonverbal vocal communication (see, e.g., Moore 2012; Samuels et al. 2010; Sauter et al. 2010) and music (see, e.g., Hallam, Cross, and Thaut 2009); (2) the effects of different environments on sound, such as ease of acoustic propagation and other physical transformations such as filtering or diffraction, through ethological studies (see, e.g., Smith et al. 2013); and (3) the consequences of the above for prospectively selective reinforcement of many social behaviors as elucidated by soundscape studies and ethnography. This type of framework should allow for a broad and bioculturally grounded characterization of situations in which sound is functional for humans in serving complex purposes that mediate social relationships and facilitate survival or resource exploitation. In the penultimate section here, as an example of how such an approach could work, we suggest a general framework for considering open-air prehistoric sites, particularly in the context of the Côa Valley rock-art site in northeastern Portugal.

1. Although for speech, all indirect sound arriving within 50 milliseconds (ms) of the direct sound is counted as direct sound; for music, all indirect sound arriving within 80 ms of the direct sound counts as direct (e.g., Bradley 2011).

Music, Sound, and Social Mediation

Scientific understanding of the physical constraints on the production and perception of sound is well represented in literature about language and music. Language can be thought of as a set of communicative—acoustical and gestural—resources that may be used to change the information about states of affairs in the world that is shared between members of a culture. The acoustic properties of speech (i.e., vocal level, speaking rate, articulation, etc.) are important factors in the sensory and perceptual processing of aural communication (Knapp and Hall 2006). These properties are modifiable in response to environmental and interpersonal milieus that affect speaker intelligibility and perceiver response (Durisala et al. 2011; Garellek et al. 2013; Krause and Braida 2004; Liu, Tseng, and Tsao 2000; Payton, Uchanski, and Braida 1994; Smiljanić and Bradlow 2005, 2009; Uchanski 2005). The physiological and cognitive abilities of human audition also allow for the processing and interpretation of complex sound events, or auditory scene analysis, which involves differentiating and processing sound sources in acoustically complex environments (Bregman 1990, 1993).

Nonverbal and paralinguistic vocalizations are crucial not only for sharing information, but for facilitating affective social engagement through phatic communication, or the nonreferential use of sound for conveying the emotional and motivational states of individuals and groups (e.g., Coupland, Coupland, and Robinson 1992; Gobl and Chasaide 2003). Although the extent to which all emotional speech vocalizations are cross-culturally recognized is debated, Pell et al. (2009) state that "vocal emotional expressions seem to exhibit a core set of acoustic perceptual features which promote accurate recognition across languages, but that there are also language-specific differences which lead to an in-group processing advantage" (418).

Sauter et al. (2010) suggest that humans compensate for language barriers by using emotional signals as a commu-

nicative system, possibly constituting a "psychological universal." They report on an experimental study with European native English speakers and Himba participants (seminomadic pastoralists in rural Namibia). These experiments sought to explore cross-cultural recognition of basic emotions, such as anger, joy, and sadness. Their results indicated "that a number of primarily negative emotions have vocalizations that can be recognized across cultures, while most positive emotions are communicated with culture-specific signals" (Sauter et al. 2010:1). This suggests that the prosodic features of vocal sounds, such as rhythm, pitch, stress, and intonation, share some commonalities across cultures, with a bias toward avoiding conflict on the affective spectrum.

Complementary to linguistic aspects of aural communication, and most likely overlapping with prosodic aspects of speech in terms of cognition and behavior (Hawkins, Cross, and Ogden 2013), "music" often involves vocalizations, sound tools, and gestures, which may be manifested in the context of everyday activities and in more formalized modes of interaction like ritual (e.g., Nettl 2005). Music can be thought of as a complex patterning of sound— pitch, rhythm, timbre, and intensity—and action that often involves cyclical temporal structures based upon a regular pulse, with social meanings that are both shared and deeply personal (cf. "floating intentionality"; Cross 1999, 2012*a*). It has the flexible capacity to affect motivational states of individuals and groups in a way that is not dependent upon the transmission or explicit understanding of language-bound information. Music's proximal functions such as entertainment, aesthetic stimulation, and social bonding—in Nettl's (2005) terms, music's "uses"—can be clearly specified, although they vary from culture to culture. However, a distal function can be proposed, deriving from McLeod's (1974) suggestion that "music tends to occur at points of conflict, uncertainty, or stress within the social fabric" (113). Cross (1999, 2012*a*) suggests that music's semantic indeterminacy, combined with its capacity to entrain participants to a commonly experienced regular pulse, means that it can be used for regulating situations of uncertainty on both inter- and intragroup levels, between individuals, and with nonhuman agencies.

This can be seen clearly with music that occurs at moments of potential conflict or stress between and within groups (e.g., Clendinnen 2005; McLoughlin 1990; O'Connell and Costelo-Branco 2010; Stallsmith 2011), or that which is employed in caring for or healing those who are ill or wounded (e.g., Chu et al. 2014; Cook and Silverman 2013; Friedson 1996; Park 2003; Pavlicevic 2005; Haile 1943; Roseman 1991; Taylor 2010; Thram 2002). For example, the North American Blackfoot, as reported by Nettl (1967), historically used music to affirm identity, and in many instances—such as transferring medicine bundles, approaching another tribe, or returning from a conflict—music was focal in situations involving significant moments of change, uncertainty, or "stress within the social fabric." In another context, Seeger's work with the Suyá of central Brazil demonstrated "the ability of music to transcend social, spatial, and psychological distance without an accompanying physical presence," an ability that Seeger proposed to be "one of its [music's] important communicative features" (Seeger 1979:384). Seeger (2010:112) has also described how music has been significant for mediating relationships between the Suyá and wider Brazilian society, where "in the absence of a mutually intelligible language, they communicated through two nonverbal forms of exchange: material and musical."

Socially organized sound such as music has been shown to play a role in memory creation and recollection (Crowder 1993; Snyder 2001). It can also act as a means for learning about the cultural ties to a surrounding environment and reaffirming a shared identity (e.g., Feld 2006; Impey 2006, 2013; Marett 2005; Roseman 1998). Impey's (2006, 2013) work in the western Maputaland borderlands of South Africa, Mozambique, and Swaziland describes a situation where music constitutes an "act of remembering though sound and performance" (Impey 2006:59), which is deeply connected to sense of place. Communities that once lived in the area occupied by the Ndumo Game Reserve in South Africa were forcibly displaced when the reserve was created. The types of songs created during and after this period reflected what Impey (2006) referred to as "social and spatial rupture" (72). In this way, music has helped to mediate the effects of social trauma and facilitate group cohesion where a collective identity is threatened.

The biocultural significances afforded by the acoustic and auditory aspects of human behavior are likely to be intrinsic components of individual and group survival (e.g., Roederer 1984), framing the dynamics of inter- and intragroup relationships. Combined with other modes of sensory interaction, the recognition and interpretation of socially structured sound can be a vital tool in the ability to negotiate situations of uncertainty or tension. The ability to adapt sound to different circumstances based on a need for facilitating fluid social interaction was undoubtedly as significant in the past as it is known to be in modern-day societies. Nevertheless, it is also necessary to consider how environments affect its usefulness as an interactive, communicative tool.

Ethological Considerations

Acoustic signaling can be thought of in terms of its survival value as a *facilitator* of effective communication within environments. In every human society, the ability to produce, perceive, interpret, and respond to sounds within a particular place can be crucial for survival because it is an invaluable component of receiving information. The propagation of sound is affected by many different factors, including production energy, methods and materials used for sound creation, atmospheric conditions or the type of medium through which a sound wave is traveling, absorption characteristics of natural materials such as vegetation, and the reflective properties of natural and human-made structures. Therefore en-

vironmental and action-based variables influence how sound is fundamentally produced and perceived.

Most studies concerning ecology and sound have focused on the animal world (e.g., Farina and Pieretti 2014; Owren, Rendall, and Ryan 2010; Richards and Wiley 1980; Wiley and Richards 1978), with a large body of work on birds (e.g., Atkinson 1997; Kirschel et al. 2009; Morton 1975; Naguib and Wiley 2001; Nelson and Stoddard 1998; Smith et al. 2013) and bats (e.g., Schnitzler, Moss, and Denzinger 2003), but also dealing with other animals in aquatic (e.g., Janik 2013; Marcoux, Auger-Méthé, and Humphries 2012; Rekdahl et al. 2013) and land-based environments (e.g., Bormpoudakis, Sueur, and Pantis 2013; Rasoloharijaona et al. 2006). In terms of sound tools used to modify or enhance sound signals, primates have been documented using materials to create sound in various contexts, including the use of leaves by orangutans to lower the frequency of distress calls (e.g., Lameira, Hardus, and Wich 2012) and chimpanzee percussion of tree buttresses for producing long-distance low-frequency sound (e.g., Arcadi, Robert, and Mugurusi 2004), where higher frequency sounds are ineffective because they are attenuated by vegetation.

These studies are useful for considering sound production and perception because they provide details about the environmental conditions and value of acoustic signaling for communication. As Finnegan (2002:45) puts it: "Its [animal communication] relevance lies not in those analyses which would explain human communication by its earlier evolution or draw sharp distinctions between animal and human communicating. Rather, it directs us to resources that human beings more, or less, share with other members of the animal kingdom, setting the modes of human communication in wider perspective." In ways that are at least analogous to (if not homologous with) auditory scene analysis in humans, animals have the ability to isolate and process acoustic signals for communicative purposes (Bee and Micheyl 2008; Hulse 2002), particularly in large groups or in areas where there is background noise that can mask vocalizations (e.g., Brumm and Slabbekoorn 2005). Auditory distance perception is similarly used by animals to process spatial information about the distances of sound sources (Naguib and Wiley 2001). The ability to produce and perceive acoustic signals and cues also has respective implications for intentional and unintentional behavior modification (e.g., Hasson 1997; Maynard Smith and Harper 1995).

The ethological literature thus reinforces the idea that the production and perception of sound are fundamental for survival and group dynamics across a very wide range of species. Understandings of the contexts in which sound propagation and perception may be advantageous for humans include the carrying power of different frequencies in different types of environments (e.g., forested or open-air settings), where sound production is adapted to frequency attenuation caused by a multitude of variables. Auditory distance perception is another important aspect of how humans acquire information about their surroundings (e.g., Zahorik, Brungart, and Bronkhorst 2005). This includes spatial awareness, such as the location and distance of potential threats or of fellow members of one's group, and the types of activities taking place in an area. The distance between sound source and perceiver is also important for the intelligibility of the acoustic features of speech (Allen, Alais, and Carlile 2009). Cultural adaptations to ecological and social milieus where distance can affect speech intelligibility include the use of sound tools as surrogate speech systems (e.g., Kaminski 2008; Sebeok and Umiker-Sebeok 1976) and variations in speech styles (e.g., Meyer 2004, 2008) to facilitate communication.

The creation and perception of sound may also have specific and significant consequences that relate to how people create and inhabit spaces, such as the demarcation of territories and social spaces, and how they create, use, and respond to sound tools. Yet current approaches to studying the relationships between influences of sound and ecology on human societies remain heavily oriented toward contexts of highly populated and structurally engineered places (e.g., Schulte-Fortkamp and Dubois 2006). The effects of environment on sound in the contemporary world are largely determined and understood using metrics that are geared toward optimizing the acoustics of buildings for particular uses and reducing unwanted noise. In order to situate sound more firmly within the discipline of archaeology, it is necessary to consider the environmental conditions in which sound propagation and perception are useful for humans, and how its dynamic functions are manifested through different cultural practices or worldviews.

Soundscapes: Environment and Sound

Approaches to conceptualizing the social roles of sound have been mapped mostly in terms of modern industrialized and urban conceptions of auditory environments, or soundscapes (Schafer 1994 [1977]; Southworth 1969). The term "soundscape" refers to the acoustics of environments or places and was developed by R. Murray Schafer during the 1960s and 1970s. Schafer sought to explore and characterize the growing complexity of sound in the everyday environments of modern urban societies. His work was critical of the encroachment of modern technology and large populations on the quality of sound. For example, positive and negative distinctions were made between environments where sounds overlapped less frequently and those where acoustic overlapping caused reduced aural clarity. Soundscapes were considered aspects of societies that ought to be shaped and managed, or as described by Schafer (1994:216): "Today, when the slop and spawn of the megalopolis invite a multiplication of sonic jabberware, the task of the acoustic designer in sorting out the mess and placing society again in a humanistic framework is no less difficult than that of the urbanologist and planner, but it is equally necessary."

Schafer's evaluative and aesthetic approach to the idea of

"soundscape" is mirrored, albeit implicitly, in most contemporary quantitative and qualitative approaches to understanding human relationships with sound. In particular, the main body of work in this area has dealt with assessment of the effects of noise exposure and noise reduction (e.g., Atkinson 2007; Brambilla and Maffei 2006; Brown and Muhar 2004; De Coensel and Botteldooren 2006; Pieren and Wunderli 2011), or with the optimization of performance spaces (e.g., Monks, Oh, and Dorsey 2000). The use of dichotomies in considerations of soundscapes—such as sound and silence; indoor and outdoor sounds; pleasant and unpleasant sounds; urban and rural sounds; human-made and nonanthropogenic "natural" sounds (e.g., Kull 2006)—have also been influential in studies of environmental sound. Other approaches, such as the burgeoning research area of "soundscape ecology," are seeking to address a perceived imbalance toward human-centric assessments of environments or landscapes and the sounds within them (e.g., Farina 2014; Krause 2008; Pijanowski et al. 2011; Truax and Barrett 2011).

Although Schaffer's work has been invaluable for considering the sonic components of particular environments or spaces and for bringing attention to a significant aspect of human experience, it is important to note that modern soundscapes are intrinsically different from those of the past, from those outside urbanized contexts, and from those where particular categories of sound may not be applicable. One example of this is the impact of industrial and technological processes, such as dense, large-scale populations and transportation, on the ways that many people today perceive their acoustic surroundings. Another example is the reproducible nature of sound as a prominent feature of the twentieth and twenty-first centuries. The development and widespread use of audio technologies—allowing for recording, listening, and dispersing of audio-based information or music—has led to a standardization of aural stimuli, which has in turn resulted in the compartmentalization of notions about socially significant sound (Howes 2006). Although positive research developments have been increasingly facilitated by such technology (hear, for example, the "Sound around You" project, referenced in supplement A, available online), for societies of the past without this technology and modern-day societies or communities that do not (extensively) use multimedia devices, sound had, and can have, a more ephemeral, transposable nature.

Sound and Ethnography

Principles that might be derived from ethnographic literature concerning the uses and conception of sound can be helpful for exploring the possible range of interpretations of sound-related activities in the past. Some work has sought to identify and examine potential generalities between the "music" of different cultures, such as the Cantometrics Project (see Lomax 1959, 1968). This type of approach to characterizing socially structured sound has been criticized for neglecting the dynamic nature of culture and abstracting from the contexts in which socially structured sound should be considered (e.g., Feld and Fox 1994). Yet knowledge of the social contexts in which sound has played a role in historic and modern-day societies is relatively limited because there are few dense ethnographies of sound predicated on Geertzian "thick descriptions" (Geertz 1973); nevertheless, there are a number of ethnographic accounts dealing with sound that have the potential to be highly informative for considering its roles outside of the cultural settings in which soundscapes have been typically conceptualized and studied.

In addition to the work conducted by Seeger and Nettl on the Suyá and Blackfoot, respectively (see above), and Blacking's seminal work with the Venda (Blacking 1973), perhaps the most comprehensive accounts are provided by Steven Feld with the Kaluli of Papua New Guinea, and Jerome Lewis with the Mbendjele in the Republic of Congo. Aspects of these studies will be briefly described to highlight how current approaches to sound in archaeological contexts must be informed by the significance of sound and sociality outside of industrialized, urban cultures. Ethnographic accounts of these quite different forest-dwelling cultures demonstrate how current approaches to analyzing soundscapes require being situated in an awareness of cultural dynamics, in that the acoustics of environments and social activities are not always separable, rigidly defined, or based upon notions of aesthetics similar to those in the high population density environments typical of urbanized societies.

The Kaluli

Steven Feld's work with the Kaluli of Papua New Guinea during the 1970s and 1980s explored the dynamic interplay of the structure and meaning of sound in Kaluli life (Feld 1982, 1984). At the time of his research the Kaluli were an egalitarian group of swidden horticulturalists who maintained large, shifting cultivation gardens and exploited the forest's range of natural resources by hunting and fishing; their staple food was sago, and their low population density exerted little ecological pressure on their environment (in comparison with other areas of the Papuan highlands: see Feld 1981). Feld's account detailed how the Kaluli perception of the environment was reflective of their coexistence with the rainforest.

In particular, birdsong surrounding a Kaluli village was thought to be the voices of ancestors, which Feld (1984:395) described as being "surrounded by the presence, through voices and sounds, of friends and relatives." Myths also concerned human-bird transformations that explained relationships between people, and between people and their surroundings. Their social construction of sound involved "extensive overlapping and alternation, layering parts and sounds in coordinated nondiscrete textures" (Feld 1984:391), which they called *dulugu ganalan*, or "lift-up-over sound." Feld (1984:392) described this as "layered" and "staggered" sounds that reflected the soundscape of the rainforest, and

noted that the "Kaluli like all sounds to be dense, compacted, without breaks, pauses, or silences." The enactive roles of social and environmental sound in Kaluli culture stand in clear contrast to the concepts and evaluations of sound in the urban contexts that have shaped views and approaches to soundscape studies.

The form of Kaluli song was described as being preferentially modeled upon birdsong and other environmental sounds. Dedicated sound tools were used for activities ranging from recreation to ceremony and included bamboo jaw harps, rattle instruments, and drums that were thought to take on the qualities of the call of the crested pitohui (a type of bird hunted by the Kaluli: listen to Feld 1991, 2001). Kaluli performance was said to have been coordinated with environmental acoustic features that were socially valued, and often melancholy. For instance, the songs that were sung during visits by neighboring Kaluli were about places in the forest that had sentimental meaning, as they reminded the community of the deceased people that they had shared experiences with at these places. Feld (1982:151) recounted that songs about "lands, particularly garden sites, places where sago had been or was being made, places where longhouses had existed, and creeks were often noted sentimentally" and that this was used in song to allow listeners to journey through "a progression of lands and places, and a progression of deeply felt sentiments associated with them" (151). In addition, song often accompanied mundane activities, such as during the rhythmic beating of sago preparation, cutting trees, and clearing brush (listen to Feld 1991, 2001). Notions of place and time were deeply entwined with aural constructs.

The soundscape of the forest environment also acted as an indicator and regulator of everyday life, with birds being significant for the demarcation of social spaces and defining the passing of days and seasons, and the sounds of water being integrated into socially structured sound production (Feld 1981, 1991). Kaluli were described as having acute spatial skills that were adapted to the acoustics of the forest environment, where auditory distance perception was more valuable for navigating the forest setting than visual references. Both the distance and height of sounds, particularly those produced by birds, were important for hunters, who were also skilled in mimicking calls to attract the birds that they were hunting. For the Kaluli, "bird calls and bird life constituted the most accessible domain from which many of the experiential aspects of the perceptual system were linguistically marked" (Feld 1982:62); for example, as Feld notes, the Kaluli "utilized levels of bird nesting and flight patterns to make comparative statements about vegetation and forest life" in terms of distance and height (1982:61).

Feld's work with the Kaluli is a clear example of why it is necessary to consider not only the acoustics of places, or soundscapes, but also how sound is perceived and created to mark social value for particular places and social activities within these places. From a materials standpoint, the significance of sound for the Kaluli was manifested not only in the creation and use of sound tools, but also in terms of the resources they exploited, how they exploited them, and how they established and inhabited social spaces (based around central longhouses). Here, the role of sound in everyday life was overtly recognizable and demonstrated how environmental contexts affect the ways in which value is ascribed to sound production and perception.

The Mbendjele

Through his recent work with the Mbendjele Yaka in the Congo Basin (Lewis 2002, 2009), Jerome Lewis has suggested that the dynamic Mbendjele communication systems may be indicative of the conditions in which language could have emerged in human populations (Lewis 2009). In his description of Mbendjele communication, "they mix words with sung sounds, ideophones, expletives, whistles, signs, hand signals, gestures, vocabulary from other peoples' languages, animal sounds and other environmental sounds, sometimes in a single speech act" (Lewis 2009:236–237).

The Mbendjele are nomadic hunter-gatherers whose way of life involves the creation of fixed campsites within the forest that may be sporadically relocated in response to both exogenous and endogenous pressures (e.g., the activities of logging companies—usually illegal—or changes within the community, such as the death of a group member). As for the Kaluli, in a dense forest environment, sound is a more significant and useful sense than vision for providing information about surrounding threats or resources, which involves the intricate use of auditory scene analysis and distance perception. When hunting, Mbendjele men are skilled in mimicking the calls of animals to draw them near. They also mimic birdcalls to communicate with each other while pursuing animals. Women and small children travel in larger groups while talking and singing loudly so as not to startle dangerous animals concealed by dense vegetation. When stories are told about animal encounters, the acoustic features of such encounters are mimicked as what Lewis (2009) refers to as species-specific "sound signatures." By utilizing these sounds and associative gestures in everyday conversation, Mbendjele children are taught about the dangers associated with particular sounds and how to respond to them.

For the Mbendjele, the forest environment is an entity that must be pleased by sounds of laughter, song, and storytelling, in order for it to provide food. In contrast, bad sounds such as shouting and fighting or the wailing of children will cause the forest to withhold valuable resources. Consequently, this can result in camps being divided and people moving to different places. Lewis (2009:249) described these auditory relationships as "a conversation with a complex multi-agent organism." As for song, Lewis (2009:252) stated that the Mbendjele conception of their polyphonic singing should not be "understood because of the words they use from human language but through the acoustic form they have adopted

based on the forest's 'language'" and that "their melodies are the forest's words."

Public rituals or ceremonies and games are concerned with members of a camp or community as a whole in order to positively affect collective well-being, or to encourage goal-oriented cooperation (Lewis 2002). *Massana* and *mokondi massana* activities are a means of managing knowledge and relationships between people, and between people and the spirit world of the forest. These activities were described by Lewis as integral to maintaining the identity of Yaka communities throughout the forest and to distinguishing them from non-Yaka ethnic groups (Lewis 2002:172). Preparations for performances and important private discussions are undertaken in liminal places that are situated away from a permanent campsite and are only accessible to those who have been initiated. These carefully selected areas are situated so that activities within them cannot be seen or overheard by uninitiated people (Lewis 2002:147).

The reciprocal nature of sound production and perception in the case of the Mbendjele is helpful for considering the complexities and nuances of socialized soundscape construction. The Mbendjele worldview is deeply embedded in relationships between and within communities, in addition to how animals and other aspects of their environment are integrated into everyday life. Sound is not only a means of communication, but also a means of promoting or enabling group stability, empowerment, and survival. The affective nature of sound production and perception underpins its value as a potent resource for facilitating survival and social cohesion.

The Kaluli and Mbendjele provide examples of how sound is an informative and dynamic tool that is used in societies outside of the modern urban contexts in which current notions of "soundscapes" have developed. Sounds of particular environments affect how people perceive the places in which they live, and they may also form key elements in social mechanisms that maintain social and cosmological identity and balance. Studies of values for sound in the past should recognize that different cultures categorize and assign value to sound in different ways, but that humans share a set of sensory tools that are bioculturally significant and useful. It is therefore important to adopt a holistic framework in which sound is considered as integral to social and environmental engagement. Of course, in archaeological contexts, the extent to which social values for sound can be accessed and assessed will be determined by the survivability or presence of cultural material.

Sounding Out the Past

Archaeology is intrinsically dependent upon the recovery and analysis of material remains. Interpretations of the social relevance of artifacts and sites are thus biased toward modern visual perceptions of them. In part, this is also due to the "Western" propensity for assigning importance to sight-dominated culture (Classen 1993), although phenomenological approaches to other spheres of sensory experience of objects and spaces have become more prominent in recent years (e.g., Day 2013; Hamilakis 2014; Howes 2006; Skeates 2010). Yet it is clear that the production and perception of sound, whether in a rainforest or urban environment, are deeply ingrained in how human societies shape and understand their worlds. Given what is scientifically known about the central role of sound in human sociality in the present day, and within many different contexts, it is possible to develop theoretical and methodological approaches to exploring how the aural experience of life in the past was implicated in—and is likely, in part, to have conditioned—all forms of social interaction and activity (e.g., Mills 2010). It is conceivable that vestiges of social values for sound can be found in the archaeological record that are not limited to immediately identifiable sound tools or musical instruments.

Dedicated sound tools can be considered as prostheses, that is, extensions of the human body that allow for the production of sounds that the body itself cannot usually or easily create. They are tools that are "actors who facilitate, prevent, or mediate social interaction" (Bates 2012:364). In Blacking's (1995:223) terms, with regard to music, "music-making is a special kind of social action which can have important consequences for other kinds of social action" and that it "is not only reflexive; it is also generative." We can consider sound tools or instruments to be materialized manifestations of what Blacking (1973) refers to as "humanly organized sound" and of biocultural needs for media by means of which sound can take on value or purpose. The identification of sound tools or "musical" instruments, and the characterization of sound-producing activities or practices through interpretation, allow for inferences to be made about social actions or constructs in the past (e.g., Loren 2008; Williams 2013).

Sound tools are typically identified and interpreted based upon their similarity to modern musical instrument types. Questions concerning whether or not artifacts were indeed used for sound production have been addressed using experimental and comparative methods to explore the likelihood of an artifact's interpreted status as a sound tool, in addition to theorizing methods for sound tool production (e.g., Caldwell 2013; Wyatt 2012). Experimental work has proven to be useful for determining whether or not supposed sound tools were indeed modified by humans (e.g., d'Errico and Villa 1997; Harrison 1978) and also establishing guidelines for detecting less readily identifiable sound tool types (e.g., Blake 2011; Blake and Cross 2008; Cross, Zubrow, and Cowan 2002; Dauvois 1996; Lawson 1995; Spennemann 1988). Even so, sound tools should not necessarily be considered as singularities, but rather as components of broader social constructs. Their significance lies not just in form and physical or acoustic function, but also in the wider archaeological settings in which they have been discovered.

Artefactual evidence for sound-producing activities should be considered contextually within socio-environmental spaces

(e.g., Blake 2011; Blake and Hayward 2012; Dams 1984, 1985; Dauvois 1996; Homo-Lechner 1998; Reznikoff 2008; Reznikoff and Dauvois 1988), as acoustic perceptibility is important for communal or group-oriented attention-focusing activities, in addition to those that may be exclusively based upon physical or social constraints (e.g., Boivin 2004; Lawson et al. 1998; McMahon 2013). From a contextual standpoint, acoustic metrics and standardized, repeatable acoustic testing should be utilized to characterize places that have become archaeological sites and to assess socially relevant sound that is not limited to display and noise exclusion or reduction. However, the role of acoustic environments in mediating affective states, and hence cognitive effectiveness in social activities, is presently unclear. To address this, consideration of acoustic, spatial, environmental, and social dynamics could be facilitated by, for example, integrating the use of portable smartphone technology with site-specific or environment-specific experience sampling (in which participants systematically record real-time data concerning their ongoing, everyday experiences and behaviors) in real-world and subsequent virtual settings, taking the "Sound around You" approach (see supplement A, available online) as a model. Given these data, computer modeling could then be used to explore and to account for social, environmental, spatial, or structural changes of places throughout time. In this way, it may be possible to determine what relationships, if any, exist between social and environmental variables related to sound production and perception. Metrics could be developed that allow for spaces to be characterized in terms of the extent to which they are more, or less, likely to host—or to have hosted—particular types of individual and group activities.

A number of studies have already undertaken pioneering research by seeking to characterize the acoustics of caves, rock shelters, monuments, and built places. These studies have suggested that environmental, structural, and activity-based constraints on sound—at least in respect to presumably "atypical" sonic environments—were valued and exploited in the past (e.g., Bruchez 2007; Dams 1984; Devereux and Jahn 1996; Helmer and Chicoine 2013; Lawson et al. 1998; Ouzman 2001; Rainbird 2002; Reznikoff 2008; Till 2011; Waller 2006; Watson and Keating 1999). However, there has been a tendency to focus on the measurement of present-day acoustics of archaeological sites, without taking into account crucial variables, including the physical and functional changes of spaces throughout time that accordingly affect sound propagation and perception; moreover, the acoustical features of the surrounding everyday environments that would have conditioned contemporaneous human aural sensitivities and thus shaped their responses to sounds in these—often acoustically unusual—archaeological sites have not been explored. Studies dealing with historic structures have implemented methods that allow for the creation of virtual realities, in which it is possible to experiment with spatial, acoustic, and activity-based variables (e.g., Boren and Longair 2011; Chourmouziadou and Kang 2008). For example, research at the Centre for Acoustic and Musical Experiments in Renaissance Architecture (CAMERA) has shown that computer modeling can be a highly effective tool for assessing acoustics within a structure and relating this to how the spaces were created, modified, and used in the past (Boren and Longair 2011; Howard and Moretti 2009).

In archaeological contexts, a similar approach could be adapted for reconstructing sites and assessing how sound production and perception correlate to spatial characteristics and behavior. McMahon's recent paper (2013) on monumental architecture in Mesopotamia, with particular focus upon the Neo-Assyrian city of Khorsabad and its citadel, provides an example where the application of CAMERA's approach could be useful. Additionally, technological advances already allow for detailed laser scanning of enclosed archaeological sites such as caves (e.g., Puchol et al. 2013; Rodríguez-Gonzálvez et al. 2012; Rüther et al. 2009). Spatial and acoustical modeling could thus be effectively used to account for a range of site-specific variables including the geological processes and human occupations or activities that have altered sites throughout time, the stratigraphic boundaries of occupation or excavation levels, changes in air temperature and humidity, in addition to the presence of people and structures; the interpretation of these variables would have to be set in an understanding of the measured or modeled everyday acoustical environments of their users. This should allow for more rigorous determinations of correlations between materialized evidence of human activities and fundamental uses of and responses to sound. Furthermore, approaches to studying the roles of sound in the past should be framed not as a separate, isolatable aspect of social activities in the past, but rather as an integral, ever-present, though contextually varied, component of social constructs (e.g., Boivin et al. 2007; Bruchez 2007; Mills 2005).

The relevance of environmental compositions must also be addressed because sounds within environments affect and are affected by how people perceive, understand, construct, and mediate their surroundings (Lund 1988; see also the Kaluli and Mbendjele case studies above). Sound forms part of the sensory matrix that humans adapt to biological and social needs, which has implications for how social values for it are manifested in material culture. With regard to both light and sound, Ingold (2007:11) refers to them as "infusions of the *medium* in which we find our being and through which we move." Therefore, as noted, the wider context in which an archaeological site is situated within a landscape is important for theorizing and researching the aural aspect of past activities (e.g., Scarre 2002). Site boundaries and evidence for activity localization can also be considered (e.g., Kooyman 2006), as they may indicate areas of attention-focusing activities based upon what is currently known about human sensitivities to and uses of sound.

Additionally, there is potential to identify locations of activity-based acoustic cues; here we refer to sounds produced as a result of physical processes without the intention to in-

form or manage behavior, in addition to signals or sounds that are produced so as to intentionally affect the physical or social environment (e.g., Maynard Smith and Harper 1995). In the context of human behavior, acoustic cues may constitute sounds produced by actions that have the unintentional consequence of perceptibility by others, that is, inclusive and exclusive actions that may be perceptible to those who are not direct participants in an activity, but who will interpret or act upon acoustic cues based upon cultural or learned constructs (e.g., food processing, tool production and use, fire making). This may include spatial conditions in which sound production, such as acoustic signals or signaling, would have been practical or advantageous for communicative purposes, or conversely, spaces that were intentionally created or modified to impede or reduce audibility.

By considering site structure and archaeological evidence of activities within a landscape, it may also be possible to take account of the perceptual flexibility and permeability of apparent physical boundaries, and how these may be different from notions of boundaries in present-day industrialized societies (e.g., Ashforth et al. 2000). These variables are integral for characterizing sound propagation and perception as they relate to how people interact with each other and with their surroundings. A biocultural framework for considering sound in the past could draw upon analyses such as those dealing with geophysical, botanical, and faunal variables, in addition to those that explore human interactions with such variables (e.g., Ballut, Michelin, and Miras 2012; Banks et al. 2008; Bunting et al. 2013; Cabanes et al. 2012; Henne et al. 2013; Lund 1988; Panzacchi et al. 2013; Rondelli et al. 2014; Shahack-Gross et al. 2004). Approaches developed to determine the ecological constituents of a past environment can be useful for informing considerations of the carrying power of sound produced in open-air or acoustic "free field" settings (e.g., Attenborough et al. 2000; Habault and Corsain 1985; Jong, Moerkerken, and van der Toorn 1983; Swearingen et al. 2013; Wunderli and Salomons 2009).

Such methods could feasibly provide means for examining and reconstructing the spatial organization and composition of places that have become archaeological sites, which can then be used to inform understandings of the contexts in which sound would have been produced and perceived by people and other entities. In addition to geographic information system (GIS) and other surveying methods, developments in digital technologies now also allow for geospatial 3-D laser scanning of landscapes and archaeological features found within areas of significance to societies in the past (e.g., Entwistle, McCaffrey, and Abrahams 2009; Siart, Eitel, and Panagiotopoulos 2008). Advances in and implementations of these techniques have potentially substantial implications for assessing how sound affected and was affected by social constructs.

A General Framework for a Prehistoric Case Study

It is likely that any attempt to characterize a past soundscape will be shaped by site-specific idiosyncrasies. However, a good starting point for a generic framework is provided by the work of Mills (2005), who sought to characterize in sonic terms a heterogeneous landscape area in Cornwall that is historically associated with mining. Mills partitioned the soundscape into features deriving from the landscape, from the faunal environment, and from human activities in the landscape: respectively, geophonic, biophonic, and anthrophonic factors (also see Pijanowski et al. 2011). He generated visual "soundmaps" of his field area for each factor (based on the total duration and the frequency of occurrence of sounds in each category), which plotted the geographical distribution of the predominant sound types.

A preliminary version of a general framework for describing, analyzing, and interpreting the features of prehistoric sites, with similarities to that of Mills although developed independently, is given in table 1. It proceeds by taking (or extrapolating, if physical data are unavailable) a range of acoustical measurements from each of these factors, and using these measurements to interpret and situate human activities in the landscape.

The range of acoustical measures in regard to geophonic and biophonic factors (or those that are extrapolated from computer modeling of the landscape or habitat) would include long term average spectra (LTAS) and sound attenuation plots from a sample of different locations within the landscape, and reflection, diffraction, or resonance measurements

Table 1. Factors to be explored in characterizing prehistoric open-air soundscapes

1. Geophonic factors
   a. Climate (e.g., wind, rain, temperature)
   b. Range of habitats and associated acoustical features
      i. Vegetation features (e.g., sound attenuation, filtering)
      ii. Geological features (e.g., sound attenuation, reinforcement—reflection—or modification—filtering, diffraction)
      iii. Flow features such as rivers (e.g., masking, or refracting and reinforcing)
      iv. (Psycho)acoustical anomalies (e.g., echoes, resonances)
   c. Large-scale temporal regularities (seasonal)
2. Biophonic factors
   a. Nonhuman species
      i. Resources
      ii. Cohabitants
      iii. Predators
   b. Large-scale temporal regularities (daily or seasonal)
3. Anthrophonic factors
   a. Range of activities
      i. Habitation
      ii. Directly instrumental activities (e.g., tool making, acquiring and processing resources)
      iii. Indirectly instrumental activities (e.g., creation of petroglyphs, musical activities)
   b. Large-scale temporal regularities (daily or seasonal)

for appropriate locations within the landscape; these would be adjusted for diurnal or seasonal variability. Archaeological materials could be used to situate human activities within the site, again qualifying these in terms of likely variations in daily or seasonal site use. The pattern of inferred human activities could then be correlated with the acoustical measures, and the nature of the activities may be interpreted on the basis of fit—or lack of fit—with the acoustical measurements.

As a potential case study, we shall give a brief description of how this framework could be applied to the Côa Valley rock-art site in northeastern Portugal. Along the rugged terrain and meandering banks of the Côa River, hundreds of engraved and pecked zoomorphic panels have been identified and attributed to Upper Paleolithic hunter-gatherers (Clottes 1998; Zilhão 1998). This area is one of the largest open-air Paleolithic rock-art sites in the world and was designated a World Heritage Site by UNESCO in 1998. The petroglyphs are thought to range in age from contemporaneous to pre-Magdalenian, with the bulk of them being attributed to ca. 20,000 and 11,000 BP (Aubry et al. 2010; Clottes 1998; Zilhão 1998). Over this period, the region experienced a gradual change from tundra to a boreal climate (Schütt 2005). Applying the framework given in table 1 to the Côa River Valley could involve the following:

- Geophonic factors
    - *Climate*: low wind and rainfall, but fairly low temperature.
    - *Habitat, vegetation*: low scrub can be assumed, in places sparse.
    - *Habitat, geological features*: a river valley surrounded by low hills, partly alluvial deposits, partly granite, partly schist.
    - *Flow feature*: river.
    - *Habitat, (Psycho)acoustical anomalies*: vertical and near-vertical granite and schist faces.
    - *Large-scale temporal regularities*: low seasonal variability (Aubry et al. 2010; Schütt 2005).
- Biophonic factors
    - *Resources*: fish, red deer, various bird species (Hockett and Haws 2009).
    - *Cohabitants*: aurochs, various bird species (Hockett and Haws 2009).
    - *Predators*: wolves, lynx, panther (Prado et al. 2014).
    - *Large-scale temporal regularities*: diurnal birdsong maxima, annual red deer rutting.
- Anthrophonic factors
    - *Habitation*: local, variable.
    - *Directly instrumental activities*: no evidence (late-glacial alluvial deposition, highly acidic: Aubry et al. 2010).
    - *Indirectly instrumental activities*: abundant petroglyphs.

While we have no direct field measurements at present, the nature of the landscape provides enough information to develop clear hypotheses. We can infer that, acoustically, a fairly stable environment existed, with limited seasonal variability. Psycho-acoustically, we find a highly differentiated landscape, ranging from scrub vegetation that would likely be fairly acoustically absorbent, through river flow with either moderate background noise levels affording masking effects (turbulent flow) or low background noise level affording refraction effects (regular flow, calm surface), to highly reflective granite and schist slabs.

LTAS will vary according to location; on hillsides and tops, wind noise and biophonic sounds are likely to predominate, while closer to the floodplain wind noise should decrease, with biophonic and any anthrophonic sounds either masked or reinforced, according to water flow conditions. In the vicinity of the granite and schist surfaces, reflections will be evident, reinforcing biophonic and anthrophonic sounds, perhaps giving rise to echoes, or affording resonances that may alter perceived sound qualities.

Aubry et al. (2010) stated that details concerning general Paleolithic habitat exploitation are elusive here because archaeological materials are no longer in primary position, though they also noted that "the large variety of biotic resources in a small territory resulted in a permanent exploration by hunter-gatherers throughout the Upper Palaeolithic" (Aubry et al. 2010: 3317). This range of biotic resources certainly shaped some of the ways in which early humans marked their presence in the landscape (a large number of the petroglyphs represent animals), and biophonic factors are likely to have been highly significant in the human experience of the landscape.

Perhaps the clearest inferences that can be made are in respect to the petroglyphs. These are located at the boundary between the rocky valley slopes and the floodplain (Aubry et al. 2010), mostly on fluvial rock terraces in proximity to the river. They are thus likely to be occurring at locations either giving rise to psycho-acoustic anomalies (reflections, resonances, or echoes, or—in still water conditions—refractions leading to relatively distant sound sources appearing nearer than they are), or aiding in the masking of anthropic and biophonic sounds by reinforcing river sounds when flow is turbulent. The petroglyphs are thus located not only at the physical margin of the floodplain but also on the "edge" of the soundscape, affording atypical and diverse sonic experiences quite distinct from those of the rest of the environment. The sounds generated by the incision, pecking, and scraping involved in their production are likely to have elicited reflections, resonances, and even echoes, which, in low flow and low wind conditions, would have created complex anthrophonic soundscapes that may in themselves have had value for the petroglyphs' creators. Hence the petroglyphs' locations, and perhaps the sonic qualities of their production, can be inferred as signifying and embedding their liminal qualities within the overall soundscape.

Conclusion

The past presents unique challenges for considering sound production and socially relevant sound, not least because of the inevitable effects of time and decay. Yet research in many different fields has established that the acoustic and auditory aspects of human sociality are vast and diverse, leaving little doubt that it is one of the most powerful and flexible tools that humans use to manage and mediate relationships with each other and with the environments that they construct or modify. In terms of archaeological investigation, sound should be considered an integral component in how past societies are understood, rather than as tangential. To achieve this, we suggest that the application of archaeological method and theory to the acoustic and auditory aspects of past societies should consider what is currently known about how humans across cultures produce, perceive, and use sound by drawing upon emerging and future research in disciplines beyond archaeology.

The ways in which humans utilize and experience sound are complex and dynamic, yet within this fluidity there appear to be overarching similarities in biocultural motivation. Research in linguistics and music psychology continues to suggest that humans have developed a range of sensitivities to sound through the production and perception of affective nonverbal vocalizations, speech, and music. Uses include, but are not categorically limited to, speech intelligibility and perceiver response; social engagement and mediation through vocal emotional expressions; management of situations of social uncertainty or stress through "music"; and memory creation and recreation on individual and group scales. The production and perception of sound not only are culturally significant but also serve complex and intentional purposes related to biological functionality and selective reinforcement of social behaviors.

Although approaches to measuring and analyzing sound have often been framed within aesthetic standards of contemporary industrialized societies, some metrics have been adapted for applications in nonurban contexts. Ethological studies underline the importance of acoustic signaling for animals and have contributed greatly to methodological approaches for examining relationships between environments and acoustics. These studies have also indicated that processes such as auditory distance perception and auditory scene analysis are abilities that are not limited to humans and represent an important aspect of processing information in acoustic signals. The effects of environment on sound and notions of "soundscapes" have helped to draw further attention to the spatial aspect of acoustic composition and auditory perception, albeit largely in urban contexts. Additionally, a number of detailed ethnographies have broadened the spectrum of how the biological and cultural affordances of sound in human societies are currently understood.

Given what is known about the functions of sound in terms of human sociality, it is likely that we can identify social values for sound in the archaeological record that are not limited to "sound tools," or those objects that are readily recognized because of their physical similarity to modern instrument types. However, once identified as objects used for purposeful sound production, sound tools can be thought of as having agency that is related to the mediation and management of social relationships. By working within a framework that considers the biocultural values of sound, it is conceivable that research questions can be formulated about the roles of sound in past societies that are answerable in terms of artifacts, their find contexts, and site construction within a landscape. Furthermore, technological advances will allow for reproducible, virtually modifiable, and nondestructive methods for characterizing how sound influenced and was influenced by the formation of social places. Through the utilization of modern technologies that can model spaces and acoustics, in addition to mapping archaeological evidence of activity with attention to physical and social variables, it may be possible to move beyond conceptual barriers that have previously made sounds of the past inaudible.

The study of sound and its relevance in human behavior should not necessarily be a search for acoustic features, but rather for the activities carried out that were conditioned by sensitivities to and uses of sound from both biological and cultural perspectives. As a communicative medium or tool, the significance of sound for human behavior lies not just in its ability or suitability for conveying information, but its importance for affective engagement on inter- and intragroup levels, between individuals, processes, and with other agents in a place or environment. Future research in archaeological settings should focus more generally on how sound shapes and is shaped by the needs and practices of human societies, incorporating consideration of the social contexts associated with places and objects. In doing so, it should be possible to examine how biological biases and predispositions expressed in human cognitive and physical capacities for sound production and perception, and social constructs, are manifested or elaborated in material culture. It is hoped that the framework suggested here will create an avenue for further discussion about the acoustic and auditory contexts of human behavior in archaeological contexts.

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Comments

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Archaeological studies of sound were immensely challenging for many decades due to a supposed lack of "material" evidence, particularly for remote periods. The approach Colin Renfrew (1994) argues for rituals may resolve the conundrum: look for sound and music in the iconography of prehistoric humans. Rock art, especially that attributed to the Paleolithic epoch of Europe, may be a good starting point.

Precedential researchers like Hugo Obermaier (1925) and Henri Breuil (Breuil et al. 1935) were convinced, possibly by ethnographic comparison, that "corporal practices" or dances were performed by ancient Paleolithic artists inside caves (Vila and Estévez 2010). Lately, Yosef Garfinkel suggests many human images, especially females represented in the portable art of Germany and France, are dancing because they appear in rows, with repeated body gestures, with movement (Garfinkel 2010:209). Could this notion be applied to strikingly similar imagery like that in the caves of the Franco-Cantabrigian region (Lasheras Corruchagas and González Echegaray 2005)? Male figures such as those of Altamira and Hornos de La Peña show upraised arms (Sanchidrián 2005), not a typical gesture or motion of mundane everyday chores. Heel prints left by a group of youngsters in the soft clay of Le Tuc D'Audoubert seem to corroborate the idea of dancing and trance in some caves (Clottes and Lewis-Williams 2007; Lewis-Williams 2002). Almost all researchers apparently concede that if there is dancing, this implicitly demonstrates the use of sound (Garfinkel 2003, 2010; Ragazzi 2012).

Sound could be grouped in two interactive functions: creation and perception.

1. Creation includes the use of voice (speech, laughing, crying, shouting, clicking, singing) and other body parts (clapping, stamping, chewing, blowing, whistling) and the production of what could be called music. From the biological point of view, human beings of 40,000 years ago were quite like us; thus, there is a shared subset of identical sounds that people, then and now, could produce (Bannan 2012; Morley 2002). For Paleolithic contexts in Europe, the number of flutes, whistles, bullroars, rattles, and rasps, more or less accepted as such, currently exceeds 200 (Adler 2009; D'Errico et al. 2003; Morley 2009, 2013). Studies such as those of Lya Dams (1984, 1985) in Cueva Nerja, near Malaga, and Michel Dauvois and colleagues in several French decorated caves aimed to show the use lithophones or gongs and their association with the painted panels (Dauvois 1996, 2005; Dauvois and Boutillon 1990; Reznikoff and Dauvois 1988). Over the last years, Elizabeth Blake and Ian Cross demonstrated the use of blades in a portable kit to produce sound (Blake and Cross 2008; Blake and Hayward 2012).

2. Perception, an awareness of the surroundings would include identification of everyday sounds (cutting, preparing food, knapping) as well as those of animals and natural phenomena (wind, fire, rain). Awareness of and understanding these must have been useful for hunting and much else. Noises emanating from the surroundings conveyed information; among various uses for such auditory information, some could warn of perils like dangerous animals. Auditory cognition of the surroundings surely included knowledge of sites with significant acoustic qualities like echoing and amphitheater-like effects. Steven Waller found over 300 rock-art sites worldwide, many open-air, featuring what he calls reflection and unusual acoustic properties (Waller 1994, 2002, 2006, 2012). Examples of similar studies include those carried out inside Parpalló cave in southern Spain by Jimenes Gonzales and colleagues (Jimenes Gonzales et al. 2008; Picó et al. 2006) and in the open air by Boivin (2004) at Kupgal, South India, Rifkin (2009) in the Kokannaberg Mountains in South Africa, and, more recently, Diaz-Andreu and García Benito (2012) in the Valtorta Gorge in the Levant area of Spain.

Blake and Cross are right to affirm crucial variables should be accounted for when studying acoustics. Good examples of the problems can be seen in the potential case study of the Côa Valley, Portugal. Engravings here did not finish under the waters of a huge dam reservoir, but a major part of the river and several decorated surfaces such as those at Canada do Inferno and Rego de Vide have been affected since the eighties by the reflux waters of the Pocinho dam. More pristine surroundings can still be found along other tributaries of the Douro. Sites in the north such as Sampaio, Pousadoro, and Fraga Escrevida in the Sabor Valley and the Mário Reis rock in the upper Águeda are ideal (Baptista 2009; Baptista and Reis 2011; Reis 2012, 2013). Equally worthy would be investigations of decorated surfaces in the few surviving Paleolithic sites in the Tagus and Guadiana basin in the south.

The discoveries of these last years have disclosed close to 400 sites with engravings ascribed to the Paleolithic, thus opening many more research possibilities.

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The importance of acoustics has been noticed for a long time. For example, in the evolution of ancient Greek and Roman theaters, the acoustics had been gradually improved: the sound level in audience areas increased along with theater evolution, and there was also a general increase in reverberation (Chourmouziadou and Kang 2008). One might under-

stand instinctively many aspects in our sonic environment. For example, people might judge distance using sound in a hunter-gather background, or have an understanding of how large a cave was from its reverberation.

Our perception of the sonic environment is determined by many factors. It has been demonstrated by many studies that the noise annoyance by inhabitants depends only on approximately 20%–30% of the acoustic and physical parameters such as acoustic energy, number of sound events, and length of moments of calm between intermittent noises (Kang 2007), whereas other aspects including sociological/psychological/economic factors play an important role. Therefore a range of disciplines are relevant (Karlsson 2000), including acoustics, aesthetics, anthropology, architecture, ecology, ethnology, communication, design, human geography, information, landscape, law, linguistics, literature, media arts, medicine, musicology, noise control engineering, philosophy, pedagogics, psychology, political science, religious studies, sociology, technology, and urban planning (Zhang and Kang 2007).

In the field of environmental acoustics, significant attention has been paid by researchers as well as practitioners, including policy makers, to the approach of soundscape, which was coined by Schafer (1977) in the 1960s and 1970s and recently defined by ISO (2014) as the acoustic environment as perceived or experienced and/or understood by a person or people, in context. In Europe, major actions are being taken on identifying and protecting quiet areas, as required by the EU Directive Relating to the Assessment and Management of Environmental Noise (EU 2002). Different from conventional noise control approach, soundscape represents a step change in the field of environmental acoustics in that it combines physical, social, and psychological approaches (Kang 2007).

In archaeological method and theory, sound has been relatively neglected, although there are growing interests from all relevant fields, which is reflected, for example, in the recently formed Acoustics and Music of British Prehistory Research Network (http://ambpnetwork.wordpress.com/) as part of the Science and Heritage Programme jointly supported by the UK Arts and Humanities Research Council and Engineering and Physical Sciences Research Council. This is of great significance since many cultures explored through archaeology were focused on the oral, and therefore the aural aspect is vital. However, archaeo-acoustic studies have often been carried out by small teams without a broad set of skills and considerations using relatively simplistic methodologies. Therefore, there is a recognized need to develop a more sophisticated methodological approach by ensuring each area of the interdisciplinary study is addressed by experts in each particular field. For this it would be very useful to develop a multidisciplinary framework.

The paper by Blake and Cross makes an important contribution for such a framework. This is based on an intensive literature review on what is known scientifically about human sensitivities to and uses of sound. The review covers a wide range of areas, including, as the authors summarized, nonverbal vocalizations, speech and music, ethological studies addressing how sound perception and environment affect sociality and survival, and the effects of environment on socially significant human sound. The review is useful not only for establishing the proposed framework but also for enhancing our comprehensive understanding of acoustic and auditory contexts of human behavior relating to archaeological method and theory. With an interdisciplinary perspective, the review offers some interesting insights. For example, for acoustic measures, somewhat different from conventional division of room acoustics and environmental acoustics, two categories are discussed for encapsulating information about the effects of indirect—reflected—sound within enclosed spaces and for aspects of the long-term average spectra of sounds in a given environment. It is also important that the Kaluli and Mbendjele works are discussed, giving excellent examples of "how sound is an informative and dynamic tool that is used in societies outside of the modern urban contexts." The review leads to a strong indication that acoustic and auditory aspects of human sociality should be regarded as "one of the most powerful and flexible tools that humans use to manage and mediate relationships with each other and with the environments."

The proposed framework, including geophonic factors, biophonic factors, and anthrophonic factors for describing, analyzing, and interpreting the features of prehistoric sites, provides an excellent starting point for a systematic approach. To make such a multidisciplinary framework more feasible, robust, or even standardized, so that it can be more suitable for practical use, further consultation and discussion involving experts in different disciplines will be needed. More detailed methods would also need to be developed correspondingly. On the other hand, the framework should be sufficiently flexible to facilitate new findings and ideas.

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Intersensorial research impetus is growing and encouragingly more archaeologists are engaging with and interpreting archaeological evidence from sensory perspectives. Cross-cultural hierarchies of the senses are no longer assumed: the expanding literature on the variable role of the senses in the past attests to this (other contributions include Banfield 2009; Devereux and Wozencroft 2014; Houston and Tuabe 2000; MacGregor 1999; Mills 2014; Rainbird 2008). There are also more opportunities for nonacademic audiences to explore aspects of the senses in the past through popular literature, at museums and heritage sites, and online (e.g., Chapman and Wilson 2011; Grey et al. 2007: Hendy 2013; Reynolds

and Adams 2014). Although a significant challenge, where relevant, sound should be integral to archaeology projects, and its study must draw on research outside of the discipline so that scholars can benefit from the wealth of existing work. Continued theorizing in archaeology about the senses is essential but equally critical is attention to developing methodologies that can be adopted and adapted to different (pre)historic and heritage contexts.

Reinforced by what is scientifically known about sensitivities and motivations to sound across cultures and by adopting a range of acoustic metrics, the authors present a preliminary version of a biocultural framework for considering the significance of sound to people in the past. The emphasis on multidisciplinarity is welcome promoting the value of integrating concepts from diverse fields of study (ecological psycho-acoustics could be added; e.g., Neuhoff 2004). It is rightly argued that everyday and wider environmental sounds at locations of past human activities are implicated in all forms of social activity and must therefore be considered. Research need not be limited to sonically atypical environments or to sound tools. That sound and communication may help to mediate situations of uncertainty is important, but why a survival aspect might be worthy of so much attention is less clear. The role of sound (particularly music) in helping affirm identity and memory is also discussed but again largely in reference to situations of social stress.

Their framework provides a useful list of factors and acoustic metrics, categorized by geophony, biophony, and anthrophony, which can be studied in the field or extrapolated from computer modeling. In the absence of field data, it is difficult to assess the effectiveness of their framework or of its application to their chosen study area. It would be helpful to know why the case study of the Côa Valley was specifically chosen and in what ways it provides a good example of the approach. Any framework should aim to be applicable to the study of (pre)historic communities across the broadest range of spatial and temporal contexts. The authors argue that research concerning sound in the past should not be bound by modern cultural contexts, but there are many archaeological and heritage contexts from the recent past that can benefit from a consideration of sound (e.g., industrial heritage).

The potential influence of background noise levels from river flow and the wind is inferred, but this demands consideration of what constitutes noise across cultures. Caution must be applied when using the term in reference to past people. Based on potential variability in acoustic metrics, they go on to discuss how sounds that predominate at different locations may have been significant to Upper Paleolithic hunter-gatherers. While inferences of this kind can be made without field data, such hypotheses must ultimately be tested. The location of petroglyphs on the "edge" of the soundscape is suggested to have the potential to afford atypical sonic experiences. To what extent were activities associated with petroglyphs spatially and temporally distinct from past daily life such that a significant "edge" to a soundscape might be inferred? Studying wider environmental sounds might help identify and interpret the impact of unusual sonic effects, but this can only be qualified with a balanced consideration of everyday sounds associated with a broad range of past human activities. Sound generated by making petroglyphs is certainly worthy of further study and could helpfully resonate with previous research (e.g., Goldhahn 2002).

Alongside application in the field, it would be helpful if the framework was further developed to incorporate other themes discussed including sound tools, digital technologies, and other concepts (e.g., ASA and ADP). It would benefit from a consideration of intentionality in relation to sound in the past given this is an important thread in archaeo-acoustics research. The acknowledged importance of language and music in the past needs a methodological platform to aid those aiming to address these issues. Opportunities to dovetail the framework with other landscape characterization principles and methods could also be explored. It would be of interest to know how *experience sampling* might operate as well as about opportunities for the participation of different audiences (e.g., through Citizen Science) and how it might contribute to the preservation and presentation of (intangible) heritage.

This is a timely contribution, and it is hoped the authors go on to develop their framework into an approach that is replicable and potentially verifiable.

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The proposal for a comprehensive framework through which to study the archaeology of sound is undoubtedly to be welcomed. The fractured nature of research within this field is illustrated by the unresolved terminology (with different practitioners subscribing to headings of "music archaeology," "archaeo-organology," or "archaeoacoustics"—all subtly different but overlapping in emphasis). Furthermore, it has yet to be brought into the mainstream of archaeological research, despite the growing literature on the anthropology and archaeology of the senses (Classen 1993; Hamilakis 2014; Skeates 2010). A particular surprise is that the archaeology of sound was not embraced more rapidly and wholeheartedly by post-processualists in the 1980s, and it was not really until the mid-1990s that systematic research in this field began.

The fundamental problem remains that of methodology. How can we develop a robust set of analytical methods and interpretive approaches that would enable us to grasp, with a reasonable measure of confidence, the nature and significance of sound for specific prehistoric societies? Blake and Cross highlight many of the salient requirements: that "acoustic metrics and standardized, repeatable acoustic testing

should be utilized to characterize places that have become archaeological sites and to assess socially relevant sound." These metrics should "allow for spaces to be characterized in terms of the extent to which they are more, or less, likely to host—or to have hosted—particular types of individual and group activities" and must "tak[e] into account crucial variables, including the physical and functional changes of spaces throughout time that accordingly affect sound propagation and perception."

How is this to be achieved? In the final section of their paper, the authors offer the outline of a research program aimed at understanding the acoustics of the Côa Valley rock art in northern Portugal. This is fundamentally an archaeo-acoustical project, focusing on sounds within the landscape rather than "sound tools" or musical instruments. One important feature of their approach is the attention paid to environmental change, which they perceive particularly in terms of vegetation. It is clear that the Late Pleistocene settings in which these motifs and images were created were relatively open and treeless, and we can assume a very different social response to sound to that of the forest-dwelling Kaluli and Mbendjele that they discuss earlier in their paper. But can we go further, and begin to specify the kind of response we would expect? Should we have recourse to ethnographic parallels from societies living in similar cool, open landscapes?

There are clearly profound methodological obstacles in the way of the more comprehensive kind of analysis that Blake and Cross advocate, and while not wishing to discourage what is undoubtedly a positive forward step, there are additional variables to consider. First of these is chronology. The Upper Paleolithic age of the Côa Valley art has now won general acceptance, but its execution is likely to have spanned several millennia (Aubry et al. 2012). A detailed chronological mapping of the rock-art panels, were that to become possible, might very well reveal that different acoustical settings were selected, whether intentionally or indirectly, at different periods, and that might be connected with changing social responses to sound. Indeed, it has already been established that older and later phases of Côa Valley art were located in different parts of the valley slope (Aubry et al. 2012:3317). A second issue is that of audience. It is clear that rock art in different contexts was directed to different kinds and sizes of audience (Bradley 2009). Sometimes these may have been entire assembled communities, in other instances, small groups of people or privileged ritual specialists. Lewis Williams has drawn a distinction in Paleolithic cave art between "vision questing" by small groups or individuals deep within the caves, and communal rituals in larger spaces (Lewis-Williams 2002:266–267). That will, inevitably, have affected the placement of the art, and hence the acoustics. The role and perception of sound will have been very different in such contrasting settings and circumstances.

There thus remains, for the present, a significant gap still to bridge between the theoretical frameworks for the study and understanding of sound in prehistoric societies, and the methodologies that are available to us. That said, Blake and Cross are to be commended for laying out the much broader perspective, integrating archaeology, ethnography, and neurophysiology, within which these issues must be explored.

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The Silent Past

The past is silent. It was not until the nineteenth century that one heard the sounds of the past. Previously, one saw representations of past sound. But, even that is recent for human existence. Language notation begins about five millennia ago, and music notation about a millennia and a half. Notations depicted sound, but were not the sounds themselves. The unfortunate de'Martinville made the first audio recordings in the late 1850s but was unable to play them back. Two decades later, Edison recorded and played back sound. Only then did the sounds of the past become available to the present.

There are few ways to enter the past. One examines contemporary documents (history and literature), learns oral traditions (folk tales and oral law), studies material culture (archaeology and history of technology), uses biological techniques (DNA, palynology, dendrochronology, etc.), and analyzes language (ancient languages, historical and comparative linguistics).

Blake and Cross's work is in the forefront of a new way to enter the past, archaeo-acoustics. It is defined as studying past and present sounds to understand past existence.

Their paper is a truly interdisciplinary, comprehensive review of the literature resulting in a framework for inferences that is not bounded by cultural contexts. They are concerned with measures encapsulating indirect sound and human auditory systems, human uses and environmental effects of sound, sound's impact for social behavior, ethological considerations of sound, sound tools, soundscapes, ethnographic generalities and particular cultural examples. They conclude their "sounding out the past" by creating a general framework for prehistoric case studies exemplified by a Magdalenian site in southeastern Portugal.

We tried their framework on the "Vikingtidsgravene" in Ustedalen, Norway (60°31′37.39″ N, 8°09′33.59″). There are 20 male and female graves along one of the ancient Nordmannslepa trails connecting western and eastern Norway across the Hardangervidda arctic tundra plateau. The site, dating from AD 800 to 1000, is at the bottom of the U-shaped valley enclosing the Usta River flowing into Ustedalsfjorden Lake.

I. Geophonic factors:
  a. Climate: subarctic averages; temperature: 1.0 C; precipitation 700 mm; snow 125 cm; growth season 127 days.
  b. Habitat:
    i. Vegetation:
      1. Birch—boreal forest transition,
        a. Sound in forest 35–39 dB without wind; with wind 47–53 dB.
        b. Sound in open fields, wetlands, peat bogs 40–60 dB without wind; with 60–78 dB.
    ii. Geological features:
      1. Moraine and mountainsides—1 km from site 70 dB without wind; with 90 dB.
    iii. Flow features:
      1. Brook 58–60 dB without wind; with 70–82 dB; Usta River without wind 47–50 dB; with 47–87 dB; Ustedalsfjorden lake without wind 47–50 dB; with wind 47–87 dB; waterfall 66–68 dB.
    iv. Psycho acoustical anomalies:
      1. Winds continuous from W-SW for 9 months 3 m/s and for 3 months 2 m/s.
    v. Large temporal regularities:
      1. Sounds: in winter snow and ice muffles; in spring "ice breakup" sounds; temperature (January −8.2 C; July +11.2 C); daylight hours (December 5.51 to July 18.54).
  c. Biophonic resources:
    I. Nonhuman species:
      1. Resources: elk, roe-deer, reindeer, squirrel, hare, trout, cow, sheep (1 sheep 65 dB, 20 sheep 70 dB), goat, horse, duck.
      2. Cohabitants: badger.
      3. Predators: fox and lynx.
    ii. Large temporal regularities: spring-summer bird songs; hare, elk, and roe-deer fall mating sounds, cattle, sheep, and goat transhumance sounds.
  d. Anthrophonic sounds:
    I. Habitation:
      1. Path sounds: people and animals moving by foot, by travois, skis, sledges, wagons.
      2. Walking on ancient path: 58 dB
      3. Outside first log building: 41–62 dB; inside 34–35 dB; slamming wood door 61–62 dB; iron latch closing 50–57 dB.
      4. Inside second log building: log room 36–37 dB; plank room 39 dB.
    ii. Directly instrumental activities:
      1. Wood sticks hitting free hanging wood sticks: 48–80 dB; iron hitting iron bars 75–91 dB; steel hitting steel bars 75–80 dB; brass hitting brass bars 68–77 dB; iron hitting slate bars 72–79 dB; slate hitting slate 90 dB; stone hitting stone bars 83 dB.
      2. Wood and tree chopping 61–65 dB.
      3. Viking iron foundries.
      4. Agricultural tools and utensils.
    iii. Indirectly instrumental activities:
      1. Bone horns, lur, drums.
        a. Bukkehorn 75–78 dB.
      2. Female cow calling—(kulokk) 80–85 dB.
      3. Female and male voice talking 70–72 dB.
      4. Male shouting 87–90 dB.

We found that the major environmental acoustic factor was the wind; second the river. Habitation interiors muted sound, and direct instrumental activities were as noisy as the wind and river. Unlike Blake and Cross's site, we infer this site acoustically is highly seasonal with sound more muted in the winter. We found a trimodal environment—quietest in the forest, noisier in the open fields, and noisiest on the hillsides.

Our analysis is a pilot, but it shows their framework succeeds cross-culturally. We found its greatest value in its breadth and how it helped direct our research step by step. One may listen to the past's silence and learn.

Reply

We are pleased that the commentators find this topic worthy of exploration and would like to thank them for contributing such diverse and constructive perspectives. It is clear that characterizing biocultural values for sound should be informed by multidisciplinary contributions from experts in a range of disciplines, but also by multicultural perspectives and empirical research on sound production and perception. Inevitably, one of the greatest obstacles faced by archaeologists is time, not only in terms of its effect on preservation but also in terms of cultural and, as Mila Simões de Abreu notes, environmental changes. The methodological and theoretical frameworks for understanding social values for sound should be as dynamic and contextually transposable as the biocultural constructs they seek to address, in that they aim to encompass or integrate most, if not all, known aspects of sound production and perception.

In the context of early prehistory, Mila Simões de Abreu discusses the importance of considering material manifestations of sound-related activities, in addition to perceptual awareness or engagement with social and environmental constructs. We agree that proposed representations of activities involving the production and perception of sound are likely to have been significant. Sound tools from Upper Paleolithic sites (e.g., Conard, Malina, and Münzel 2009) are clear evidence of activities that must be conceptualized as musical behaviors. We also agree that, on a site-by-site basis, geological or anthropogenic changes in a landscape, such as dam-building, will present challenges. But here recent advances in computer modeling of sonic environments can prove useful, en-

abling experimentation with and evaluation of cultural and environmental variables.

Of course, the use of technology must be underpinned by the development of sophisticated methodologies for exploring and understanding soundscapes. In their informative comment, Jian Kang and Mei Zhang describe some of the advances that are being made in addressing the idea of soundscape, although, as they note, more detailed methods still need to be developed, and further conversations need to take place across disciplines. We wholly agree that further research is urgently required, and in the paper have tried to outline some of the known unknowns in order to provide a context for future research.

Steve Mills's comments reinforce Kang and Zhang's points that methodologies should be multidisciplinary, encompassing rigorous empirical research, while also aiming to understand cultural constructs. This is particularly true for concepts such as "music" or "noise," which can easily be construed in unwittingly ethnocentric terms in multidisciplinary research (see Cross 2012*b*). In the paper, we have employed Cross's approach to framing music as a biocultural phenomenon (see Cross 2012*c*), which provides a broad context for interpreting a range of possible activities and material traces in "musical" terms. The question of how to conceptualize "noise" in different cultural contexts is perhaps less clear-cut. One of the few papers to address aspects of noise across cultures is Peek (1994), who explores ideas of noise in various African societies, noting that certain categories of sound—which may or may not align with the Western idea of "noise"—may be conceived of as undesirable for reasons other than their annoyance value. He notes (1994:476) that the Lele of Zaire distinguish between day and night human noises to which the spirits will and will not respond—especially on days of religious activity; that in Morocco, contingent human sounds such as whistling or humming "are thought to be the talk of *jinn*;" and that the Malian Dogon conceive of noise in opposition to both human speech and the sounds of instruments as it "lacks meaning and harmony." The cases adduced even in this single paper indicate that the question of how to operationalize ideas of noise requires substantial further research across a wider range of cultural contexts.

We agree with Mills about the importance of outreach opportunities for exploring sensorily significant aspects of past societies. While technological and financial obstacles can impede the integration of sound into the presentation of archaeological objects and sites, these are beginning to be overcome through developments such as relatively low-cost electronic printing, whereby images can be integrated with programmed sounds that are activated by touch (e.g., see and hear Novalia at http://www.novalia.co.uk/). In addition, the ever-increasing ease with which people can create, record, and share sounds widens the body of available and potential sounds for use in reconstruction or interpretation.

Indeed, this increasing facility for recording and sharing sounds could be exploited so as to yield new and invaluable data through the application of the *experience sampling* method, in which experimental participants are contacted periodically in their daily life and asked questions about their activities, feelings, and so on. As we suggest in the paper, we could envisage a research program that integrates the sound-recording facilities of smartphones with their use for experience sampling (several such apps already exist) so as to provide a body of data that would enable correlations between activities, emotional states, cognitive capacities, and sonic environments to be explored in a principled way that should advance our understanding of relationships between human behaviors and their acoustical contexts.

Returning to an archaeological perspective, Chris Scarre suggests that what we have produced is fundamentally an "archaeo-acoustical" framework, focusing on sounds within the landscape rather than on sound tools or instruments. Our aim is rather to situate sound-producing behaviors and perceptions in the landscape; hence practical explorations of archaeological sites as soundscapes would have to take into account evidence for sound production, including the use of sound tools and instruments. In the light of the Côa Valley case study that we present, involving an open and treeless tundra-to-boreal late Pleistocene landscape, Scarre asks whether it might have been informative for us to have had recourse to ethnographic parallels from societies living in similar cool, open landscapes. The fundamental problem is that we lack a key ethnography of sound for such a society; however, surveying a sample of the ethnographic literature on the music, language, and lifeways of tundra-dwelling cultures does offer some potentially interesting and informative insights, though conditioned by the caveat that such details are derived from contemporary societies.

In the first place, in several different tundra-dwelling societies, there appears to be a bias toward inner-directed modes of copresent behavior (Abramovich-Gomon 1999) and mimetic modes of learning (Crago 1990), as well as a privileging of learning through watching and listening rather than explicit instruction (Wenzel 1987)—perhaps partly conditioned by living in small kin groups and inhabiting environments with generally high levels of exterior background (wind) sound. This bias toward inner-directed copresence is strongly manifested in song in some cultures; for the Nenets of the northern Russian arctic, songs are often solitary, seemingly performed for self—or perhaps for nonhuman agents in the environment—but may also be performed in the company of kin and perhaps close neighbors (Niemi 1998). As Abramovich-Gomon (1999:37) puts it, "In the Nenets communities, singing is more like a mode of life rather than a staged or framed behaviour. . . . For every Nenets to be able to express him/herself through song while alone is a necessity." She relates this type of performance practice to what she describes as a "democratized shamanism" that persisted—submerged in private life—through Soviet rule, that underpins much of Nenets culture, and that appears to condition their musical performance practice.

Shamanistic elements are also evident in north Greenland musical practices. While the music of contemporary Nenets is purely vocal, early evidence indicates that it used to be accompanied by a frame drum, as in the traditional music of east Greenland and Thule, which consists of solo drum songs in which the soloist sings, drums, and dances (Hauser 1993; Olsen 1972). While the performer in Greenland will dance, the Nenets performer may almost withdraw, appearing detached from reality, but in both cultures music is a central element in articulating the individual's personhood within their society. In several tundra cultures, both the texts of songs and their manner of performance are extraordinarily complex and multilayered (Gaski 1999; Lázár 1988; Ojamaa 2003), involving convoluted shifts of perspective and being delivered in ways that almost obscure meaning; for instance, as Ojamaa notes (2003:262), when singing, "The Nenets breathe at random locations, so that breathing does not *show* anything."

These cases, drawn from Inuit, Eskimo, Nenets, Sami, and Ob-ugrian contexts, show some convergent features—inner-directedness, a close connection between song and personal identity, and embedding of complex song in shamanistic practice. It may be that certain of those features characterized the sonic and ritual behaviors of the inhabitants of the Côa Valley in the period in question. The engraved rock panels, offering both reflective and resonant surfaces as well as potential relief from background wind noise, might then have been the focus for solitary ritual activities, or the settings for song performances addressed not so much to audiences as to small groups of "overhearers" (to adapt the term from Schober and Clark 1989).

Scarre also suggests that there are "profound methodological obstacles in the way of the more comprehensive kind of analysis," in particular, chronology. We do feel that we have addressed this aspect of exploring sound in prehistory in the body of the paper, although the sample application of the framework that we present is very much a "broad brush" approach intended to give a flavor of what might be done rather than a detailed analysis. Ideally one would want more detail, and an essential element of that detail would be chronology insofar as it can be determined, and the potentially changing nature of sonic experience and practice over time. Detailed case studies would also enable more nuanced accounts of the possible types of activities and agencies involved (including "audience," a term that may have connotations other than those expectable in contemporary Western contexts, as noted above). We have to agree that there is still a significant gap to bridge; however, we hope that we have laid some foundations—or perhaps just prepared some ground—for subsequent research to build on.

As described by Zubrow and Lindstrøm, perceptions and understandings of past sounds have been greatly influenced by technological developments, especially since the nineteenth century. Present and future developments in technology and methodology should allow for exploration and testing of hypotheses about the ways in which sound may have been relevant to different societies. Their application of our broadly structured framework suggests that models for integrating sound in the interpretation of archaeological sites have the potential to accommodate dynamic variations, or nuances, in environments and social significance.

Although there is still much to do in terms of establishing such methods, it is important to consider sound as an integral component of the ways in which humans interact with each other and with their environments. As should be evident, we feel strongly that theoretical and methodological approaches for studying human relationships with sound should not be considered peripheral aspects of archaeology (e.g., "archaeoacoustics"). Instead, the development of methods that extend beyond those outlined and envisaged in the present paper should lead to sound coming to be conceived of and treated as an essential—and standard—aspect of archaeological theory and practice.

—Elizabeth C. Blake and Ian Cross

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Links to a Sample of Sound, Sound Archaeology, and Soundscape Web Sites

- Acoustic Ecology Institute (acousticecology.org/)
- Acoustics and Music of British Prehistory (ambpnetwork.wordpress.com)
- Bernie Kraus's Wild Sanctuary soundscape site (www.wildsanctuary.com)
- British Library Sounds collection (sounds.bl.uk)
- Chavín de Huántar Archaeological Acoustics Project (https://ccrma.stanford.edu/groups/chavin/current.html)
- Cornell University Lab of Ornithology Bioacoustics Research Program (www.birds.cornell.edu/page.aspx?pid=1667)
- International Study Group on Music Archaeology (www.musicarchaeology.org)
- Listen to the Deep (LIDO) (listentothedeep.net)
- Museum für Naturkunde, Berlin (www.tierstimmenarchiv.de)
- Purdue University Human Modeling and Analysis Laboratory (ltm.agriculture.purdue.edu/soundscapes.htm)
- Sound around You (http://www.soundaroundyou.com/)
- Steven Feld recordings at the Smithsonian: Feld 1991 (http://www.folkways.si.edu/voices-of-the-rainforest/world/music/album/Smithsonian) and Feld 2001 (http://www.folkways.si.edu/bosavi-rainforest-music-from-papua-new-guinea/world/album/smithsonian)
- Trevor Cox's Acoustic and Audio Engineering website (acousticengineering.wordpress.com/trevor-cox)
- World Listening Project (www.worldlisteningproject.org/about)
- World Soundscape Project (www.sfu.ca/truax/wsp.html) www.sfu.ca/~truax/wsp.html
- Xeno-canto bird sound site (www.xeno-canto.org)