EXPLORING ANCIENT SOUNDS AND PLACES

Theoretical and methodological approaches to archaeoacoustics

Edited by Margarita Diaz-Andreu and Neemias Santos da Rosa



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Front cover: KRM aerophone wave pattern, captured in Logic Pro. by Neil Rusch; Rock art site: Game Pass I, South Africa. Photograph by Margarita Díaz-Andreu ©Artsoundscapes Project

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Chapter 1

Exploring ancient sounds and places: The challenges of hearing intangible heritage in the past

Margarita Díaz-Andreu and Neemias Santos da Rosa

Abstract

This introductory chapter explores the diverse ways in which sound can be integrated into archaeology. Three major perspectives are presented: the first focuses on objects that produce sound, including musical instruments, sound-producing objects, and geophonies in natural soundscapes. The second block examines the contexts in which sound is transmitted and heard, such as enclosed or semi-enclosed spaces, urban environments, and landscapes. The final section investigates the functions and uses of sound. Examples of all three ways of studying sound in archaeology are found in the chapters of this book. This interdisciplinary volume presents a collection of essays that illuminate the sonorous dimensions of the past, highlighting how sound has influenced cognitive, cultural and spiritual aspects of human societies across different periods and locations. A general overview of the book is provided in the last section of the chapter.

Keywords: archaeoacoustics, music archaeology, soundscapes, urbanscapes, room acoustics

Since the 1980s, scholars in the humanities have been increasingly drawn to sensory research (Howes 1991; Rodaway 1994; Feld 2012), a leaning that, albeit with some delay, has also included archaeologists (Gosden and Hather 1999; Ouzman 2001). However, in contrast to senses such as taste or touch, and, perhaps because of its role as the most important sense after vision, at least in the Western World (Classen 1993, 2), hearing – and sound in general – had already attracted scholarly attention from early on. This was already the case with musical instruments from the 18th century

(Smith 1750; B.B. 1763). However, from the 1960s an interest also emerged in how sound was propagated at archaeological sites and the effect that sound events may have had on past communities. The latter developments, however, were largely unknown to the archaeological profession, given that behind them there were architects (Canac 1967; Shankland 1973; Lehmann 1983), historians (Giedion 1962) and historians of art (Reznikoff 1981; 1987), who only very occasionally collaborated with archaeologists (Reznikoff and Dauvois 1988; Dauvois 1989; Dauvois and Boutillon 1990).

Therefore, for most of the history of archaeology the past was largely imagined as being voiceless. This silence was contrary to the experience of past people: sound is an essential source of knowledge about our surroundings and constitutes the basis of communication with others (see Brabec in this volume). It may also have advantages over sight on particular occasions; for example, when visibility is impossible because of darkness or dense vegetation, or when the emitter is at a distance beyond sight recognition (Letowski and Letowski 2012). Sound is also employed to convey emotion and feelings (Blood and Zatorre 2001; Juslin and Västfjäll 2008) and group cohesion (Morley 2013, 280–283). It may elicit stress, annoyance or therapeutic effects (Bruscia 2014; Stanhope and Weinstein 2020) and is used to express identity (Connell and Gibson 2002; Stocker 2013).

Ethnomusicology and ethnohistorical sources can assist archaeologists in establishing questions (Arsenault and Zawadzka 2014; Liwosz 2017; Díaz-Andreu *et al.* 2021, 170; and see Alarcón-Jiménez *et al.* in this volume and Díaz-Andreu *et al.* in this volume). However, the closer these sources are to the particular period under study, the better. As Blake and Cross mention when discussing music, "With regard to ethnographic analogies to prehistoric populations, care should be taken in presuming, or ascribing, apparent similarities in 'musical' behaviours of hunter-gatherer societies from very different temporal and geographic proveniences" (Blake and Cross 2008, 15).

As this book reveals, there are many ways in which sound can be introduced into archaeology. In the following pages, an overview is provided of this kaleidoscopic field by subdividing the research undertaken into three major blocks. The first focuses on the objects that produce the sound (musical instruments, sound-producing objects or geophony in a soundscape). The second major block centres on the type of context in which sound is transmitted and heard (an enclosed or a semi-enclosed space, urbanscapes and sound in the landscape). The final section looks at the research undertaken into some of the functions and uses encompassed by sound.

Producing sound

If the focus is placed on the origin of sound, four main themes can be identified: musical instruments; other sound-producing devices; sounds produced as a result of human actions whose purpose is not related to this result; and finally, the sound produced in the landscape. Regarding the first, it would be impossible to provide a good, rounded summary of the research into the music and musical instruments of the past, given that

there is a staggering bibliography containing general approaches to this (Hickmann 2001; Both 2009). Archaeomusicologists work with "musical instruments or parts of instruments; scenes of music-making in cave paintings [i.e. rock art], reliefs, frescoes and mosaics; more rarely, written sources such as inscriptions or descriptions of music; and, even more rarely, specimens of musical notation" (Hickmann 2001). In addition to archaeological evidence, archaeomusicologists can make use of historical accounts and iconography (see Đorđević and Knighton in this volume). Myths and legends, oral tradition and ethnography may also provide useful information (Hickmann 2001; see Díaz-Andreu *et al.* in this volume). It is important to take into account the fact that musical taste is cultural and, therefore, as Scullin and Boyd argue for the case of the Moche ceramic whistles, "sounds which often appear harsh and unwanted to modern ears (and bodies) – sounds routinely categorized as noise – may not have been viewed as unwanted sound/noise in certain past contexts" (Scullin and Boyd 2014, 362). In the last few decades, most research on musical instruments has been led by members of the International Council of Traditional Music (ICTM), with sessions organised on an irregular basis, and also the International Study Group on Music Archaeology (ISGMA), in that case gathering every two years. The proceedings of both these meetings have been compiled in many volumes (e.g. Lund 1986; Hickmann and Eichmann 2000; Hickmann *et al.* 2006; Jiménez Pasalodos *et al.* 2013; Homo-Lechner 2015; Kolltveit and Rainio 2020). There was once also a journal, *Music Archaeological Bulletin* (1984–1986), followed by *Archaeologia Musicalis* (1987–1990) and now the book series *Flower World* published by the Ekho publishing house, in addition to other books.

Topics under discussion in music archaeology are manifold and here only a couple will be mentioned. The most popular is typology and cultural classification in the whole spectrum of human evolution, from the earliest periods (Cross 2016; Montagu 2017), and see Brabec in this volume) to the Palaeolithic (Morley 2013; and see Wyatt this volume) and modern times (Neuenfeldt 2020). In some cases musical instruments may be created out of geological forms, such as lithophones and rock gongs, i.e. rocks that sound when struck (Fagg 1997; and see Jiménez Pasalodos *et al.* in this volume and Martorano in this volume). Performance practices are also the focus of some research projects (García Ventura *et al.* 2018). Experimental archaeology has also been useful in the reconstruction of musical instruments (for example García-Benito *et al.* 2018; Pomberger *et al.* 2018; Kumbani 2023; and see also chapters by Martorano and Rusch in this volume). A final topic relates to outreach, museums and the public (Both 2019; Milosavljevic 2020). It may be worth mentioning that the number of publications included in this paragraph could be multiplied many times.

In an often-referred-to article, Casja Lund distinguished between five classes of sound objects. The first is those artefacts that were distinctly used as sound-producing devices. In this type, she includes musical instruments (see above) and others that might (also) be used for communication, such as bells. They fulfil both roles, music and communication, depending on their size and location. A small bell, for example, is a multifunctional sound object that may perform many purposes:

it can be a signal/noise instrument, an acoustic offensive weapon, a prestige object, a status object and an apotropaic protective shield (Pomberger *et al.* 2023, fig. 10). Large bells, as well as other large percussion instruments such as semantra, are mostly used in religious buildings like churches. Their main role is to act as religious sound markers and to communicate religious or civil messages to audiences some distance away (Djordevic *et al.* 2023).

Lund (1981) also mentions items that may have served more than one purpose. These include sound-producing ornaments such as teeth, molluscs or small stones attached to garments or as accessories and as portable pendants found, for instance, in burials in Northern Europe (Russia and Sweden) dated to the Late Mesolithic and the Neolithic. The study of their wear patterns through traceology allowed Riitta Rainio to argue that they acted as rattles. These pendants created sound when the wearer moved, perhaps to reinforce the effect of dancing (Rainio *et al.* 2021).

Some objects were not musical instruments per se, but the sound they produced generated sensorial experiences (the fourth type in Lund's 1981 typology). In addition to the silver bracelet from Hammarlöv (Sweden) she mentioned, we can illustrate this with the jangling rings for chariot axles found in the Netherlands. These were included by Joan Rimmer in her review of musical instruments and soundmakers from the Netherlands between the Iron Age and the medieval period (Rimmer 1981). Finally, some objects were clearly sound-producing devices with functions other than music, such as decoys for hunting (Lund *et al.* 2015; García-Benito *et al.* 2018).

A sixth category in Casja Lund's scheme could have been the sound derived as a by-product of producing or handling objects. There have been some studies of this, especially regarding the sound produced at the time of manufacture: pounding plants for food or drink, such as sakau or kava in the South Pacific (Rainbird 2002, 97), or in mortars at rock art sites such as Writing Rock (Devereux 2008, 22), lithics (Mills and Pannett 2009) and rock art (Lødøen 2015, 73–74; Vergara 2019).

In some cases, it has been claimed that particular sonotopes, i.e. landscapes with particular acoustics, attracted the attention of those living in the area. We can illustrate this with scholarly work linking archaeology and underground noises originating either with fire or water. In the first case, volcanoes can be mentioned. There have been some studies into the relationship between them – and therefore their sound – and archaeological sites in Mesoamerica and Central America (Sheets 2001; Holmberg 2013). Sounds sometimes originating in the subsoil may also have been perceived as magical and this may have been the case in Kinomagewapkong or Teaching Rocks in Petroglyphs Provincial Park near Peterborough, Ontario, Canada. In this place 'the sound of underground water can be heard issuing from its depths. Witnesses describe the sound as similar to the babble of human voices" (Devereux 2008, 27–28). In Scandinavia, it has also been suggested that the choice of sites at which to create rock art may have been linked to the sound of water in the area (Coles 1991, 133; Goldhahn 2002; Lødøen 2010, 45–46).

The acoustic effects of sound propagation at archaeological sites

An alternative way of exploring ancient sounds and places is to look not at the sound source, as in the previous section, but at the space in which the sound is propagated. Four types of approach can be highlighted: the acoustics of enclosed and semi-enclosed spaces, urbanscapes and sounds in the landscape. The way in which sound performs in enclosed spaces has been one of the major topics of study among architects and acoustic engineers for the last two and a half centuries (Mills 2016, appendix 4), although it is only since the 1960s that this interest has been reflected in the study of ancient buildings. In the last few years special attention has been paid to caves in areas and periods as diverse as the European Palaeolithic (Fazenda *et al.* 2017; Jouteau 2021, 384), the Mesopotamian (McMahon 2013) and Greek eras (Yioutsos *et al.* 2018) and Mayan caves (Bruchez 2007). In addition to caves, megaliths and hypogea can be added to the types of sites. The acoustic analysis of megalithic sites in Britain and France has highlighted their good reverberant properties, especially in relation to low voices (Devereux and Jahn 1996; Manaud and Watson and Keating 2000; Barrandon 2014). Regarding hypogea, their plans are more regular than caves, as are perhaps megaliths, but still less so than built environments. One of those that has attracted more attention is the Hal-Saflieni Hypogeum in Malta dated to the 3rd millennium BCE (Till 2017)

In contrast to the above, most scholarly attention has focused on built environments. In addition to acoustic testing *in situ*, the regularity of spaces has also allowed an alternative method of analysis: the reconstruction of acoustics using computational modelling techniques and dynamical estimations. In other cases, the approach is based on the information from ancient texts that are read through the lens of the archaeological remains. Research has focused on prehistoric sites such as Neolithic structures for group gatherings located in the area of southern Anatolia and Syria (McBride 2014), or ancient buildings such as Egyptian temples (Warusfel and Emerit 2021), Greek temples and halls (Vassilantonopoulos and Mourjopoulos 2001) and pre-Columbian palaces in the Andean area (Rick 2008; Collecchia *et al.* 2012). Studies of the acoustics of enclosed spaces in the medieval and postmedieval periods have been undertaken at a number of religious sites, including Christian churches (Girón *et al.* 2017; Djordevic *et al.* 2020; Adeeb and Sü Gül 2022), mosques and Buddhist temples (Gül 2019; Gupta 2021; Zhang *et al.* 2024). The different faith traditions within the Christian church and the changes in liturgy practices throughout the centuries have led to a series of studies including the acoustic analysis of Hagia Sophia in Constantinople (Abel *et al.* 2013) and eight relatively well-preserved Byzantine churches in Thessaloniki (Antonopoulos *et al.* 2017; Foteinou *et al.* 2023). There have also been studies of meeting rooms (Alvarez-Morales *et al.* 2020). In some cases, the acoustic reconstruction of historical spaces is allowing the general public to experience the lost acoustics of past buildings, such as the damaged cathedral of Notre Dame in Paris (Katz *et al.* 2020).

The earliest acoustic analyses undertaken of archaeological buildings did not focus on enclosed spaces, but on architectural structures that are not fully covered by a roof, such as Roman theatres (for a summary see Girón *et al.* 2020). In Europe there have been other studies dealing with the prehistoric period with positive results at sites such as Stonehenge (Till 2009). Moreover, many prehistoric rock art sites are located in concave shelters whose acoustics have also attracted scholarly attention (Rainio *et al.* 2018; Alvarez-Morales *et al.* 2023; Santos da Rosa *et al.* 2023). Other studies have dealt with the medieval (Bertoldi *et al.* 2022) and modern periods (Boren 2022), including the sound of courtyards and gardens (Almagro-Pastor *et al.* 2022). Across the Atlantic, interaudibility has been demonstrated between various locations in the central area of Pueblo Bonito at Chaco Canyon in the United States (Loose 2008), as well as the role at the same site that a platform mound may have played as a speech podium or performance space, for example, to play a sound object such as a conch shell trumpet (Witt and Primeau 2019). In another research project undertaken in Mexico, acoustic tests were made at a sunken patio on the site of Peralta and a great stone bell outside it (Ramos-Amezquita 2014).

In addition to the acoustic analysis of enclosed and semi-enclosed spaces, a different set of studies could be subdivided into those focused on urban and non-urban areas. In relation to the former, urban soundscapes have been researched on the basis of written documentation (e.g. Terpstra and Rose 2016; and Knighton in this volume) and archaeological information. Regarding the latter, acoustic analyses have been carried out in particular built spaces, including the Maya ritual centre of Chichen Itza, specifically focusing on the acoustic phenomenon of the chirped echo created by short percussive sounds such as handclaps at the pyramid of Kukulkan (Lubman 1998; 2008). There has also been research into the acoustic raindrop effect at the same place (Cruz Calleja and Declercq 2009). Furthermore, sound (together with vision and movement) has been simulated at the Maya site of Copán (Honduras), generating viewsheds and soundsheds from Stela 12 (Richards-Rissetto *et al.* 2023). At the Inca site of Las Pailas (Argentina) (Izaguirre and Ferrari 2018) the authors mentioned that one of the weaknesses of their simulation was that they had not considered the noise caused by people moving in the space, which may have deeply affected sound dispersion. This has been the precise focus of a series of studies contextualised in the Roman (Holter, Muth, and Schwesinger 2019; Kopij *et al.* 2023) and post-medieval periods (Boren in this volume). Regarding the latter, in this volume Braxton Boren has analysed whether the written sources were correct in the number of people and the space of a particular audience listening to a speech given by 18th-century preacher George Whitefield (Boren in this volume). In a different vein, Stephen Mileson has examined the connection between power and sound and the role of the latter in creating and maintaining a feeling of attachment to a village, speaking of the role of bells and other sound tools and sounds (Mileson 2018).

Finally, in non-urban areas it is useful to think about three types of sonotopes: geophonies (natural sounds produced nonbiologically), biophonies (biologically

produced natural sounds) and anthrophonies (sounds produced by humans) (Farina 2014, 17). The last of these was discussed in the section above relating to the production of sound. Regarding biophonies, the location of Greek temples such as that dedicated to Hera in Poseidonia in an area of lush vegetation has been linked with sound and nature, given the goddess' role as a patroness of nature (Bellia 2023). The importance of daily sounds has also been proposed in a variety of prehistoric areas such as the Teleorman River Valley (Romania), Çatalhöyük (Turkey) and West Penwith (England) (Mills 2016), as well as in Mesoamerican Oaxaca (King and Sánchez Santiago 2011). The sound of volcanoes and water would have created geophonies (see the section on producing sound above).

Sound waves hitting rock surfaces created acoustic effects that might have impacted the way people perceived the landscapes in which the sound was propagated. The following will be discussed in relation to this: music and speech clarity, echoes, resonance, augmented audibility and reverberation. Music and speech clarity have been proposed as acoustic properties that fit well with the likely social and ritual activities taking place at Altai rock art sites (Díaz-Andreu *et al.* 2023). Echoes seem to have influenced the selection of rock art sites in particular areas of the world, including Spain (Díaz-Andreu and García Benito 2012), Finland (Reznikoff 1995, 551–554; Lahelma 2010, 48; Rainio *et al.* 2018) and North America (Waller 2005; Waller and Arsenault 2008). In turn, resonance has been linked to the presence of rock art, for example at the Herschel petroglyph site in Saskatchewan, Canada (Steinbring 1992; 1993). Finally, augmented audibility, the perception of sound amplified above the expected level, seems to have been behind the selection of sites in the Sierra de San Serván (Spain) (Mattioli and Díaz-Andreu 2017).

Reverberant landscapes have also been discussed by scholars as having been especially chosen for rock art production. This is illustrated in the case of Didima, where the impressive reverberation leads Mazel to see this as the reason for the high number of rock art sites in the valley (Mazel 2011, 291). A similar relationship has been ascertained thanks to some basic acoustic tests in some areas of Spain (Díaz-Andreu and García Benito 2015). Moreover, at Writing Rock in North Dakota, it has also been argued that the exceptional acoustics of the natural amphitheatre in which the site is located would have enabled the sound of a ringing stone to reverberate along the valley (Devereux 2008, 26). Reverberation and sound amplification are two connected but distinct phenomena. Devereux also tells us that "in one experiment, five drums were beaten within the rock-shelter by American Indian musicians and the sound produced was broadcast so effectively that traffic stopped on a highway several kilometers distant as drivers got out of their vehicles to investigate the source of the sound" (Devereux 2008, 22). Sound propagation is mentioned by Deveraux regarding the White Shaman rock shelter in Lower Pecos, Texas, where conversations at the site may be understood by someone on the opposite side of the canyon. At Wikwip (Echo Rock) in San Diego County, it is possible to hear a conversation held at the site from a distance of some 100 m. Finally,

at the Canebrake Wash site, the sound of someone talking in front of its paintings is broadcast across the landscape (Devereux 2008, 26–27). As seen above, in the last few years sound transmission has also been explored through GIS tools (Díaz-Andreu *et al.* 2017; Primeau and Witt 2017; Witt and Primeau 2019; García Atiénzar *et al.* 2022; Santos da Rosa *et al.* 2023; van Dyke *et al.* 2024). Some work has also been carried out on sound propagation in non-rock art prehistoric (Sciuchetti 2023) and medieval landscapes (Mlekuz 2004; Bertoldi *et al.* 2022)

Sound, emotion and the brain: the combination of archaeoacoustics with psychoacoustics and neuroacoustics

Since the 2000s there has been some research combining two disciplines that until then had ignored each other: psychology and archaeology. In the field regarding sound, one of the main challenges of the auditory system is making sense of the multitude of sound waves arriving simultaneously at our ears. This process is essential for clear auditory perception, such as identifying the elements of language in a conversation, the notes in a melody or interpreting a specific sound correctly. Psychoacoustics is the science of the hearing system as a receiver of acoustical information (Fastl and Zwicker 2007). It attempts to understand how humans perceive and are affected by elements of sound such as pitch, loudness, timbre and spatial location.

Psychoacoustics has been the focus of one of the lines of research undertaken at the Andean Formative site of Chavín de Huántar (c. 1500–300 BCE). In one of the projects carried out at the site, the acoustic characteristics of an ancient mortared-stone complex were analysed using a swept exponential sinusoidal test signal emitted at a height corresponding to that of the average human head at the time. Recordings were taken at two sets of receiver locations to determine reverberation time (RT), echo density, interaural cross-correlation coefficients and lateral energy fraction (Abel *et al.* 2008). These measurements were then used to construct a computational acoustic model of the site's interior architecture (Collecchia *et al.* 2012). Additionally, an on-site psychoacoustics experiment involved 45 volunteers who were tasked with locating sound sources within Chavín's interior galleries. It was reported that "participant responses to systematic testing of sound source/receiver 'perceiver' location combinations demonstrated broad consensus regarding the perceptual effects of gallery acoustics on sound transmission, providing verifiable 'mappings' of sonic communication dynamics within those spaces" (Kolar 2017, 49). Subsequently, the same researchers developed an archaeoacoustics method, comparing human-performed sound sources and standard electronic acoustical test signals across various survey points at the Inca administrative complex of Huánuco Pampa. By integrating ecologically valid acoustic measurements with subjective observations, they mapped sound transmission and reception for different types of sounds, identified environmental influences, and evaluated the site's acoustic properties (Kolar *et al.* 2018).

A different project involving psychoacoustics was undertaken at the Greek sanctuary of Mount Lykaion, Zeus' birthplace. There, Pamela Jordan speaks of soundlines, places that have a sonic connection between them (Jordan 2020, 13), denoting that people could indeed feel such a connection. Fieldwork was conducted at the site to ascertain whether the visual connection between the starting blocks of the Lower Sanctuary and a hill could be matched by a sonic link. Although the results were unclear, the author argued that this type of research "helps to reposition sonic experience as a driver in archaeological work... it produces a new way of moving through the site, of reading meaning into sound that may have been consequential for the experience of ancient users" (Jordan 2020, 25). While Jordan's experiments were conducted *in situ*, in other cases scholars make use of auralisations using several scales to rate perception and emotion (see López-Mochales and Escera in this volume). Through auralisations, a comparison was made between the sonic behaviour of sites with and without art in the area of the Caroig Massif in Valencia. The results from the analysis of the contingency tables determined that the differences in reverberation between the groups (slightly higher in the sites with rock art) were perceived by the individual participating in the experiment (López-Mochales *et al.* 2023b). In a different study, the contrasting morphology of the Diosa I and Horadada rock art caves was perceived by listeners (López-Mochales *et al.* 2023a). Other ways in which psychoacoustics and archaeology have been combined have led Valenzuela to propose the term psychoarchaeoacoustics (Valenzuela *et al.* 2020).

Beyond subjective perception, neuroacoustics investigates the cognitive effects of present-day sound and music by measuring brain activity in response to different auditory stimuli (see Aparicio-Terrés and Escera regarding ritualistic music in this volume). A few neuropsychological experiments related to sound have been undertaken in recent years (for example Devereux and Jahn 1996; Cook *et al.* 2008; Gaona *et al.* 2014), but this field is in need of further study. However, some of the results of research undertaken into subjects such as the relationship between music or speech and emotion (Huels *et al.* 2021; Janata and Parsons 2013; Loui *et al.* 2013; Koelsch 2014) can be applied to archaeological sites where it is known or suggested that music was played.

This volume

This volume presents a comprehensive collection of essays that explores the sonorous dimensions of the past through an interdisciplinary approach. Integrating archaeological insights with sound epistemology, this book's contributions illuminate the ways in which sound has influenced and shaped the cognitive, cultural and spiritual facets of human societies across different periods and locations around the world. From the auditory enchantments of the natural world to the application of digital tools for reconstructing historical soundscapes, this compilation expands our understanding of sensory experiences in the past and underscores the importance

of incorporating sound into archaeological research. Each chapter offers a detailed analysis of how people perceived and engaged with their sonic environments, establishing this volume as an essential resource for scholars and students at the crossroads of archaeology, anthropology and cognitive science.

In Chapter 2, Bernd Brabec explores the evolutionary aspects of sound, examining how the auditory experiences of early humans facilitated the development of speech and song and thus complex social structures. The author proposes that the "auditory enchantment" of the natural world was a crucial element in the cognitive evolution of Homo sapiens, aiding in the shift from basic communicative gestures to sophisticated symbolic communication. His work is followed by the contribution of Simon Wyatt (Chapter 3), who introduces the concept of "archoustemology" to study Upper Palaeolithic aerophones. Wyatt's work highlights how these ancient instruments are not just artefacts but also representations of the profound acoustic knowledge of early humans. He bridges cultural, ecological and psychological dimensions to suggest that musical instruments were integral to the social and ritualistic dimensions of ancient societies. In a similar vein, Neil Rusch (Chapter 4) discusses how the concepts of re-enactment and actualisation in archaeology can shed light on the cognitive engagements and material interactions of past cultures with their sound-making tools. In this study, Rusch employs Material Engagement Theory to demonstrate how such engagements enhance our understanding of prehistoric societies' interactions with their material world and the soundscapes in which they were immersed.

Chapters 5 and 6 delve into the cognitive dimension of auditory experiences. In this regard, Raquel Aparicio-Terrés and Carles Escera examine the effects of music in ritual contexts, linking historical practices with contemporary neuroscience research to explore the impact of sound on human behaviour. Subsequently, Samantha López-Mochales joins Carles Escera to discuss the use of psychoacoustic methods in the analysis of archaeological soundscapes. Their focus on auralisation and its application in studying ancient environments highlights the innovative approaches being taken to preserve and understand the acoustic heritage of archaeological sites.

In Chapter 7, Ana-María Alarcón-Jiménez and colleagues use ethnohistorical sources to explore and interpret the acoustic environments of rock art sites in South-Central California (United States), offering a critical examination of how these data can enhance our understanding of past sound-worlds. This contribution also considers the challenges and biases inherent in interpreting such sources, highlighting the complexities of translating ethnohistorical information into meaningful archaeological interpretations. Similarly, Chapters 8, 9 and 10 present case studies that highlight the archaeological dimension of sound research. In the first, Marilyn Armagast Martorano expounds her work on portable lithophones from Colorado (United States), offering a new methodology for identifying and analysing these ancient musical instruments. In a different context, Raquel Jiménez Pasalodos and her team explore the archaeoacoustics of cup-marked sounding rocks found in the Gredos Mountains (Spain), discussing the cultural significance of these sonorous elements in past cultural contexts. In Chapter 10, Margarita Díaz-Andreu and her

colleagues explore the rock art soundscapes of the Karakol Valley in the Republic of Altai (Russia), an area associated with shamanic practices characterised by intense auditory experiences. In this study, the authors also analyse representations of shamans in rock art and delve into the complex relationship between sensory experiences and ritualistic practices.

Chapter 11 examines Zorana Đorđević's research on how frescoes in medieval Serbian Orthodox churches enrich the auditory dimension of religious services. In her study, Đorđević identifies key elements of sound imagery, including musical instruments, musical gestures, voices inscribed on scrolls and in books, and celestial sounds depicted in Heavenly Liturgy, to address the link between the visual art and sonorous dimension of these sacred spaces. Chapter 12 presents Tess Knighton's exploration of digital tools, including virtual reality and auralization, to reconstruct historical soundscapes. Her research illustrates how modern technology can integrate historical data with sensory anthropology, offering new perspectives on the auditory experiences of historical environments. Finally, in Chapter 13, Braxton Boren reviews the history of research on speech intelligibility and highlights the relevance of the lessons learned from an experiment conducted by Benjamin Franklin, whom the author refers to as the first archaeoacoustician.

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Chapter 2

The role of listening in the prehistorical emergence of speech and song: A precursor to becoming human?

Bernd Brabec

Abstract

This article explores the nexus between the emergence of language, music and the metaphysical through the lens of auditory enchantment. It is argued that before the divergence between linguistic phonemes and morphemes, the environment was imbued with enchantment through sound, laying the groundwork for symbolic abstraction. This enchantment, rooted in the shared experience of special sounds, facilitated the transition from indexical to symbolic systems of communication and understanding. Enchanted listening, wherein sounds were correlated with imagined entities, played a pivotal role in human cognitive evolution by fostering communal rituals and proto-musicking. The coalescence of auditory enchantment, ritualistic repetition and symbolic abstraction gave rise to the metaphysical realm, intertwining the fabric of music and language with transcendent meaning. Ultimately, it is suggested that music, through its capacity to invoke the metaphysical, played a foundational role in shaping the cognitive landscape of early humans, potentially preceding the emergence of modern humanity itself.

Keywords: emergence of ritual, symbolic thought, proto-musicality, proto-religiosity, enchanted listening, human communication origins

Introduction

In the context of past sounds, or soundscapes of prehistoric human environments, essential attention must be paid to the human capacity to hear, and to listen. The listening capabilities of early *homo sapiens* may hold the key for understanding how the most prominent passage into human behavioural modernity – that is the

emergence of speech, musicality, and especially symbolic abstraction – occurred. In this paper, a terminological distinction will be made between "archaic humans", that is all extinct humans plus early *homo sapiens*, and "modern humans", that is *homo sapiens* in behavioural modernity, apt of abstraction and at least proto-language and a proto-musicality.

Psychophysically speaking, there is no reason to doubt that already archaic humans were well equipped with an ear that would probably outdo most present humans' listening skills. At least since the emergence of *homo ergaster* around 2 million years before present, the archaic humans' listening apparatus became very similar to the ear of contemporary humans. For instance, a heightened sensitivity for frequencies around c. 400–4000 Hz that enhances the perception of the human vocal range is evident since *homo ergaster* (Morley 2013, 171).

Before the advent of sedentariness only around 12,000 years ago, we can assume that humans would definitely not have been in the position to consider themselves the "crown of evolution". Contrastingly, human life was precarious due to a variety of threats, among them a massive presence of menacing and predatory megafauna against a relatively small population of humans (cf. Rodríguez *et al.* 2012). Obviously, early detection of predators was not only favourable, but a life-saver. With this affordance, the human hearing apparatus became well trained for detecting any sonic signal that would indicate a predator's presence. Archaic humans, therefore, presumably had to devote much attention to what they heard in any given situation.

In the following pages I will present a hypothesis about the emergence of modern forms of listening that has the potential to explore and explain the passing from a society of archaic humans communicating in purely indexical manner through embodied sounds and sounding movements into the social world of modern humans including the capacity of symbolic thought. Symbolic thought is a necessary prerequisite for complex speech in the sense of a proto-language that employs at least a minimum of compositional morphemes that are connected to each other. Symbolic thought is also related to producing and understanding non-semantic sonic sequences, in a form of proto-musicality. Contrary to "music", the term "musicality" is more useful in referring to the capacity of organisms to organise in perception and production the kind of sonic sequences that in modern Western scholarly understanding we subsume under "music", including dance and related activities. "Musicking" (Small 1998) is also often used to denote the whole range of activities around "music", regardless if the activity in any vernacular language can be translated as "music" (for the problem of defining "music" see e.g. Nettl 2005; Stoichiţă and Brabec de Mori 2017).

Therefore, I will at first provide a brief overview of some classical and contemporary theories about the origins of musicality, which mostly involve the question of the origin of speech, and language. Thereafter I will elaborate on a proposal by Victor A. Stoichiţă and myself (2017) that analyses modes, or postures, of listening among contemporary humans. This will aid in highlighting the crucial role that listening

obtained also in prehistory. Specifically, the posture we call "enchanted listening" seems to be rather unique to modern humans when compared to other animals, and because of this a full section is devoted to analysing how this way of listening may have come into existence during the onset of behavioural modernity. The proposal made in this chapter will contribute with some new thoughts to existing origin theories. It is not my intention to replace them, but to complement and enhance them, while sharpening the picture we are painting to illustrate the emergence of human modernity.

Before turning to this endeavour, I wish to draw attention to a backlash teleology, a subversively inevitable effect that any formulation or acceptance of origin theories has on the present. On the one hand, an origin hypothesis tells us more about the circumstances of where, when, and by whom such a theory is put forward. We will hardly find evidence for what actually happened in the past, but the hypothesis constitutes evidence for its formulation in a certain present, including political positions and cosmological beliefs in that present. On the other hand, an origin hypothesis also has an effect on the present through its possible acceptance. If we agreed, for instance, that musicality would have solely emerged from training for warfare, we would be tempted to believe that "the nature of musicality is training for war" – thus carving out some understanding of what current musicality would be, or even, should be. Therefore, I prefer to bear these effects in mind and ask – what do I want to convey by putting forward a certain narrative of origin? The listening hypothesis in this paper, as will be shown, pictures musicality as a nexus of interaction and communication with Others, rather than, for example, promoting competition, selection, or potential marginalisation of non-musical Others. Thus, I wish to highlight that musicality's potential of bridging boundaries is more important for its very "nature" than its identitarian potential of precluding certain communities from others.

The common ancestor of speech and song

Today most scholars agree that the question if music emerged from certain uses of prior existing language, or vice versa, has lost the importance it held in the 19th and early 20th centuries. Nowadays a common origin of the two is envisioned. This position is not new, however. Although the musician Richard Wagner (1813–1883) is often quoted as a proponent of Rousseau's and Spencer's claim that music emerged from language, he also explicitly hypothesised a prehistoric tonespeech, enriched with gestures, a "*reine Tonsprache*" in the sense of non-linguistic emotional utterance, which he regarded the common origin for both language and music:

> In pure tonespeech, when transmitting any impression that was received, mere emotion made itself understood; and it could – supported by the gesture – achieve this only through manyfold practice and lowering, extending and shortening, raising and diminishing the sounding tones (Wagner 1852, 232; translation by the author from German: *"In der reinen*

> *Tonsprache gab das Gefühl bei der Mitteilung des empfangenen Eindruckes nur sich selbst zu verstehen, und vermochte dies, unterstützt von der Gebärde, durch die mannigfaltigste Übung und Senkung, Ausdehnung und Kürzung, Steigerung und Abnahme der tönenden Laute"*).

Without referencing Wager, this idea was re-termed "musilanguage" by Brown (2000) for the anglophone readership. In the same vein as Wagner, Carl Stumpf (1848–1936) went a step further and integrated the gesture that was only hesitantly mentioned by Wagner. Stumpf assumes "a common root for music and language" which he describes "in the form of sound- and gesture-signs that are closely linked together and intelligible through themselves" (Stumpf 1911, 29; translations by the author from German: *"in Gestalt eng miteinander verknüpfter, durch sich verständlicher Laut- und Gebärdezeichen [...] eine gemeinschaftliche Wurzel für Musik und Sprache"*).

With his "sound- and gesture-signs", Stumpf precisely anticipates what was much later termed "gesture-calls" by Robbins Burling (1993). Today, "gesture-calls" are – along with "musilanguage" – most often recognised as the common base for both speech and musicking. Burling, and many other scholars, including myself, agree that inquiring if music or language came earlier is futile, as both emerged, probably in rather parallel paths, from this common progenitor, which is frequent among many animals, including primates, and is also retained among contemporary humans.

Possible origins of musicality in selection, sociality or exaptation

It seems impossible to mention and comment on each of the existing theories about the origins of music, so they will here be organised in three groups: selection, "social glue" and exaptationist theories. First, also historically, are these that seek to explain the emergence of musicality, song and dance, as based on selection, as an adaptation that directly provides benefits to the individual. This was first put forward by Charles Darwin (1809–1882) in his book *The Descent of Man* (1871). Here, he transfers his observations of songbird behaviour by analogy to human social behaviour. Males, at some point, by being musical, would improve mating attraction among females, thus gaining an advantage compared to non-musical males; the abstract machine of evolution, therefore, selected the musical male from the non-musical (see also Miller 2000; reviewed by Morley 2013, 284–289). This hypothesis is easy to refute: empirical evidence, contemporary as well as historical, easily shows that there are, and always were, male non-musicians who reproduced well, that there also were and are female musicians, and that during the ages that the adaptation would have needed, archaic humans probably did not even perform what we call "music" now. Considering attractiveness, however, does not entirely lack reason: recent research shows that there could be a general preference especially among contemporary females to find males more attractive when they were told that these males were active musicians (Marin and Rathgeber 2022). Contemporary female statistical preference for male musicians, though, may rather be based on rock star or genius composer images that developed from the 19th century onwards and have little to do with what happened

in prehistory. Still, a simple advantage in reproduction for musical humans should not be fully discarded because there is some chance that such effects may add up to the question of why humans started to behave musically and kept to it.

Other scholars prefer the idea of musicality serving as a form of "social glue" that does not provide merely individual benefits but increases a group's survival again in an adaptational sense (see e.g. Huron 2001; Cross and Morley 2009; Morley 2013, 289–291). These hypotheses are mostly based on the observation that musical performance, especially when combined with physical movement in dance, resembles many skills that can be useful in other areas of life, as for example in synchronised action, and especially in social bonding. Therefore, a musicking human collective would achieve denser social interactions in situations like hunting, or faring war, thus gaining an advantage that could turn out in a *longue durée* adaptation: using musicking as a form of training for "more serious" processes in life directly connected to survival. Cross and Morley conclude that:

> Musical or protomusical behaviour has the potential to make use of several cognitive capacities at once, relying on the integration and control of biological, psychological, social and physical systems; it gives the opportunity to practise and develop these integrated skills in a context of limited risk (Cross and Morley 2009, 77).

Here it appears that musicality could have worked as a training for skills and such could have contributed to fostering human sociality. The same, however, can be said about games, rituals, competitions or "proto-sports"; it is not sufficient to explain the specificity of musicality. In the same vein as the first group (individual selection theories), the "social glue" theories may add up, though, to a general construction of origins of musicality. It likewise gains merit by explaining why music, or musicking – as a developed skill – may be beneficial for humans to perform and maintain.

Other scholars also argue in this line of thought: although it may be advantageous to behave musically, this still does not convincingly explain how music emerged in the first place. The question remains, how did humans come by the idea to behave musically? Therefore, some scholars seek exaptationist explanations: "whereas an adaptation is a trait that was selected to perform at least one of its current functions, an exaptation performs a completely different function from that for which it evolved" (Thompson 2009, 33). Some human behavioural features, including musicality, would not have emerged out of selection, that is individual or group adaptation, but as a "side effect" of very different skills (which in turn may be based on adaptations). Here, cognitive scientist Steven Pinker's (1997) "auditory cheesecake" metaphor stands most prominently. He argues that although nobody needed cheesecake (there is no evolutionary pressure for adaptation), people still make it and enjoy it. Music, he would reason in reversion to the "social glue" theories, emerged from these activities that Cross and Morley (2009) mentioned as being trained through musical behaviour. As a consequence, people enjoyed and kept it, although musicality by itself would not posit any evolutionary advantage. This hypothesis is heavily contested, though.

An original take in the exaptationist cluster comes from art scholar Ellen Dissanayake (2000) and musicologist Richard Parncutt (1993; 2019). Dissanayake sees an analogy between "motherese", the form of proto-language that is employed by mothers and infants, and the phylogenetic emergence of music from proto-musical gesture-calls. Parncutt, going further, interprets the reason for musicality being a universal trait among humans as lying in the ontogenetic origin of each human person in their mother's womb: where the fetus starts hearing after c. 22 weeks and is conditioned by muffled speech and rhythmic sounds like their mother's gait towards later in their life seeking to "return" to this by acting in pitch and rhythm. He also makes a rare connection between musicality and religiosity: the feeling of total immersion within a greater being in the mother's womb would predict religiosity as the fetus' listening abilities predicted musicality.

Many contemporary scholars prefer an incremental approach to evolution. This removes importance from adaptation versus exaptation issues and fosters an understanding of co-evolving niche adaptation and niche construction, pointing to a nature-culture continuity in evolutionary feedback (see McBraerty and Brooks 2000; for music e.g. Morley 2013; Patel 2023). In this approach, the emergence of phenomena takes time and is embedded in a deep history of slow and small changes. Starting from archaic humans' gesture-call taskscape, wherein human-environment-interaction as well as intra-human-interaction slowly grew more and more frequent, practice and repetition led to the emergence of new behaviour in biocultural coevolution. For example, language came with symbolisation (c.f. Deacon 1998; 2006, among others), and musical behaviour through ritualisation (see e.g. Morley 2013; Tomlinson 2018). A very detailed account of incremental approaches, as well as a warning of the "perils of adaptationism", is provided by musicologist Gary Tomlinson (2015). This author focuses on the emergence of musicality in terms of semiosis as based on Peirce but developed in an evolutionary sense by anthropologist Terrence Deacon (e.g. 2006). Along with Deacon, Tomlinson regards any beings' interpretations of their environment via perception as either iconic, indexical or symbolic. He finds that the key transition to modernity occurred when crossing a "symbolic threshold" (2013, 672). This crossing brought a realm of symbols into existence:

> As associative indices multiply and accumulate through learning, there occurs something like a phase transition in cognition. [...] At this threshold a categorical change in semiosis occurs whereby the accumulated indices form and circulate in a system of their own. The elements in this system —symbols— point to one another in the manner of indices (Tomlinson 2013, 655–656).

There we have a system that resembles language (or Saussurian *langue* to be more precise), in the way the symbols behave in their symbolverse, in a "space" wherein they point to one another. With this realm of symbolic cognition in place, both discrete combinatiorial units (morphemes) and discrete pitch/duration sequences (melodies) could slowly gain momentum and later define one feature of distinction of the modern human.

Some observations on musical evolution theories

As anticipated above, I would like to add some comments and observations to the theories mentioned here. These observations concern emotions, rituals, ontology and the "missing link". My first comment relates to the emotional: most authors acknowledge the specific emotional content of music. It is rather clear that in opposition to language, music does not, or only at a very low level, communicate propositional information. Rather, it conveys emotional contents, affects or moods. Based on this observation, many scholars (e.g. Perlovski 2012; Snowdon *et al.* 2015) often directly link music with the emotionally loaded gesture-calls that precede both music and speech. Contemporary humans, however, usually do not reveal their current emotional states or feelings by instant musicking, but still through gesture-calls. A person sinking forward and sobbing performs a gesture-call, as does a person jumping up and laughing, or somebody pointing in surprise to an event exclaiming "Oh!". Otherwise, people employ language and tell about their emotions, with their prosody "coloured" by the experience. This is done with a voice maybe fast and frantic when anxious, somewhat agitated or bouncing when happy, slow and grave when sad, and so on. Musical emotion is different: it mediates an emotional state or trajectory, but does not mirror current experience. At least, in my personal experience, I have never ever witnessed anyone spontaneously and imminently expressing their fresh emotions by singing. When bursting into song, even in emotionally laden situations, the person externalises the emotional state, it becomes mediated (Amy de la Breteque 2012). Listeners then can perceive the musically mediated emotion (which usually imitates, or models, speech prosody or gesture-calls, see e.g. Patel 2008), but their state is still different from the state of directly experiencing the emotion on themselves. There are many studies in music psychology supporting the claim that musical emotion is related to, but very different in terms of experience than, personal imminent emotion (see Juslin 2013 for a review); musical emotions, at least on contemporary humans, also sublimate into what some authors call musical pleasure (Saarikallio *et al.* 2019). Therefore, scholars who propose that musicality emerged from direct emotional expression commit a category error: personal, imminent emotion is directly expressed through gesture-calls, or speech prosody and content. Music, in all its known forms, mediates emotion, and builds a distance to the current, personal state of concerned musicians or listeners.

The second comment to musical origin theories builds on an observation in historical, ethnographic, and modern sociological context that is fairly intriguing by its almost universal presence among humans. This is the association of musical behaviour with the metaphysical, be it called religious, sacred, invisible or visionary, spiritual, shamanic, or otherwise. Performances of the metaphysical, most often in what we call "ritual", seldom can do without music or other forms of organised non-linguistic sounds, and vice versa. Practically all kinds of music carry a certain possibility that they may convey metaphysical experience (whether this is exploited in a given situation or not is a matter of choice, though). Although most proponents

of abovementioned theories do acknowledge that musicality is often tied to ritual, or ritualised action, to religious or spiritual behaviour, it is mostly not considered that both could be tied together by a common origin. Few scholars (e.g. Parncutt 2019) have explored the possibly primordial connection of the musical with the metaphysical. French musicologist Jules Combarieu (1909) assumed that all kinds of music were based on a "magical" function in ancient times, and that modern uses of music for entertainment, intellectual delight or artistic purposes came much later. Carl Stumpf (1911) also hinted at this, but did not elaborate on the idea. In 1930, Austrian anthropologist Siegfried Nadel wrote a seminal piece on the "Origins of Music", deducing from collected ethnographies that people tend to connect the musical with what he called the supernatural. With the prominence of such properties he views "the elements of music, as representing a non-natural, out-of-the-ordinary sound-language" (1930, 541), and that this "out-of-the-ordinary, supernatural tone-speech of song is held to be the language of the gods and demons" (ibid., 542). He concluded "that music was a product of man's purpose to create for his own use a 'peculiar' magic language of invocation and exorcism" (ibid.).

Following up on Nadel's highly original approach, the magical, or supernatural primary function of music became popular in German literature of the mid-20th century. Musicologist Karl Heinrich Wörner, for example, somewhat bluntly echoed Nadel in that most ancient forms of music must have been functional "means for sorcery with extrasensory content" (*"Zaubermittel mit übersinnlichem Gehalt"*). He deduces this from music among the "primitives", which he deemed was always magical in nature, simply because all life of "primitives" was guided by magical beliefs and superstitions (see Wörner 1954, 4). Beyond post-war Germany, however, serious approaches to the possibly "magical", that is metaphysical, or transcendental function of hominins' first musical utterances, were only taken up much later. Most authors mention this feature of musical functionality, as well as music's close association with ritual, but do not trace this relation back to its very origins, except Tomlinson (2015), and myself (Brabec de Mori 2017).

Gary Tomlinson, in his fascinating *A Million Years of Music* (2015) suggests that the musical faculty co-evolved with the transcendental faculty in gene-culture coevolution. In surprising consonance with Nadel (whose work he does not seem to be aware of, though), he writes about "all manner of more-than-ordinary gesture: rhythmically regular vocal articulations, intonation, chant, song, patterned movements of all sorts, and emergent synchronies among these" (Tomlinson 2018, 158). He adds that the utterances he mentioned, as a form of (proto-) music, ritual, and dance, emerged within the growing capability of abstraction in palaeolithic humans, especially the early *homo sapiens*. The imminent coalition of a proto-musical faculty and the faculty of abstraction is highly interesting. Tomlinson goes on to describe that these "nascent ritual systems [...] formed a nodal point of pasts and futures, closing temporal distances and yielding an effect of the presence of absent things, events, or people" (2018, 159). With his "transcendence" he would, of course, not go so far to interpret, as Nadel did,

emergent musicality to be the language of gods and demons; he restricts this term to "realms that are not fully but only partially counterintuitive [; ...] a movement beyond the physical but also a new force for shaping that beyond in ways that have characterized humanity ever since" (2018, 169). However, he highlights the intimate connection imminent in ritual sounding: "The bond of music and metaphysics reaches back to the first inklings themselves of other worlds" (Tomlinson 2015, 50).

Although Tomlinson can be understood beyond the colonial assumptions about "primitives" that abound in continental literature from the 19th to the mid-20th centuries, there is still no clear acknowledgement of the ontological consequences of such thinking – my third observation on above-mentioned origin theories. In my article "Musical Spirits and Powerful Voices" (Brabec de Mori 2017), I argue that most of the present theories are rooted, unsurprisingly, in an ontological environment that Descola (2005) terms "naturalism". Ontological anthropology, though, advances (in a nutshell)[1] the idea that Indigenous, or many non-modern societies (in e.g. "animism") engaged in "worlding" other ontological premises. This means that non-modern people live in a world where animate beings are acknowledged as persons with certain human features (a human "interiority" says Descola), and especially as persons or collectives one can socialise with. One of the main agents for trans-human interaction and communication in such an animist world is sound, and consequently, songs, dance and music (Lewy 2017). Assuming that maybe such animist worlds are the oldest, or "first inklings themselves of other worlds", as says Tomlinson, we also have to think about how not only a (other-)world could come into being, but also how this world of human genesis would have been peopled with beings (like the absent, spirits, gods, the deceased, and so on) in the first place.

The final observation I have on many of the theories in place is the problem of the "missing link". For example, when Carl Stumpf (1911) proposed that long tones (discrete pitches) came into being by long-distance calling, this seems feasible as long as we ignore the low position in the food chain obtained by archaic humans. Very often, the exact point of departure from gesture-calls towards musicality remains shrouded. It is clear already from Darwin's adaptationism, that practicing musicality may yield some advantage. But during the prior absence of this advantage, how did humans come across the idea of uttering discrete pitch/duration sequences in the first place? Were they visited by extraterrestrians who taught them? Incremental approaches try to circumvent the problem of the missing link by drawing long lines through long eras, but still have to find the mechanisms of *longue durée* emergence and name them to come by. Somewhat reminiscent of German economist Karl Bücher's (1847–1930) rather naïve proposal that music was brought into the world by the means of synchronised work processes (Bücher 1899), Tomlinson (2015) argues in much more sophisticated terms that millions of years of stone-knapping from *homo ergaster* to the middle Palaeolithic encompassed increasing rhythmic entrainment through practice and transmission, that is teaching, of more and more complex sequences of stone toolmaking, that is factually, rhythmicised work processes. Here is

the missing link: entrainment and synchronised movement is unique in humans and may account for how dance/music/ritual (ritual in the sense of repeated action in dedicated space-times) came into the world, but there is still the question left of the "symbolic transition" from what Tomlinson calls "hyperindexicality" to the abstract realm of symbolic thought. He writes: "Involved here is a shift in cognitive capacity that remains opaque to the evidence we have – perhaps, as I and many others have suggested, it was a marker of sapient difference already 200,000 years ago – but it is important to recall that the modeling of computational machines suggests that the shift need not have been large" (2018, 171). The shift, however small it was, remains opaque, still. Maybe it can be filled with listening.

Postures of listening in prehistoric perspective

Much research has been carried out regarding the ways contemporary humans hear and listen to their environment, to speech, or to music (see, among many others, Graf 1970; Adorno 1975). In psychophysical terms, acoustic waves move the tympanum, and with it, the auditory ossicles, transmitting the vibration to the lymphatic liquid in the cochlea, where specialised nerve cells transform the movement into waves of neuronal firing. This is the "standard" procedure. Besides, we also hear extraordinary things like sounds that are not acoustically detectable, as in cases of auditory hallucinations like voice hearing or tinnitus. Non-detectable sounds also occur in more common situations: voices and sounds in dreams, inner speech, as well as imagined sounds. In all these instances, though, when sounds lack an obvious material source, listeners connect them to beings, imagined or real persons. This indexing of extraordinary sound perception (uphonia) will return in the main part of our argument.

Furthermore, listening is not a passive process, but the listener actively parses the available sonic environment: first, acoustic events are grouped and streamed in what Bregman (1990) calls "auditory stream segregation". Most animals with functioning hearing capabilities are able to do that (Faragó *et al.* 2014; Itatani and Klump 2017), and it seems that this is a pre-conscious process. As listeners, we cannot help but hear these streams, and the salience of the respective streams is guided by, and guides, our attention towards certain streams. This is the first major task most hearing animals undertake in order to actually construct auditory objects (or beings, see later). Auditory streams are not present as such in acoustical waves that encompass our bodies and move our eardrums (and skins, hair, intestines, and bones, to be precise), but the streams are selected and defined in the process of perception between cochlear stimulation and conscious reception. Streams are similarly relevant in hallucinated, imagined or dreamt sounds.

Auditory streams are then related to the environment (with exceptions such as inner speech). For example, a sound can be connected to a frog croaking in a swamp. The ear groups all the "clicks" of the croaking into one "croak", and subsequent

croaking into a sequential croaking stream. Various croaking frogs in the swamp are grouped into a "frogscape", and it takes focused attention to isolate one frog from the "frogscape" in order to detect its spatial position. Conversely, attention is more often directed to "un-hear" the frogscape; to make it recede to an auditory background, so that other sounds apart from the background stream can be detected like, for example, the gnarling of a tiger. This is what Bregman (1990) calls "auditory scene analysis", the process of parsing acoustic waves for different streams and contrasting them to each other – separating, in our example, tiger sounds from frog sounds, and attributing them distinct agencies.

An animal's attention then determines which stream is put to the fore, and which are marked un-heard (unimportant and, thus, blocked out from attention. Did you hear that a radio was still running, or that the clock over there is ticking?). When an attended auditory stream reaches the cortex, it becomes an auditory object, e.g. croaking, or gnarling. In that moment, we "hear a frog croaking". Note that we hear "a frog" instead of just some sequence of croaks in a volume of air around us. This is what we call "indexical listening" (Stoichiţă and Brabec de Mori 2017). It is quite certain that most animals with functioning ears and a brain can do this: to hear "a frog", or "a tiger". The listening brain, before even making the act of hearing conscious, connects the perceived sound with its source, constructs a pointer, an index indicating the frog, or tiger. This is based on experiential heuristics that develops as we learn to orient in the environment.

Various scholars have pointed out that human subjects do not only listen in the way that connects acoustic streams to events or beings. Contemporary humans can also listen to signs and codes, usually in the form of language. This is "structural listening": striving to abstract relevant patterns from auditory data (Stoichiţă and Brabec de Mori 2017, 24). Note that Theodor W. Adorno's (1975) "structural listening" ("*strukturelles Hören*") is always related to music listening and treated similarly to rational thinking. This is remotely related to, but not the same as, structural listening as exposed here.

What we hear when obtaining this posture of listening are abstract patterns rather than the actual sounds encoding them. We hear spoken language, morphemes, sentences, or (if we listen to something musical) harmonic-rhythmic progression, or intervals. We hear things we can, if we learned to, easily write down, because what we hear is not the sound but a pattern that can be transmitted also in written form. It is obvious, that in order to obtain this listening posture, we need the capacity of abstract thought. The listener constructs an abstract space, a "symbolverse" wherein oppositional meanings of the sonic events are mapped relative to each other. Sound passes through a filter of oppositional values before entering this symbolverse. Imagine that you hear somebody uttering an ambivalent sound, like "kət". If you are only proficient in English or expect it to be English, you will hear either "cat" [kæt] (and point to the animal in your abstract symbolverse), or "cut" [kʌt] (and point to the activity or result of cutting); or you perceive it as unintelligible. There is no

in-between. It has to be either cat, or cut, otherwise it does not "work" as a morpheme. Proficient structural listening rather ignores the sonic event, but operates by activating and relating the abstract entities and patterns in your learned symbolverse. Without learning there is no structural listening. You cannot listen structurally to a language you do not know. Similarly, you can only listen structurally to music whose principles of construction or composition you have learned (e.g. hearing chord progressions in Western art music). Note, however, that when listening structurally, you hear the meanings, not the syntactic/grammatic system. You hear a story, not the morphemes pointing to each other constituting a complex interplay of symbolically loaded units. Such sonic objects are constructed pre-consciously, too; after auditory stream segregation, but before conscious recognition. If you listen to somebody addressing you in a known language, you "cannot help but" hear the meaning of what they say.

The capacity of structural listening probably emerged in parallel to the morphing of gesture-calls into more discrete sound-signs, proto-phonemes, which were available in what Tomlinson calls "The Indexical Age" (sic, in capital letters). A "cat"-utterance indexes a feline animal; if visible, you can point towards it while saying "cat". If invisible, the "cat"-utterance reaches into a presential void, the feline animal it indexes has to be created by the listener. The index points to an imagination. In prehistory, as soon as simple sonic indexes started to interact with imaginations, that is with other icons or indexes, the abstract symbolverse was opening up. With this emerged an abstract space that can be understood as a Deleuzian abstract machine (Deleuze and Guattari 1980; see also Tomlinson 2015, 21). This abstract machine organises indexes among other signs and builds connections and rules (a proto-grammar). This opening-up resembles what Tomlinson (2018, 171) called a "shift in cognitive capacity that remains opaque", a very tiny missing link.

The third posture of listening is "enchanted listening" (Stoichiță and Brabec de Mori 2017, 33). "Enchantment" carries connotations of magic, and of singing, chanting, literally denoting something that has been sung to, so that it obtained properties beyond its physicality. Although this musical and magical touch is intended, we use the term as proposed by Alfred Gell. In Gell's work on technologies he distinguishes between technologies that are put to use in order to modify the world, and others that instead modify the way the world is percieved, that is, "technologies of enchantment" (Gell 1992, see also Stoichiță and Brabec de Mori 2017, 33). The third listening posture is a technology, or rather an applied technique for *adding* things, properties, and qualities, even entities, to the sonic event as detected in acoustic waves or other stimuli (still, we sometimes hallucinate, dream or imagine sounds). The enchantment starts as soon as we hear "a tone". This is an abstract category of a more or less discrete pitch over duration. It can be as short as to be merely recognised; a "tone" does not carry an index to something in the outer world, but engenders the possibility to "live on its own" in a space, a realm independent from the space as constructed around a being by e.g. vision and touch. A tone may relate to another tone, in an interval. As soon as we "hear" the interval, we hear something that is *added* by the abstract technology

of sound enchantment. A pitch interval (melody) goes "up" or "down", while a time interval (rhythm) constitutes a fast, or slow "progression". The steps, however, of the tones building up, down, or forward, are not properties of the acoustic waves: these only transmit vibrations that occur more or less frequent and more or less ample. The up and down and forward are enchantments that are attached to the sounds, again after stream segregation but well before conscious recognition. We hear motifs going up or down, interacting, and pacing, or running, or flowing. These terms are more than simple metaphors. If somebody who is used to Western tonal music hears a melody reaching the seventh, they will await it to "resolve" into the tonic. The seventh "wants" something, it "seeks to resolve", it "calls for" the tonic to appear. Although the use of language may add some metaphorical quality, the embodied experience of following the sonic movements and its agencies is well known, if you listen to music. Enchanted listening is not only possible with music, as music can equally be listened to indexically ("how does the guitarist pluck the strings so quickly?", or "where is the hornist seated, I can hear a horn!"), or structurally ("ah, this is G – C – D^7 – G"). Enchanted listening, however, makes us hear things that are not in the sound. Most often, these things give the impression that they would be able to "live on their own" in a specific hearing space-time:

> Enchanted listening is the only mode where auditory objects stand by themselves. This entitles them to a distinct mode of identification (neither indexes nor structures will do) and a distinct mode of relation (auditory objects relate directly to other auditory objects); in other words, an ontology which exists only in audition (Stoichiță and Brabec de Mori 2017, 50).

Detached from their sources, these sonic objects can be correlated with meanings or loaded with metaphor beyond the auditory domain. For example, an Indigenous healer can sing a song during a night-time ritual. By masking their voice, that is, by changing the sounding properties of their voice, their audience may perceive the presence of a powerful spirit. Likewise, a European opera visitor may feel the pain of loss in Isolde's voice who sings while sinking down over her beloved Tristan's body. In Papua New Guinea, the Kaluli people could identify the voice of a deceased child in the call of a bird that sounded through the playing of the *ilíb* drum (see Feld 1982; 1991). They could do this to such an intensity that some listeners would burn themselves or try to set the drum on fire in order to ease the pain of the emotion experienced. Steven Friedson, in his book about Tumbuka healing (1996), tells of his own experience – one that most of us also had, or probably can intuitively understand – when he felt that the very drums that were played in front of him made him dance. He had the impression that he did not control his movements, but the drum sounds would move his body: "I felt as if the drums were moving my hips for me" (Friedson 1996, 15). In all four examples, the sonic events, some waves that reach the eardrum, say, sounds, are "enchanted" with additional agency which they receive through the act of listening.

A prerequisite for this mode of listening is a space-time that is different from the outer world, and that exists detached from the common environment. Contrastingly,

the above-mentioned symbolverse of structural listening (which is a prerequisite for language and related code systems) is not an area of actual experience; it is a space of abstraction. The auditory time-space of enchanted listening, however, is similarly detached from the visual-tactile environment but at the same time it is clearly part of human experience – evident when we dance in synchrony, listen to operas or ritual drum music, or when we recognise a spirit's presence in the singing healer's voice.

From this phenomenology of listening postures, we can infer that the respective treatment of space is distinctive: indexical listening (what all animals can do) overlaps the auditory space with the outside environment: the frog's croaking comes from the point in the environment where the frog is sitting. Structural listening practically abolishes the notion of space in order to replace the sounds with meanings extracted from an abstract code that is sedimented in a common inter-individual "symbolverse" (a language). Enchanted listening adds an additional layer of reality, an auditory space where "up" and "down" does not mean that anything in the environment is raising or sinking, but that sonic beings (like melodies) interact in a however perfectly experiential time-space. Structural listening, in a basic sense, can be achieved by various animals (Kreutzer in Dokić *et al.* 2018). Enchanted listening, though, is probably quite unique to humans; at least from a human point of view, or a human point of experiencing the world.[2] Most humans can easily "enter" a sonic time-space full with auditory entities that move, interact, and have agencies of their own – even the agency to make a human tap their feet or shake their hips in full conscious experience.

Tomlinson (2015) consistently shows how the feedback cycle of interactions between humans and their environment, in what he calls "gesture-call taskscape", created cultural epicycles. Epicycles form when intergenerational transmission of learned elements sediments into cultural archives. These sedimentations provide abstract machines that foster feedback within their own archives and that can result in feed-forward (see Tomlinson 2015, 44–47). Two such epicycles are of interest here (Fig. 2.1). The first one built on archives that sedimented through proximity interaction among co-present humans. Gesture-calls that were transmitted to the younger generation could sediment into ever more precise and complex systems of indexes. The second epicycle revolved around addressing the absent, the invisible (the transcendent in Tomlinson's terms). By transmitting techniques to address the transcendent, these techniques could also become more precise, condensing in discrete pitch and duration.

Figure 2.2 shows how at some point, when sedimentation was sufficiently high, the epicycles produced feed-forward leaps: The first epicycle (proximity, intra-human) incremented phonemic indexes that fed forward to a leap into the abstract symbolverse, what would later become speech and language. The second epicycle (distant, extra-human) amassed systems of acoustic indexes that fed forward to a leap into the experiential time-space of discrete pitches and durations, much later being called "music". Figure 2.2 also shows that the basic feedback cycle of humans in their environment is marked by indexical listening (what virtually all animals

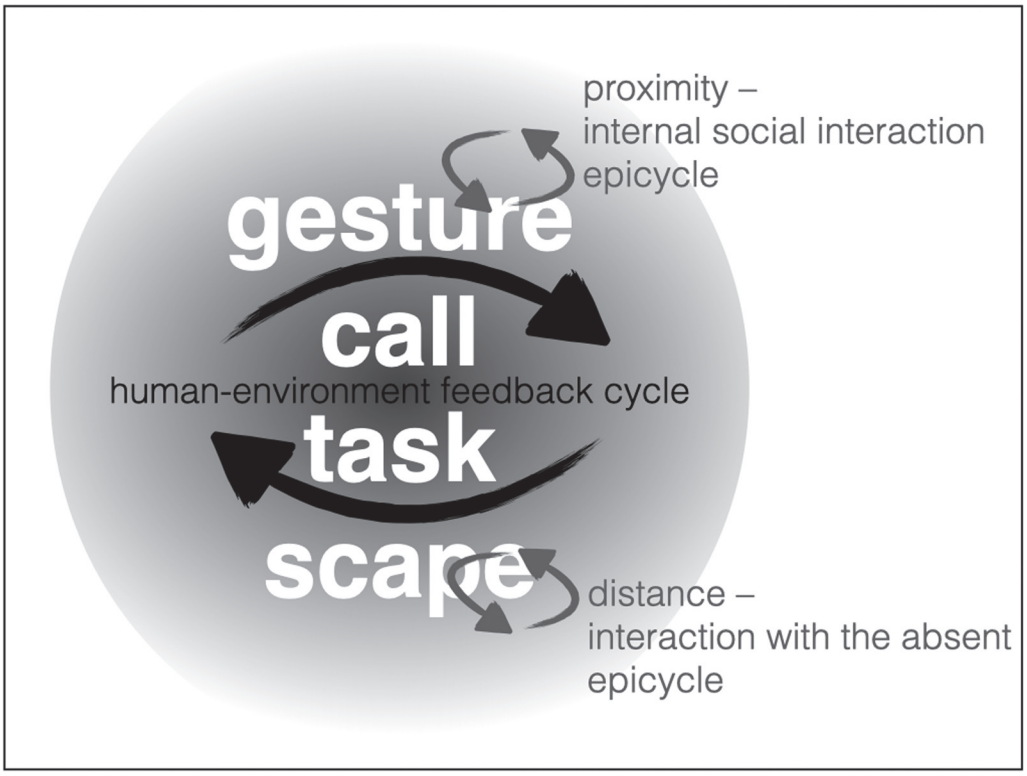


Fig. 2.1: The basic human-environment feedback cycle and the two emergent epicycles that form proximal interactions between co-present humans and distal interactions with absent entities. This and subsequent figures by the author.

can do): the sonic component of the gesture-call taskscape. Structural listening (what few animals are capable of) marks the leap from the proximity epicycle to discrete phonemes, and enchanted listening marks the sonic aspect of the emergence of discrete pitches and durations.

In a prehistoric world of archaic humans, indexical listening was probably extremely precise and employed in all situations of life simply for its crucial property of detecting dangers and prey as early as acoustically possible. In their indexical task-scapes and small-group interactions, communication via gesture-calls exploited the capacities of indexical listening, as many animals do, including for example, present-day chimpanzees.

For structural listening, we have to distinguish two "modes": first, what I would term "proto-structural" listening, and second, "true" structural listening. On the one hand, there is evidence that a couple of nonhuman animals like whales, primates, and birds (see e.g. Kreutzer in Dokic *et al.* 2018) can listen structurally and detect semiotic patterns (Kohn 2013) in sounds. This can also be achieved in a non-symbolic world, before any leap to symbolic abstraction would occur. True structural listening,

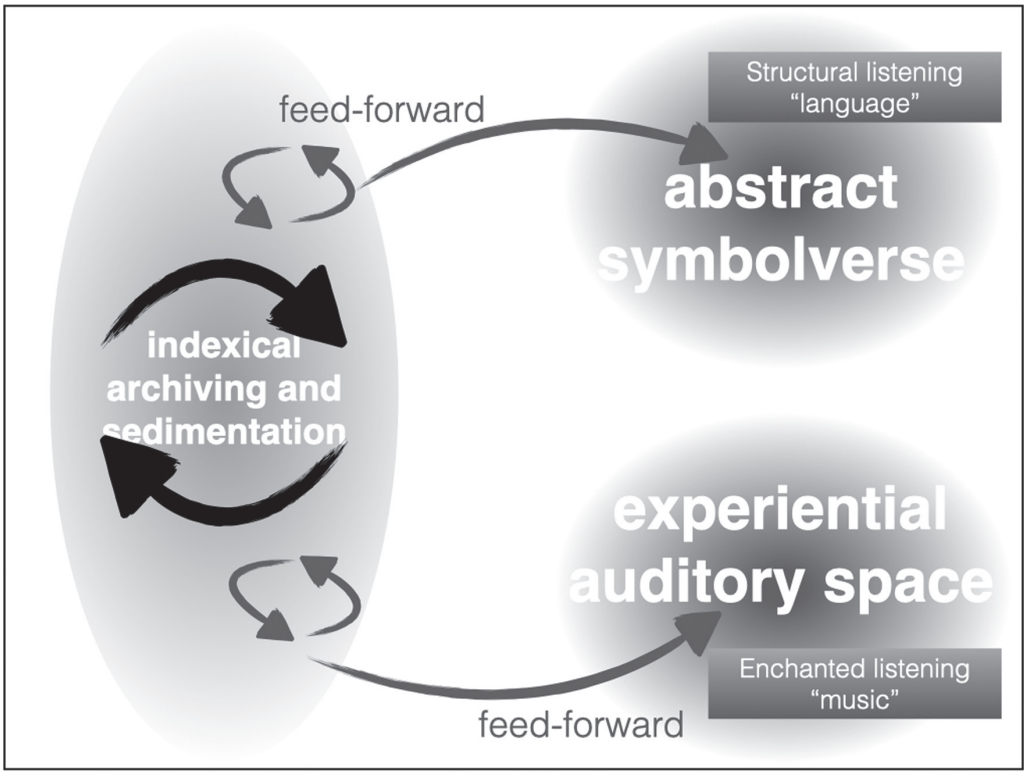


Fig. 2.2: The epicycles of proximal and distal interaction respectively feed forward into the emergence of an abstract symbolverse and an experiential auditory space.

on the other hand, would then only emerge when communication left the mere indexical mode and "jumped" to the opening up of the abstract symbolverse, following Tomlinson's "shift" that remained somewhat opaque. Proto-structural listening, in its most basic form of increased hyperindexicality, may have the potential, in the case of massive sedimentation of intergenerational archives, to "jump", or "shift" into abstraction. By analysing only structural listening (thus focusing on the emergence of proto-languages), it seems that we cannot find the "missing link", the point when and why this "shift" happened in human-environment interaction. It seems that there is a lack of instances in the environment that would afford this structural "leap" into abstraction. But there are sound-enchanting entities around, disembodied sounds that are in need of a body. Enchanted listening is the only mode left that could lead us to a bridge between indexing and symbolising.

Enchanted listening and the peopling of the environment

Early humans could hear frogs croaking, tigers gnarling, and other sounds that more or less clearly index their source. But they could also hear "special" sounds, disembodied

sounds that lacked a detectable source. Let us call them "uphonia", no-sounds. Such uphonia refer to echoes, resonances, wind howling, or things one hears when listening to a waterfall, for example. Try to sit beside a waterfall and listen for an extended span of time: you will probably hear "things" in the noise (Vercammen *et al.* 2007; Schepers *et al.* 2019). Echoes are very easy to understand if one has a sonic-wave theory available, but extremely difficult to assess if one lacks this theory: one makes a sound and "somebody" repeats it. "Somebody" reacts to any sound you make. Similarly, wind howling in certain places is easy with the turbulence explanation of sound generation (flutes exploit the same effect), but quite enigmatic only through observation. There are certain special places with fascinating resonance effects, especially caves and shelters (see Rainio *et al.* 2018; also Díaz-Andreu *et al.* 2023; Valenzuela *et al.* 2020). The cave acoustically analysed by Rainio and Hytönen-Ng (2022) "answers" with a high pitched "ringing tone" to repeated stimuli like clapping.

Another form of "special" sounds could have been what Bregman (1990, 459) termed "chimeras": emergent properties of two or more sound sources that accidentally or intentionally sound together and create the impression of one sonic event (in music, chords are a good example for such chimeras). In terms of auditory scene analysis, this would actually be a failure, because a grouping is constructed that suggests one source, while in actuality there are two or more sources. Bregman writes that in environmental orientation, chimeras should be detected and avoided, but in music they are paramount:

> Natural hearing tries to avoid chimeric percepts, but music often tries to create them. It may want the listener to accept the simultaneous roll of the drum, clash of the cymbal, and brief pulse of noise from the woodwinds as a single coherent event with its own striking emergent properties. The sound is chimeric in the sense that it does not belong to any single environmental object (Bregman 1990, 459–460).

Such chimeras, composite sonic events, could likewise have suggested to early humans that there was another sound source ("somebody") that could not be detected in the environment and therefore, its nature appeared as disembodied as other uphonia. Most uphonia would require specific places (e.g. echoes), while chimeras appear tied to specific times: some chimeras come together quite regularly (like a roll of thunder plus howling winds), others only in specific temporal overlaps (like animal calls that sound together). Uphonia can be provoked or intensified when listening for chimeras during special times at the above-mentioned special places.

It is very probable that archaic humans experienced such disembodied sounds on a rather regular basis. Uphonia could not be linked per index to a source (like a frog, cat or tiger), because there was none around. Perceiving a frog croak creates a pointer, an index to an existing frog; hearing a tiger's gnarling points towards an existing tiger. Perceiving uphonia, however, during The Indexical Age (Tomlinson's term) created pointers, indexes, but they pointed into void. Other animals may likewise hear such sounds, but they have not amassed indexes in the way humans had done, they lacked the sedimented archives enabling hyperindexicality. Tomlinson

(2018, 78) calls thus the "in-between semiotic practices where indexes themselves take on some degree of systematic organization, even though they do not wholly depend on it for their semiosis", that is, an organisation of communicative abilities that are not (yet) symbolic, but allow for complex index-based interactions. Among a society endowed with such complex indexical abilities, an index that points from an auditory experience to void would probably urge the listener to accomodate it within the systemic organisation, so to consequently index "somebody". In the moment that there "might be something" responding to my sounds in echo, or emerging from the waterfall's white noise, enchantment is born. The experience can easily be shared among a group of early humans, because uphonia can be perceived, imitated and shared among them, still without requiring symbolic capacities. The shared experience of the enchanted sound creates a target for the index, a "sonic being" (Stoichiță and Brabec de Mori 2017, 34) whose existence can be agreed upon. We should not yet call it "spirit" – just some entity that is there.

The enchantment, consequently, can be produced (e.g. echoes, resonance) or re-produced: humans could "summon" the being by imitating the sounds, either at the place, or elsewhere. When howling like the wind, the wind-entity comes into being. When one individual answers with clapping to another individual's clapping, the echo-entity becomes present. Here we have the space that does not directly coincide with the visual-tactile space of the environment but wherein beings exist; beings that are perfectly experiential without prior abstraction. By recognising these beings in their space, however, abstraction occurs as a result: a space is created, an auditory space that houses sounds that only "exist on their own".

Through performance of such disembodied sounds (clapping, howling, ringing) humans intentionally created what Bregman called auditory chimeras. The sonic beings can be summoned at other places, they can be "taken away"; they can be transferred to any place that may or may not resemble the place of origin, the place where these sounds could be heard in the first place. They can also be transferred in temporal distance, and at points in time when chimeric sounds would not occur "naturally". They can be (re)produced by humans. More places and times in the environment can be peopled with entities that are invisible but experiential in the auditory domain.

The world, the wider environment, thus enchanted and endowed with an abstract layer of potential sonic beings around may then, finally, trigger what archaeologist Clive Gamble called the "release from proximity" (Gamble 1998, 440). Gamble suggests that the release of interactions from relations in necessary co-presence into larger extensions in space and time defines one important predictor of human modernity. Interactive co-clapping at a non-echo site mimics the echo-entity, and enchants the site with its auditory presence. Experiencing the echo-entity when no echo is around enables humans to predict an existence, to lay the grounds for "thinking-at-a-distance", it creates the space required for imagination and abstraction.

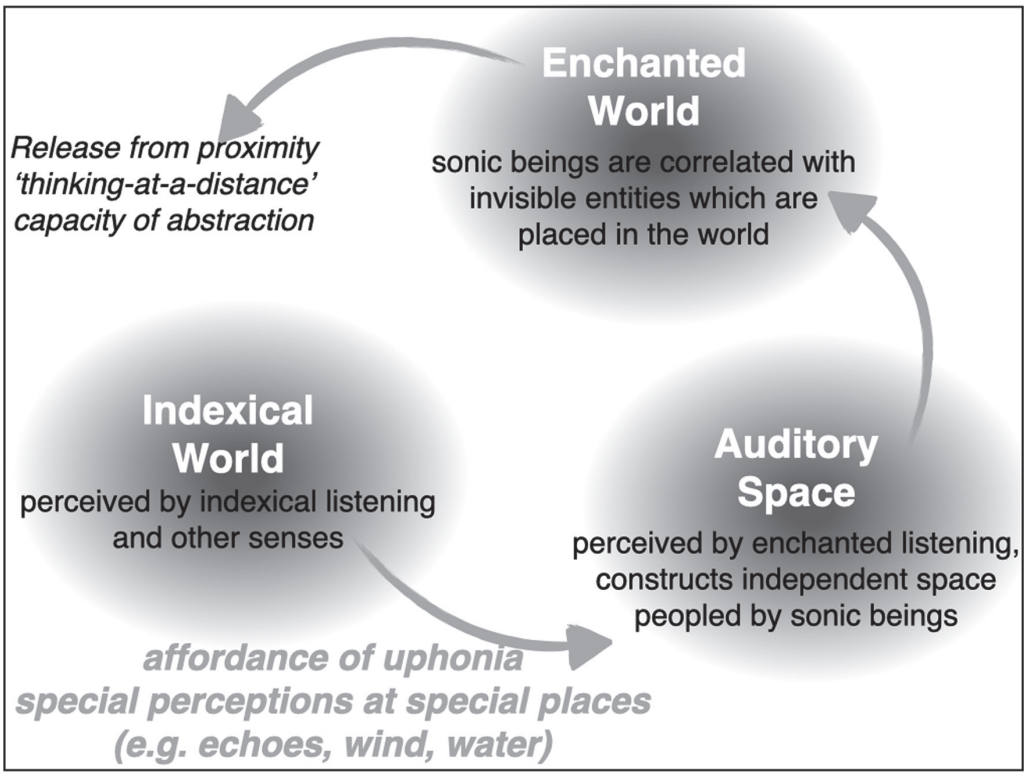


Fig. 2.3: Detail of the distance-epicycle from Figs 2.1–2.2. Affordances of uphonia make listeners create sonic beings that only exist in an auditory space. This space overlaps with the environment and results in release from proximity.

The world is now open for indexes that point somewhere imagined, for the first inklings of symbolic enactment (Fig. 2.3).

By mimesis and repetition of these sonic beings, sedimentation takes effect in the same way as it did with the indexical archives, and pitch, duration, and timbres become shared among the group and ritualised, so that sonic beings reproduce. The experiential auditory space sediments into a transcendental sphere, an invisible layer on the world that is peopled with its invisible entities. Thus, the prior indexical world increments, receives a layer of abstraction, new potential for new indexes that maybe point to other indexes. Abstraction and symbolic thought are made possible – through the agency of disembodied sounds in the experiential environment (Fig. 2.4). The indexical world leaps into a symbolic world. This "leap", although spectacular in description, may have passed unnoticed. The "shift" from the merely indexical to symbolic interaction with a world newly populated by metaphysical beings appears tiny in practice. It will be noticeable only later, when the archaelogical record starts displaying markings at places, symbols on bodies, or first musical instruments.

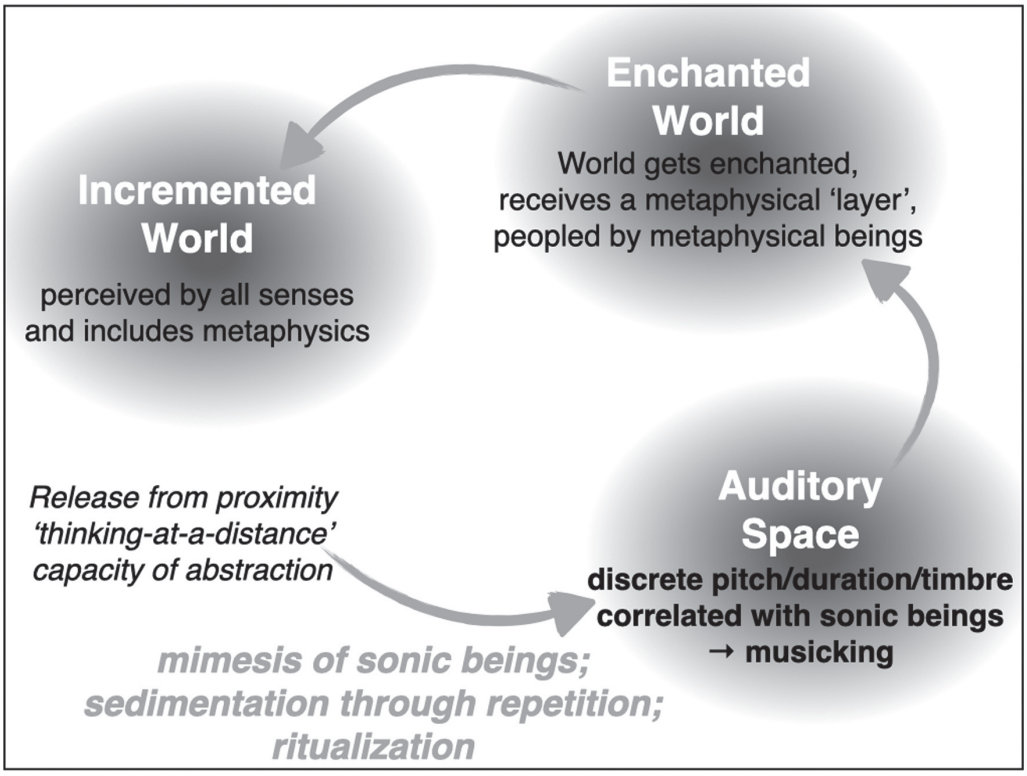


Fig. 2.4: Detail of the distance-epicycle from Figs 2.1–2.2. Following the release from proximity, the sedimentation of mimetic interaction with the beings in the symbolic world feeds into discrete pitch and duration: proto-music that by its execution peoples the world with sonic beings.

Conclusion

Potentially, the enchantment of the environment with sounds took place before phonemes could reach the point of opposing each other and pointed to discrete morphemes as symbols, because the latter requires abstraction while the former results in abstraction. I would not, though, argue that language emerged from music, but keep the common predecessor of sign-sounds, or gesture-calls. In a parallel way, indexical interactions sedimented into proto-structural systems (Tomlinson's hyperindexicality) while the enchantment of the environment occurred, as has been argued above, due to the enchantment of listening to special sounds. This was long before mimesis and repetition resulted in the sedimentation of something resembling music (with discrete pitches and durations that relate to each other). Here occurs the early bifurcation of the modes, or postures of listening that are prerequisite for the emergence of language and music. The enchanted posture created new beings and a new, abstracted layer of the world. The structural posture of listening could then pass from indexical (proto-structural) to symbolic (true structural) systematisation of the perceived. Symbolic structural listening could thus exploit the capacity of abstraction and the "thinking-at-a-distance" in order to enable humans to develop proximate, inner-group modes of understanding.

These inner-group modes of interaction (proto-languages) would be hard to understand for outer groups; they could even deliberately use symbols unknown to outer groups in order to protect proximity. Contrastingly, the enchanted modes of interaction should be shared, not only by members of the same group, but also by inhabitants of the outer world: other humans would similarly recognise mimicked echoes, winds or waterfalls and share the peopling of an enchanted, incremented auditory layer of the world.

With that, the "missing link", the "shift in cognitive capacity that remains opaque [...] already 200,000 years ago" (Tomlinson 2018, 171) can be filled in. Humans started to create beings in what we would call imagination when they heard the disembodied uphonia and auditory chimeras at special places and times. These sounds pointed into void because the world was still purely indexical. By creating "somebody" or "something", by imagining entities as invisible sources of these sounds, humans invented enchanted listening. This posture of listening *adds* something to the perceived sound, enchants it with an entity in its own right. This entity, however, can be experienced and shared in the collective and thus is apt to trigger the "shift", the transition into the symbolic age, into human modernity.

The first task for the niche construction that is necessary for bringing "other worlds" into being is listening to uphonia, the no-sounds that can be heard, experienced, and shared. By hearing something that has no "material" (visual-tactile correlate) index, a link to an invisible, or potentially absent being is created. Absent animals, absent friends, deceased persons can possibly inhabit the auditory domain; by mimicking and repeating uphonias, early modern humans entrain to "summon" these beings and to people an imaginary world with them. Through the sedimentiation of mimesis, repetition and entrainment, new habits (most often called rituals) are then shared inside and especially outside of the group. Utterances form discrete pitch-duration-timbre systems and are thus detached from individuals' current emotional or social states, but become communal utterances: proto-musicking.

This explains well why music and other modalities of formalised sounding are so closely linked to the metaphysical. The metaphysical was "listened-into-existence" at the same time as listening to (metaphysical) uphonia resulted in the potential of proto-musicking. The entities of the environment: rocks, caves, water, wind afforded to archaic humans to be recognised as such and to be brought into their auditory, and consequently transcendental layers of reality. These layers enabled the symbolic faculty and opened the world to be filled with words and other meanings. It would be possible to argue that it was not the early modern human who invented music, but it was music that invented modern humans.

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Notes

1 For further discussions on Descola, and treating the claims and problems of ontological anthropology see e.g. Holbraad and Pedersen (2017), Heywood (2018), among others.

2 In many non-modern societies, it is perfectly intelligible that animals, from their point of view, experience themselves in their environment like humans do in theirs; see the theory of Amerindian perspectivism as formulated by Tânia Stolze Lima (1996) and Eduardo Viveiros de Castro (1998).

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Chapter 3

Archoustemology and the Aurignacian: Ancient ways of knowing through sound

Simon Wyatt

Abstract

The sophisticated aerophones of the Upper Palaeolithic represent the culmination of a long development. But a serious problem for the music archaeologist is the nature of the remains, which even in the more durable material of bone or ivory are commonly fragmentary. Yet, the surviving evidence does provide some interesting lines of enquiry, if we consider the perspective of acoustic studies of aerophones. Such explanations are based on cylindrical and conical tubes; not on the non-uniform bore of bones. However, several acoustic factors are intriguing, given the nature of the finds: how they were made, and the original dimensions of the materials used. Furthermore, if we consider that the surviving form of the aerophones was intentional, it may imply a well-developed tradition and acoustic understanding that supports the claim for sophistication. This discussion is presented against a backdrop of double description, a model presented by Gregory Bateson to create a deeper form of relational knowledge, with the aim of combining cultural, ritual, ecological, psychological and musical aspects of the past. This being the case, I propose the use of the term archoustemology, a combination of archaeology and Steven Feld's acoustemology: acoustic epistemology. The narrative here explores the relational nature of epistemology through the lens of neuroscience. It then examines the relational ecology of the Aurignacian before examining the acoustic nature of the aerophones. It is suggested that each of these three perspectives represents a small part of the epistemology of the self.

Keywords: archoustemology, Bateson, Feld, self, agency

Who is the third who walks always beside you?
When I count, there are only you and I together
But when I look ahead up the white road
There is always another one walking beside you
(T. S. Eliot)

Caminante, son tus huellas
El camino y nada más;
Caminante, no hay camino
se hace camino al andar
(Antonio Machado)

Introduction

The British anthropologist Gregory Bateson made many far-reaching observations in relation to how minds, cultures and environments interact. Primarily, a unit of classification is a unit of difference: a unit of information (Bateson 2000, 459). In addition, the evolutionary "unit of survival", and thus for us, the unit of interest, "is a flexible organism-in-its-environment" (Bateson 2000, 457). For Bateson the nomenclature we use, based upon our recognition of specific characteristics – derived from embodied interactions between our senses and the world – affects our very perception of that which is classified, and subsequent interpretations (Bateson 2023, 189). At the same time, any attempt to comprehend a living context requires us to embrace as many facets of its ecology as we are able.

With this in mind, it may be beneficial to situate the field of Music Archaeology within the broader scope of Archoustemology. This label is developed from Steven Feld's concept of acoustemology (Feld 1996, 96–98; 2015, 12–19), which combined the terms acoustic and epistemology, implying a way of knowing through sound. Feld made clear that this approach is relational and, despite the use of the term acoustics, the knowledge is intended to be synaesthetic, and he specifically argues against sonocentrism (Feld 2017, 84, 87; see the conversation between Tom Rice and Steven Feld (2021)). By prefixing the concept of acoustemology with arch, we have the nod to the Greek word *archaeo* (ancient), but also *arch* (primary), the latter producing, I think, a more pleasing metre.

One final point on a relational epistemology comes again from observations by Gregory Bateson. His model of research, termed double description, is analogous to binocular vision. Each human eye transmits only two-dimensional data to the visual cortex, where we construct our perception of depth (Bateson 1979, 69–70, 87; for discussion see Harries-Jones 1995, appendix 4, and Hui *et al.* 2008, 77–92). Bateson suggested that any subject presented in two or more formats produced analogous extra depth: deeper knowledge. Another such occurrence of double description is the beat produced through the interference of sound waves. The beat, heard by the listener when sound waves interact, does not exist in either of the two sources, but is the result of interaction between them. Bateson presents this as a sonic analogy for

binocular vision. It is also a phenomenon embraced in the musics of many societies. Similarly, our perception of self, constructed from memory and the senses that modulate each other, is such extra depth. Subsequently, no perspective is either final or reductionist: understanding is found in the conjunction of models.

We shall explore three wide-ranging points of a relational nature: the relationship of experience to sound, agency and self, the relationship of self to ecology and the relationship of artefact form to acoustics. It all comes down to how we know anything, our epistemology, and with this in mind, we begin by examining the logic of an archoustemological model.

From music archaeology to archoustemology

Over the years, alternative names for the field of Music Archaeology have been proposed, dependent upon the different emphases given, whether the priority has been Archaeology, Musicology, Organology or Acoustics, to cite a few examples (e.g. Megaw 1968; Scarre and Lawson 2006; Both 2009). In this context, a key component has always been experimentation (Lund 1992, 173–174; Lawson 2010, 270; García Benito 2011; Ringot 2012; Wyatt 2016a; Gill 2020, 70–81; Megaw pers. comm.). Subsequently, the Phenomenology of Soundscape has pondered how we relate to sound, and more recently a Psycho-archaeoacoustics has developed (Jiménez Pasalodos 2011, 443; Valenzuela *et al.* 2020, 3). Together these may be considered a neuro-phenomenological approach.

The scope of Music Archaeology is generally considered to begin with the earliest humans who left behind traces of musical behaviour (Lund 2012, 61). Yet, it is clear that evolutionary adaptations within the fossil record are of equal importance, and biological abilities to refine vocal expression are found in Homo erectus (Morley 2013), and as early as Ardipithecus ramidus (Clark and Henneberg 2017). Here I take the position that musical behaviour, and indeed musicality – the foundational ability enabling such activity (Trehub *et al.* 2015, 1–2) – is closely related to ritual and originated in "the ritualisation of ordinary behaviours which have become formalised, exaggerated and repetitive" (Rappaport 1999, 26, 33; for further discussion see Dissanayake 2006, 36, 43–46; Keller 2013, 7; Krueger 2016; Gill 2020, 62, 73). Rituals are segmented and have no overt meaning, but are largely symbolic and consist of bottom-up – perceptual, attentional and memory – input combined with top-down processing involving interpretation that reaffirms purpose. They balance emotional and social states (Hobson *et al.* 2017, 261, 263). On the point of symbolism, Kartomi (1990, 4) noted that in indigenous societies classification of an instrument may depend on the context of use, and that while some cultures may have several classificatory schemes in use for musical instruments, the most symbolic system is often the most representative of the culture (Kartomi 1990, 12). Furthermore, it is feasible that musicality and rituality among our early ancestors manifested as a relational response not only to other humans, but also to the other creatures, other-than-human beings,

in a shared environment. Consideration of the emergence of song and speech may provide insight into contemporary vocalisations in the liminal, ritual space between song and speech. Bernd Brabec de Mori (2017c) explores the meanings found in acoustic behaviour from the viewpoint of the listener (see also Stoichiţă and Brabec de Mori 2017). Their model – Postures of Listening – identifies three distinct forms of auditory perception. Indexical listening provides knowledge of the environment, its inhabitants and perhaps the inner thoughts of a sound source. Structural listening is similar to hearing a code, where sounds superfluous to the meaning play no part and are ignored. Enchanted listening layers properties, implicit in the listener, onto an acoustic experience (Brabec de Mori 2017c, 119) in the hope of communicating with the environment, its inhabitants and spirits (Brabec de Mori 2017c, 123). Multimedia "tricks", employing strange timbres and costumes, enhance such a listening posture. Perhaps here we find a parallel for Bateson's double description where the postural interpretation and the sound source are combined to create a transcendental depth: an enchanted acoustic space. Such ritualisation, as a form of patterned behaviour, stabilises the fragile identity and reinforces the relationship of self, society and environment (Mol 1976, 65 and 233). It is due to this broad perspective that I am drawn to Steven Feld's acoustemology (1996; 2015; 2017) as a basis for the interpretation of sound in the past.

Acoustemology originated in a dissatisfaction with previous paradigms, which failed to consider non-human sound, environmental acoustics and the technological mediation (Feld 2017, 84). Other overlooked features included language and poetics. Feld is arguing for the role of recording music when talking about technological mediation, but here I take the liberty of considering that technological mediation is any use of technology to further our knowledge, such as the use of recordings to analyse the acoustic features of a place and the use of neuropsychological procedures to examine the effects upon the mind. Feld sought to interrogate how the dynamism of sound was able to index social immediacy (Feld 2017, 84), and this relates to perceived agency. The nature of non-human agency has gained a prominent role (e.g. Viveiros de Castro 1998, 476), and there are clear parallels in the recognition of human-like qualities, or detected agency, within organised sound and art (Gell 1998; Watt and Ash 1998; Robb 2004; Krueger 2016). An interesting example of how art may act as an agency cue is examined by Krátký *et al.* (2016), who discuss the placement of eye-imagery that seems to be unconsciously interpreted as an intentional agent, resulting in an increase prosocial behaviour. This is intriguing given the examples from prehistory of pottery or stone plaques with painted or engraved images resembling eyes. If music may be perceived as a person or agent then perhaps we should expect similar effects.

Feld's analysis of the Kaluli people revealed a relationship of immense depth. For the Kaluli, sound signifies the time of day, or season (Feld 2012, 11; Rice 2018, 2), but simultaneously has an entangled relationship with the birds of the forest. Feld makes the case that while sound communicates through socially organised

acoustic patterns (Feld 1991, 79), this is a system that manifests at the intersection of cultural and acoustic analysis. We shall find below that it is beneficial to include a further level of analysis to this mix – that of neuropsychology. For the Kaluli, birds were believed to be spirits calling with ancestral voices, and their song was reflected in the Kaluli music. The singer's voice was often heard as that of a bird, and subsequently an absent relative. Indeed, the Kaluli drum was also deemed to sing with the voice of a bird, and a *tibodai* was caught and its feathers, throat and tongue placed within the wood of the drum during the long process of construction. The accompanying invocation sought to bind the voice of the bird to the drum (Feld 1991, 86). At the same time, the flow of song acted as a mnemonic for the spiritual and social construction of place, while also reflecting the confluence of sound and the riverine environment (note that Fiona McGowan (1994) identified a similar relationship where the Yolgnu of north-east Australia related rhythmic elements of music to specific riverine currents). Among the Kaluli, the classic myth of the Muni Boy constructs these relationships within a narrative of kinship and expected social behaviour. Use of the four descending notes, the Muni bird song, is perceived as an ancestor's voice. Music was an enmeshed phenomenological reflection of the acoustic pattern of the forest.

Archoustemology expands Feld's model for its use in the past, where no ethnography is possible. It does so by embracing the technological mediation of research in archaeoacoustics and engaging with neuropsychological perspectives as part of the relational repertoire required to understand the self. Here, archoustemology also follows Feld's thought in that it is not sonocentric and understands that experience of an embodied self is not a manifestation of any single sensory form, but an integrated relational construction (Feld 1996; 2015; 2017). Applying the term archoustemology presents a foundation of knowing through sensory engagement, this is wider than just music or archaeology, encompassing broader approaches of neuroscience and ecology (compare this to similar proposals for a multidisciplinary approach by Morley 2014; Blake and Cross 2015; Van der Schyff *et al.* 2022). Archoustemology is no replacement for Music Archaeology but a frame within which to set it. With archoustemology set to frame an ancient way of knowing through sound, we begin our double, or multiple, description, by articulating exactly how we know in any form: our epistemology.

Archoustemology and the self

Bateson held that "epistemology is an indivisible, integrated meta science whose subject matter is the world of evolution, thought, adaptation, embryology, and genetics- the science of mind in the widest sense of the word", it is also "always and inevitably personal" (1979, 87). Similarly, archaeologist Gordon Childe (1956, 54–56) wrote that the shared pattern of knowledge is constructed through sensory perception in our heads as a representation of the external world and it enables people to act

within the world. We perceive that which society has taught us to perceive. My point in citing Childe is that he, like Bateson, was clearly writing about a sensory approach to knowledge and was a forerunner of today's approaches within archaeology and anthropology (e.g. Hamilakis 2015, 3). Feld (2012, 45) supported essentially the same view: "Knowledge is something more: a method for putting a construction on the perceived, a means of scaffolding belief systems, to guide action and feelings." All research is a quest for knowledge, which is constructed in our heads from sensory perception (Feld 2012; Wyatt forthcoming). The ability to act upon any such model of the external world based upon sensory integration validates the reality of the perceived relationship of subject and object, and our sense of agency (Childe 1956, 54; Cashman 2008; Beck *et al.* 2017). A working epistemology requires the ability to predict any change in the model (Childe 1956, 68; Bateson 2000, 412; Seth 2021, 112–113). In this manner, knowledge exists as a relational marriage of the self and the environment, both past and present.

At a practical level, each sense modulates the others; thus, vision affects our hearing, hearing and olfaction affect tactile sensations and so on (Guest *et al.* 2002; Invitto *et al.* 2019; Chen and Spence 2022, 465). This being the case, although a culture appears to give precedence to one sensory form, all senses contribute to perception. Furthermore, if two stimuli are synchronous, that is within 250 ms, neuron activation is enhanced, and they are processed as one stimulus (Occelli *et al.* 2011, 431–432). Conversely, experiments have shown that a temporal lag between action and perception of melody, between 100 and 400 ms, diminishes one's sense of self-agency (Couchman *et al.* 2012, 189–190, 193). The counterpart of synchrony is asynchrony, which leads to sensory disintegration, beginning with a loss of self-agency. Rhythmic sound enables the neurons to entrain with an external rhythm, firing in synchrony with the external sound, and other participants. So, while entrainment and synchronization drive sensory integration and consolidation of the self, they simultaneously promote group bonding or merging (Adler *et al.* 2014; Tarr *et al.* 2014; Trainor and Cirelli 2015, 45): other group participants come to be processed, and in a sense perceived as part of the self. However, it should be noted that a sound, heard synchronously with a visual prompt, may be experienced as though it originates at the point of the visual stimulus. Conversely, a flash may be experienced as synchronous with a sound when it is not: time and space are somewhat malleable (Chen and Vroomen 2013).

Any discussion of sensory modulation should include recognition of cross-modal adaptation, such as when a feeling of warmth increases interpersonal warmth (Williams and Bargh 2008, 606–607). Ackerman *et al.* (2010) examined the effect of tactile sensations on perception, highlighting associative links between structured concepts and sensorimotor events meaning that touch triggers tactile conceptual processing. This results in rough tree bark equating with metaphorical roughness in motion, emotion and consciousness of temperature and space. While I know of no research exploring whether warmth affects sensory integration, it is likely that

there is a personal parallel for this effect. This is hinted at by the experiences of a sensed presence in extreme environmental conditions, where the temperature is one of the factors affecting the individual (Suedfeld and Geiger 2008, 7) (The lines from T. S. Eliot's *The Waste Land* cited at the opening of this chapter recall Shackleton's experience of sensed presence under extreme environmental conditions). This point has relevance here, since the Aurignacian was somewhat cold, and we must assume that the harsh conditions of the Upper Palaeolithic played into the cross-modal sensory perception of sound in the past, and its role in the construction of the self. Indeed, we find a reversal of this chain of events in the laboratory, where alteration of bodily self-consciousness causes widespread physiological changes, including a decrease in skin temperature (Salomon *et al.* 2013, 1, 9–10). Furthermore, Iain Morley (2013, 270 citing Blood and Zatorre 2001) noted the relationship of musical chills with the reward response. Given the recursive, relational nature of perception, and the fact that music also affects emotions and subsequently body temperature (McFarland 1985, 255; Panksepp and Trevarthen 2009, 124), it is likely that a situation which lowers body temperature has a knock-on effect on bodily self-consciousness. Might we even consider that the extreme temperatures during the ice ages drove sensory disintegration, sensed presences and the development of religious explanations? A practical example of the sensory modulation of spatial awareness is given by Feld, who observed that, for the Kaluli, adaptation to a forest environment helped develop "acute spatial skills for audition" (Feld 2012, 62). He further noted that performance of *gisalo* (emphasised lament) is carried out in darkness, which may suggest that the environmentally driven perceptual bias was deliberately engaged with during ritual practice (Feld 2012, 180). Was a similar affect sought in Palaeolithic caves?

Having emphasised the interconnectedness of the senses (for a longer discussion see Wyatt 2014; 2016a; forthcoming), we ought to note that such modulation is also driven by cultural ideas: our cultural model of reality acts as priming, which has an additional effect on individual sensory percepts. We are, in a sense, *taught* by our cultures which senses to focus on and which percepts are important (Childe 1956, 54–56; Haggard *et al.* 2003, 170–173; Bergson 2005; Blanke *et al.* 2008, 448; Adler *et al.* 2014, 68; Howes and Classen 2014; Hamilakis 2015). Bateson also considered the role of belief within discussions of perceptual processing, where he identified a distinction between what we may consider a type of perceptual or culture bias and the belief of the individual in that cultural bias (Bateson Notebook 16/1953 cited in Harries-Jones 1995, 132). We do not perceive what is in the world, but what we use to act. Our model of the world changes based on the modulation of all senses, our memories, cultural concepts, environmental conditions such as temperature and humidity and also suggestion and belief. The role of belief affecting sensory processing has been discussed by Schjoedt *et al.* (2013), while Cohen *et al.* (2014) explore the manner that belief and priming alter the effects of music on numinous experience within an experimental setting (see also López-Mochales *et al.* 2022, 3).

Generally, we may say that the spatial plane is dominated by vision and that the auditory sense drives the temporal characteristics of perception, yet both these processes are modulated by conceptual priming (Haggard and Chambon 2012, 391; Tiipana 2014, 1–3). By conceptual priming it is meant that an idea or suggestion, either a deep seated cultural concept or perhaps a clever advertisement, is able to affect one's perception and thus reaction in any given context. The root of the matter is that, in the context of a discussion on perception, there are no raw data: at a fundamental level everything we perceive has already been modulated or manipulated by other senses, environmental context, culture, belief and memory. The integration of sensory perception is relational on multiple levels: neuronal, temporal, spatial, ecological, cultural and spiritual: it blends top-down and bottom-up processing. Such complex modulation by the senses and cultural driving has strong parallels with Bateson's concept of meta-communication (for a discussion on this see Harries-Jones 1995, 135). Since our very perception is relational, and such perspectives are found within anthropological and archaeological interpretations (Viveiros de Castro 1998; Bird-David 1999; Bateson 2000, 454–471; Hussain and Floss 2015, 86), it is fitting that there should be a more explicit recognition of this within the study of sound. This is particularly true since rhythmic behaviour, be it musical or ritual, acts as a driving force in the synchronisation of the senses and as a stabilising factor for the construction of the self (Wyatt 2016a; forthcoming).

So far, we have contended that any combination of music and archaeology is part of a broader exploration of the self related to musical rhythm and entrainment (Clayton *et al.* 2004), which, like ritual, has a cohesive effect (Lindenberger *et al.* 2009). Beyond these observations, we inevitably ask what are the experiential effects that music may have upon us. One line of enquiry worth pursuing is to explore why people react to music as though they are responding to a person (Watt and Ash 1998; see discussions in Wyatt 2009; 2016a; forthcoming), or virtual partner, on whom they are able to offload various aspects of thought: perhaps as an intangible form of external, symbolic storage (Donald 1993, 269; Watkins 2004, 12; Krueger 2016). Brabec de Mori (2017b, 186-187) discusses a parallel situation where agency is attributed to sound, observing that this occurs solely within the act of listening. Brabec de Mori, citing Gell (1998), writes that it occurs when the infinite causal chain is broken and a "beginning" is attributed to an individual entity. For example, when we hear a recording of white-noise or the sound of a vacuum cleaner it is possible that we interpret any perceived patterning in the structure of the sound in a meaningful way. Although there is no external sentient agent producing this structure, we may feel that we recognise any patterning as though it has a deliberate source (see also Stoichiță and Brabec de Mori 2017). One explanation for these responses to sound, where we find pattern of our own making, is based on the ability of music to trigger motor cortex regions which prepare us for mimicry

(Overy and Molnar-Szakacs 2009), and relates to agency- and empathy-detection. It is likely that such sensations have a multifaceted explanation (Tarr *et al.* 2014), for example, endorphins released through action and music are thought to have an important contribution to this effect and our propensity to sense agency in sound. Although the discussion in Chiao and Blizinsky 2009 examines different endorphin effects within different global populations, and this suggests that we must be wary of generalisation on this subject.

Here we shall focus on the issue of sensory disintegration. This occurs when senses are asynchronous, resulting from a temporal lag between an action and an effect. Such occurrences may result in a loss of agency, disintegration of self and a sensed presence (Blanke *et al.* 2014, 2682). Such incidences occur naturally in childhood, in extreme environments or during bereavement, and are likely to be the source of numinous experiences. The ubiquitous nature of lamentation seems to be a musical manifestation of such an experience, where ambiguous musical form and lyrics emulate the sensations of bereavement (Feld 1990, 241; Tolbert 1990, 82, 85–87; Wyatt forthcoming), for examples of ambiguity outside the genre of lament see Brabec de Mori (2017a, 2). Such musical anti-structure may continue to drive such experiences long after actual bereavement, and belief in such an effect and conceptual priming, drive it through top-down processing (Schjoedt *et al.* 2013, 47–48; Cohen *et al.* 2014, 10–18). Bearing in mind that disruption of self-construed agency occurs within a very small time-frame, between 100–400 ms (Couchman *et al.* 2012, 189–193), such acoustic features may cause sensory disintegration, especially when an individual perceives sound as occurring uncoupled from their own actions. An important observation then is that reverberation and EDT measurements recorded in the Songs of the Caves project coincided with this figure, ranging from 200 ms to 1500 ms (Fazenda *et al.* 2017, 1347).

In a recent article, Valenzuela *et al.* (2020) discussed an ongoing project exploring the effect of sound on the listener within a laboratory (see also López-Mochales *et al.* 2022). Recordings made in rock art shelters will be used, with control recordings produced in sites without art. The authors observe that there are some epistemological challenges to the project, and the comments here are intended to address these epistemological issues constructively. Indeed, I enthusiastically welcome their project as an inspired development in archaeoacoustics.

As has been argued above, the self is constructed through the relationships of perception, experience, culture, ecology and belief: this is an embodied self and rhythmic behaviour acts as a binding factor. Yet, despite musicality being a ubiquitous human capacity, within western societies it is a restricted practice (Blacking 1974, 4). Elsewhere, ethnographic research demonstrates that within many cultures all the individuals are musicants, and any examination of the effects of music should include, at the least, the perceived effects on the musician. At the same time, music "is or implies a social performance" (Trehub *et al.* 2015, 1) and while great insights

have been gained about sensorimotor and cognitive skills with engaged musicians or listeners, this has not examined "the significance of music for individuals, peer groups and communities, and for cultural evolution" (Trehub *et al.* 2015, 6). When examining the effect of music in the past we must consider the myriad of ways in which sound affects us, such as the release of endorphins (Tarr *et al.* 2014, 4), which may encourage numinous sensations, the promotion of efficient neural processing (Violante *et al.* 2017, 1–22), or encouraging altruism (Valdesolo and DeSteno 2011, 262–266) and happiness (Eerola *et al.* 2017). What is lacking in this list is a recognition of the value of group synchronisation and entrainment, and indeed the role of action and audition (compare this point to Overy and Molnar-Szakacs 2009, SAME – Shared Affective Motion Experience), beyond the role of passive listening. Thus, while the complexities of the effect of music on us are difficult to unpick, without a doubt some important features relate to social interaction and perception of self-agency. Indeed, recent research suggests that social interaction is the default mode of the human cognition and must be incorporated into future models of research (Hari *et al.* 2015, 190).

Consequently, I suggest that the experience of the musician making the recording *in situ* is crucial, if we are to come close to explaining the effect and value of music is past societies. Based on the discussion above, we may predict that acoustic effects would result in a diminished sense of self-agency for the musician, perhaps even giving rise to the anomalous experience of a sensed presence. Secondly, although laboratory studies have revealed significant insights, they lack the very real social impact of participation, and this factor needs to be taken into account. This is not intended to undermine the exploration of the acoustic effect: far from it, but to highlight the need to recognise the role of musician's perception, musician-to-musician interactions (Donnay *et al.* 2014) and musician-to-audience relationships (Hou *et al.* 2020, 7). This being the case, while the recordings may produce interesting results, I predict that they will not have the direct effect on the perception of one's own agency, which I have argued are bound to anomalous experience.

One last issue is that of the effect of total ecology. While we have considered the importance of sensory interaction for the construction of the self, and the social factors of performance, we must also consider total ecology; after all, we began this discussion with the assertion that information, the unit of classification, related to the perception of the individual within their environment (Fig. 3.1). This case is supported by the fact that experimental work within a natural setting has been shown to improve the participants' immersion in an experiment, and highlights that auditory input should not be thought of as the sole driving factor (Chabin *et al.* 2022). In the context of this discussion, the full effect ought to include temperature, humidity and the scent of the damp earth, rock and animal skins only possible in a cave context. To step even close to this ecology of mind portrayed by Steven Feld (Feld 1996; 2015; 2017), we must explore the relationships between people and their environment and the other beings that lived within it.

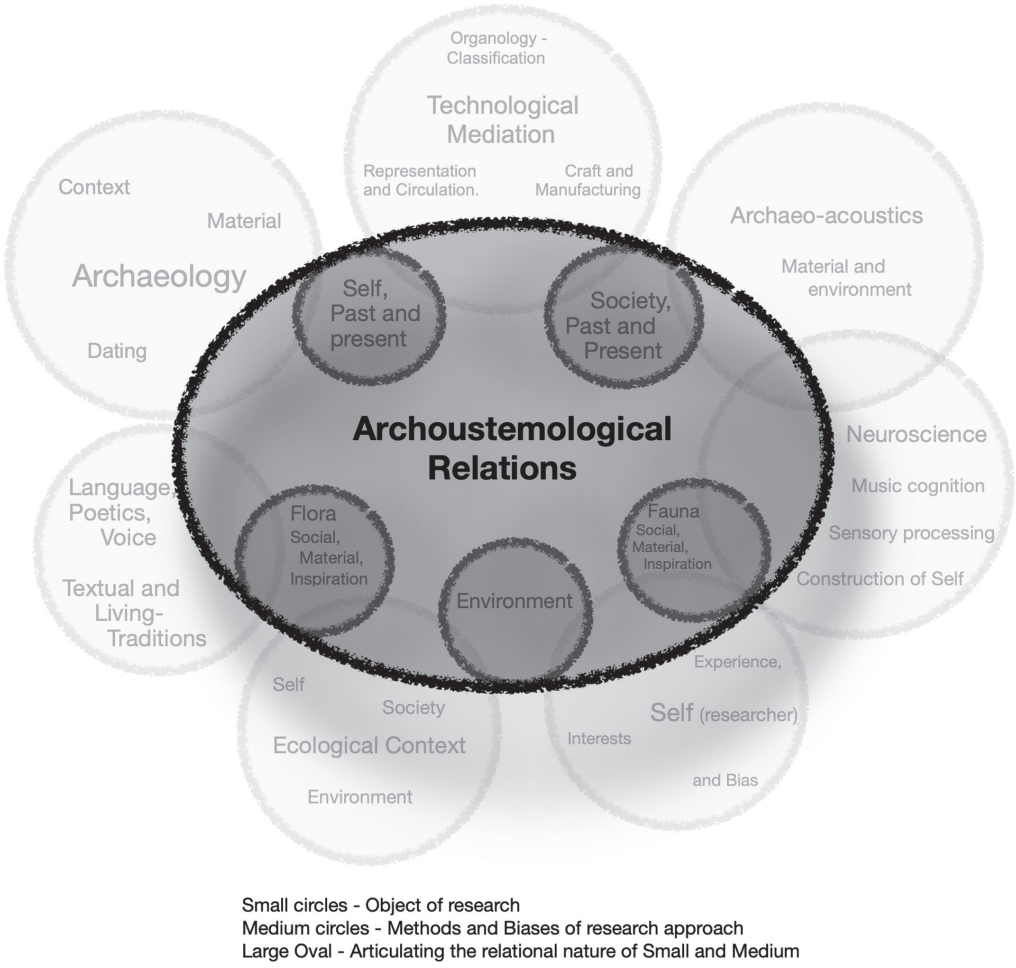


Fig. 3.1: Working draft of the interactions of archoustemology. Source: author's elaboration.

Archoustemology and the mammoth steppe

The following discussion relies on recent publications by Hussain and Floss (2015; Hussain 2018). Hussain employs the contextualism of Stephen Pepper, which he proposes is the sole method of making sense of entangled interrelationships of action, intention and purpose, which reach beyond the mere human (Pepper 1935; 1942, cited in Hussain 2018, 85). This is not a single event but is extended through space and time. We may compare such contextualisation to Bateson's (Ruesch and Bateson 1951, 229) view, where "context markers", perhaps non-verbal, set out the premises that enable unambiguous communication. So "'meaning' must also have a set of rules about how to relate part to whole in communicative contexts" (Harries-Jones 1995, 134; see Wyatt 2016a; Hussain 2018, 87). For our discussion, we

must consider multiple relational histories, the Aurignacian environment to the mammoth, the 21st century population to the elephant, the archaeologist to the past community.

Hussain and Floss (2015; Hussain 2018) challenge, therefore, any notion of human dominance during the Pleistocene and emphasise the marginal role of humans for almost all of evolutionary history. Our ancestors lived in an environment where animals were supreme: the Eurasian mammoth steppe (Hussain 2018, 88). Here, herbivores dominated both the visual and physical environment during the Aurignacian, and human consciousness was bound to this niche, a relationship mirrored in artistic expression (Hussain and Floss 2015, 87–88). Zimov *et al.* (2012) have estimated that 150,000 mammoths lived in Germany during this period, that is one mammoth to each square kilometre (cited in Hussain and Floss 2015, 87), in addition to 5 bison, 7.5 horses, 15 reindeer, 0.25 lion and 1 wolf. Comparing this to a recent estimate of between 900 and 3800 humans for the whole of western and central Europe during the Aurignacian makes for a stark contrast (Schmidt and Zimmerman 2019, 5)!

Animal dominance is recognised not only as a demographic phenomenon, but also in terms of ecological impact, which further "helps to decentralise the human in the prevailing narratives of the deep past". Hussain extrapolates that "human life is constituted not in opposition to, but through its connection with animal others" (Hussain 2018, 89; compare Viveiros de Castro 1998; Bird-David 1999; Bateson 2000, 454), where the world view of foragers was deeply reliant on the living habitat (Hussain and Floss 2015, 87). This tallies with our previous discussion of sensory integration. Ethnographic research is teeming with human-animal interfaces that inform an understanding of human use of animal resources. The concept of other-than-human-persons, as described by Viveiros de Castro, tallies with this model. Hussain and Floss propose that this perspectivism is ideally suited to explaining the Umwelt of the Aurignacian hunter-gatherers. On a physical level, mammoths were comparable to the Asian elephant, and their spiralling tusks made a unique visual experience (Hofreiter and Lister 2006 cited in Hussain and Floss 2015, 88). With a barren, glacial eroded landscape (Hussain and Floss 2015, 87), the Aurignacian perspective was diametrically opposed to the Kaluli visual experience. Like African elephants, mammoths profoundly shaped their environment, sculpting the land and even organising elephant bones (Haynes 2006; 2013 cited in Hussain and Floss 2015, 90). This behaviour includes digging or extending water holes, rooting for minerals and uprooting trees. Furthermore, their pathways enhanced human mobility (Haynes 2006 cited in Hussain and Floss 2015, 88, 91), while the sheen produced on rocks and trees, possibly to mark territory (Clapham *et al.* 2013, 1; Hussain and Floss 2015, 88), signalled such routes as much as human perception.

Beyond the mere physical mark, elephant social organisation mirrors that of humans, including personality traits (Kellert 1993, 91 cited in Hussain and Floss 2015). African elephant populations may suggest how a mammoth community

worked where adults live to 70 years within stable female-dominated family groups. This was juxtaposed by solitary, roaming adult males (Sukumar 2003, 170–184 cited in Hussain and Floss 2015, 91). They have a strong mother-infant bond, and an important degree of self-awareness, empathy and memory (Masson and McCarthy 1996; Sukumar 2003, 137–158 cited in Hussain and Floss 2015, 92–93). They share traits of intentionality, sociality and personality with humans (Hussain and Floss 2015, 92), and also have a range of distinct vocalisations conveying different messages. Hussain and Floss argue that these features drew "humans into mammoth agencies" (2015, 94).

Hussain and Floss (2015) further discuss ethnographies such as that of the Samburu of Northern Kenya, who work with the elephant-managed landscape and recognise individual animals and groups, going so far as to use terms reflecting the elephants' social organisation in relation to the human family members. Great respect is appointed to old females, and human-elephant groups have interacted for generations, framing the Samburu worldview. The Samburu use ivory for decorations, and dung and even the placentas are used in ritual contexts, but a dead elephant is treated with the deference given a human (Hussain and Floss 2015, 94–96). "Samburu cosmology rather speaks of elephants as ancestors" and relates that elephants "once lived in Samburu homes and worked closely together with their women" (Kuriyan 2002 cited in Hussain and Floss 2015, 96). Hussain and Floss argue that the human-elephant connection was a crucial adaptive interface where mammoths, as "proto-typical *co-dwellers*", shared our environment (Hussain and Floss 2015, 89). Mammoth behaviour mediated our own (Hussain 2018, 90).

This human-mammoth interface inspired the material culture of the Aurignacian (Hussain and Floss 2015, 98), manifesting in art as an abstraction of the mammoth theme. Further, this intimate relationship of culture and ecology, as we have established, was as important as sensory integration in the construction of a stable self and group identity. In line with this thesis, the fact that they chose to shape aerophones from mammoth ivory (Munzel *et al.* 2016; Hussain 2018, 91), when other resources, such as swan and vulture bone, were available speaks of the immense symbolic value of the material (Lawson 2020). Currently, the majority of upper palaeolithic bone wind-instruments were constructed from unidentified species (34) or unidentified bird (25). The most prevalent identified species used was the vulture (17), which may be Griffon or Lamergeier, but identification is difficult after the manufacturing process. Of the remaining materials used, there are presently examples of mammoth ivory (4), eagle (3), bear (3) and one example each of hare, lion and deer (data from Morley 2013, appendix table 1).

The Aurignacian people are known to have stored ribs and tusks as a resource, yet little evidence is known for hunting and butchering, although Münzel *et al.* (2017) have demonstrated that butchery may leave little evidence. Graeme Lawson (2020) observes that in the case of Geißenklösterle, as in many others, musical incentive pushes the forefront of technology. So we find a binding together of sensory and

ecological culture, and if we consider the model of Feld (1996; 2017), we must ponder the importance of the mammoth meaning behind their organised sound. Yet, while the mammoth held an important position, it was not the sole other inhabitant during the Aurignacian, and Hussain and Floss (2015) consider a similar value in the lion. To this we may add the vulture, which played a highly significant role in ecology and also in the material used for aerophones from the Aurignacian to the Magdalenian, and indeed beyond. See Wyatt (2016a), for a discussion of some of the differing symbolic values of the vultures in different cultures.

Musicologist Ellen Dissanayake has made much of the link between mother and infant vocalisation and the origins of human musical behaviour (Dissanayake 2006). In Wyatt (forthcoming), I have argued for a relationship between lamentation and the origin of song and religious experience, yet the validity of this relies on the mother-infant model as argued by Dissanayake: it is a recursive loop. Elephants are no less maternal, and recordings of calls between mother and child are of great interest,[1] where they display a range of timbre unlike the expected style of an elephant call, and perhaps reminiscent of the sounds produced through the Geißenklösterle artefact. Recent experimentation with bone aerophones played by sucking rather than blowing produced sounds reminiscent of these elephant calls (Rainio 2016; Wyatt 2020). This is not to rule out their role as actual musical instruments, since practised artefacts may have multiple functions (Lund 2012). One final point here: we previously discussed the affect of music on the body, and noted that high crescendos may cause musical chills and lower body temperature. In relation to this, I suggested that the general harshness of the climate may additionally affect such responses. It comes as no surprise then that Panksepp and Trevarthen (2009) have related the affect of musical crescendo to the bodily response to infant cries, and it is not too remote a possibility that empathy for mammoth-infant cries resulted in a similar response. In fact, if Hussain and Floss (2015) have any validity in their thesis, such empathy would affect the human population in a similar manner to the cries of their own infants.

Archoustemology and organology

The third level of our epistemology concerns the nature of the physical object, the archoustemology of the Aurignacian aerophones from Geißenklösterle. The fragmentary nature of the palaeolithic aerophones means sounding techniques are unclear (Conard *et al.* 2004; Ringot 2012; Wyatt 2012; 2016b; García Benito *et al.* 2016; Münzel *et al.* 2002; 2016; Wyatt and García Benito 2016; Gill 2020, 75–78). For example, the reconstructed ivory example from Geißenklösterle (GK3) is damaged at the presumed playing end, yet the short, inclined embouchure appears, to me, to be the closest evidence for a flute-like instrument that we have. The Hohle Fels (HF1) vulture bone instrument, also fragmentary at the presumed embouchure (Conard *et al.* 2009; Wyatt 2016b, 201–203, 209), has a similar though longer, less inclined edge,

which is virtually impossible to sound as flute, but works with an attached reed. Nevertheless Ringot has suggested that multiple techniques may have been employed, for a change of atmosphere (Ringot pers. comm. September 2014; cf. Ringot 2012; Wyatt 2012). Having said this, the Geißenklösterle ivory example has a short, squat end not conducive to a reed. The most complete Geißenklösterle swan example is of no help in this aspect of discussion, due to damage of the presumed, proximal end (the embouchure).

The mammoth ivory aerophone (GK3) is 187 mm long and has two complete finger holes of different sizes, an apparent notch at the almost complete end, and a third partial hole. The swan radius (GK1) is 126.5 mm long, it has three surviving holes with significantly different sizes, and a slight rounding at the break, perhaps representing another hole or a notch (Hahn and Münzel 1995, 8; Münzel *et al.* 2016, 228). Wulf Hein noted that the holes were scraped not drilled (Münzel *et al.* 2016, 228), and the subsequent bevelling results in no significant vertical depth, a factor that may be significant in the playing of an instrument, a point to which we shall return below. We may expect that the surviving artefacts, with the exception of the possibilities of discarded faulty examples or practice pieces (see Lawson 1999, 135), exist in their intended form (Fig. 3.2).

Current dating places the reconstructed Geißenklösterle mammoth ivory and swan radii aerophones to between 43,150 and 39,370 years ago (cal BP): the earliest evidence for structured musical behaviour (Higham *et al.* 2012, 9). (The identification of the second swan aerophone as a radius is not set in stone (Morley 2013, 327).) These aerophones along with antler ornaments and artwork are found within the context of Upper Aurignacian (AH II), and although early Aurignacian (AH III) contexts did not contain this range of artefacts, ivory working was far more prevalent (Higham *et al.* 2012, 2–3; see also Buisson 1990; Laroulandie 2004; Conard *et al.* 2009; Morley 2013). Having said this, Conard *et al.* (2009, 3) place the Hohle Fels example and the

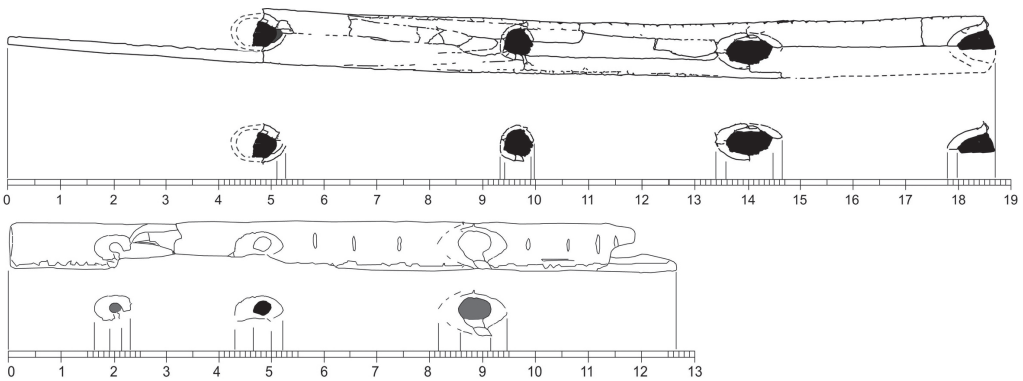


Fig. 3.2: Top: Geißenklösterle mammoth ivory aerophone (GK 3) (Redrawn from Münzel et al. *2016). Bottom: Geißenklösterle swan radius aerophone (GK 1) with three bevelled finger holes. Source: image elaborated by the author after Münzel* et al. *2016 and Hahn and Münzel 1995).*

mammoth ivory fragments from Hohle Fels within the early Aurignacian. I emphasise this point since the following discussion applies equally to the near-complete Hohle Fels vulture radius, due to similar discrepancies in hole size.

Comparing the finger hole size and position with an understanding of acoustics, may provide insights into the practical acoustical knowledge of the Aurignacian population. For example, at low frequencies, a finger hole can be thought of as the end of the pipe, although the sound wave does extend a little past the hole. The basic idea is that the closer a hole to the source of the air vibration, the higher the pitch, and the further down the pipe the lower this tone (Fig. 3.3A). This much is clear. Yet, the tone produced is also affected by the ratio of the size of the hole to the diameter of the bore (Fig. 3.3B) (Benade 1990, 449; Hopkins 1996, 169). Subsequently, making a finger hole larger effectively sharpens the note (Benade 1990, 450; Hopkins 1996, 83). The converse is also true in that a smaller hole flattens a note, so it may be placed closer to the embouchure, and this will produce the same pitch as a larger hole placed further down the pipe.

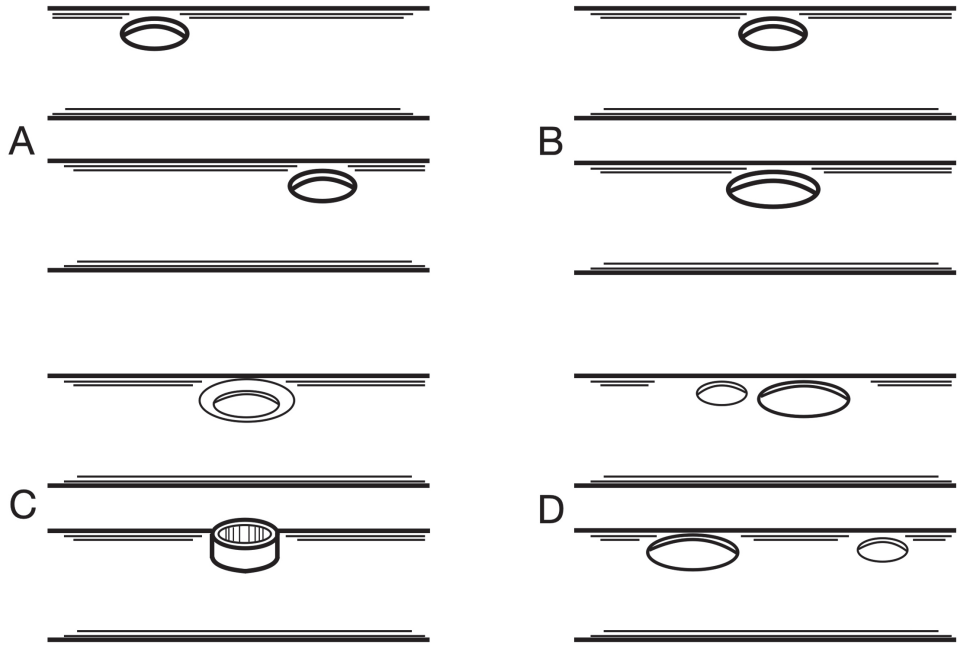


Fig. 3.3: Four factors affecting tone hole size and placement, mouthpiece to the left (adapted from Hopkins 1996, 169). A: a hole close to the mouthpiece produces a higher pitch (top) than one further down the pipe; B: a larger hole produces a higher pitch, a smaller hole produces a lower pitch, for the same positioning in relationship to the mouthpiece; C: the thinner the wall of the pipe at the fingerhole the higher the pitch. Bevelling a fingerhole removes the depth of the pipe wall, which if left acts as extra length to pipe and lowers pitch; D: the smaller the first tone-hole, the greater the effect by lower holes. The larger and closer a second hole the more the pitch of the first hole will be raised. Source: author's elaboration.

Yet, there is more to the role of size than simply the pitch, and positioning on the pipe. A larger tone hole also increases volume and the brightness of the tone's timbre (Wolfe and Smith 2003, 2263). Consequently, smaller holes hinder high-frequency sounds, although a narrow bore does favour higher harmonics (Baines 1967, 34). Indeed, at higher frequencies, a sound wave may extend down the pipe and act as though any small holes are sealed (Wolfe 2018, 54). A larger hole counteracts this problem, essentially re-opening the hole. This leads us to consider the possibility that the top holes of GK1 and GK3 may have been enlarged to alter sound or indeed to make a hole function properly.

Another method of altering pitch (Fig. 3.3C) is by bevelling the finger holes, as found in these examples, which as noted by Wulf Hein (Münzel *et al.* 2016, 228), had been scraped to create holes with no depth. Jean-Loup Ringot (pers. comm.) observed that when you drill bone it invariably fractures on the inside of the bone. This might affect sound, including timbre, and perhaps scraping and bevelling was a way to avoid damaging the inside for this reason. Moreover, a finger hole, like a small chimney, adds to the length of a pipe, while cutting the wall material away removes this discrepancy (Benade 1990, 448; Hopkins 1996, 169). Thus, thinning the wall sharpens the tone, although this may be more important with modern instruments with thicker walls. Indeed, in the case of a bevelled hole in a bone, the finger-pad may protrude into the bore, which could raise or lower the pitch further due to perturbation effects (Benade 1990, 495–497). This is when a narrowing or widening of the bore increases or lowers the pressure and speed of the air and thus affects the pitch. Finally, the combination of proximity and size of holes affects the tonal range of the hole further up the tube, since the vibration of air, as noted, extends slightly past the open hole and is altered by any changes within that extension of the standing wave. This can be used to great effect during performance (Fig. 3.3D).

On a more practical side, hole-placement affects the ease of playing. If the gap between two holes is an uncomfortable stretch for the fingers, a larger hole enables a similar pitch to be created but with the hole positioned closer to the hole that is further down the pipe. On the other hand, a smaller hole enables it to be positioned closer to a more proximal hole. It might be interesting, in light of these comments, to examine the average hand-size from excavated bodies from the Upper Palaeolithic.

What are the practical, acoustic effects of these differences in hole size? I made two models using plain plastic pipe, which guarantees a standard bore and that any pitch discrepancy is the result of the finger hole size, positioning or, admittedly, the embouchure. Natural changes in bore diameter affects pitch in relationship to hole size, when considered in relation to a modern cylindrical bore. Outram (2008, 2) championed the use of modern materials and techniques, in the first instance, for experimental archaeology, but here the added benefit is that the modern material enables us to examine the effect of the finger holes unaffected by the differing bore shape and size invariably found in natural materials such as bone. Since, on an end blown flute, it is possible to alter pitch through changes in the embouchure of the players mouth, for this test, I played the lowest tone and the highest tone

possible through alteration of the embouchure. This demonstrates the full range of tonal possibilities, and thus takes into account the variability of changes due to the embouchure. The models each had one finger hole, one small and one large. The larger hole was placed further down the pipe so that there was no overlap between



Fig. 3.4: Two plastic aerophones made by the author with different fingerholes sizes and positions. The pipes are identical lengths. Source: author's photograph.

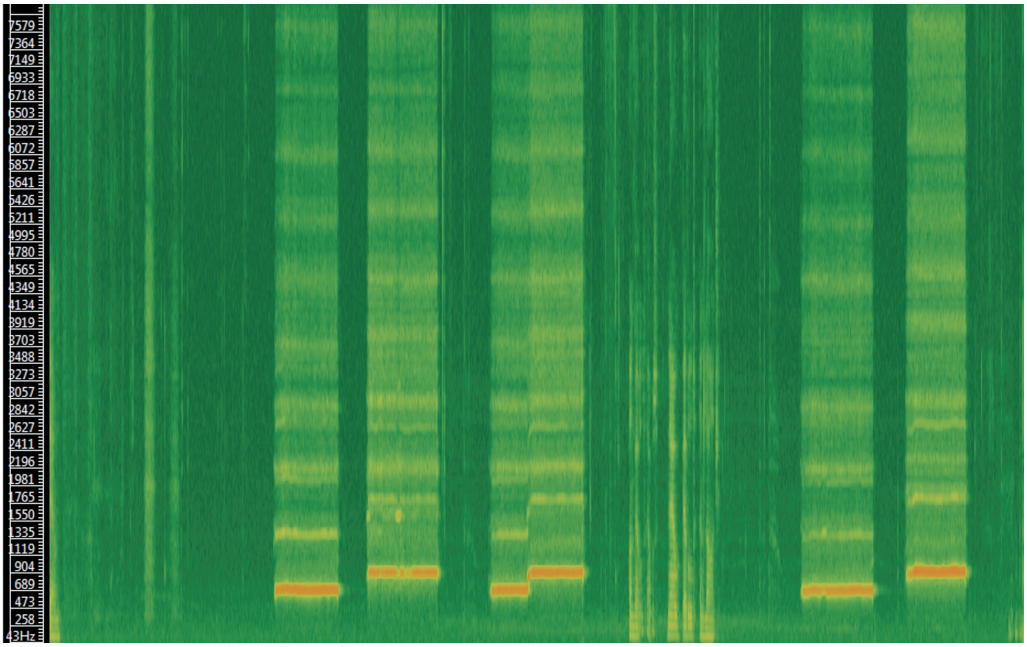


Fig. 3.5: Spectrogram produced with Sonicvisualiser (Cannam et al. *2010). The smaller hole is shown left and in the centre (repeated) (680 Hz to 890-2 Hz) and the larger hole on the right (680 Hz to 902 Hz). Source: author's elaboration.*

the position of either hole (Fig. 3.4). Despite the difference in hole-position, the pitches were virtually identical to the ear. A spectrogram produced from recordings showed that the lower hole was actually slightly sharper (Fig. 3.5).



Fig. 3.6: Two elderwood models of the Geißenklösterle ivory aerophone made by the author. The top model has a top hole as the original artefact. The bottom model has a much smaller hole. Source: author's photograph.

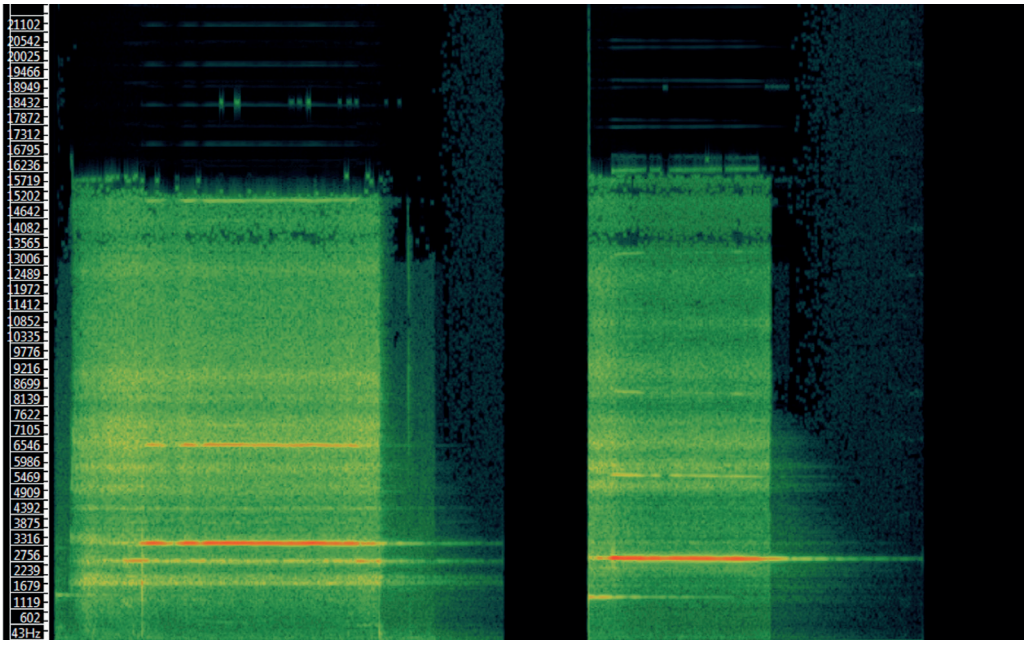


Fig. 3.7: Spectrograms of the models of the Geißenklösterle of Fig. 3.6 produced with Sonicvisualiser. The small hole creates a note but has a lot of noise. The main pitch G# 7 +19c — A7 -37c (3359.18 — 3445.31 Hz) is accompanied by a harmonic around G#8 +30c — A8 -48c (6761.43 — 6847.56 Hz), traces of a further harmonic at A#9 +38c — A#9 +47c (15245.5 – 15331 .6 Hz) and a hint of a lower pitch F7 -23c — F7 +30c (2756.25 — 2842.38 Hz). The larger hole produces a much clearer tone 2842.38 — 2928.52 Hz (F7 +30c — F#7 -18c) with a partial harmonic at 5727.83-5813.96 Hz (F8 +43c — F# 8 -31c). Source: author's elaboration.

In light of these observations, one question might be: did such subtle changes in pitch matter? Was the concept of organised sound as sophisticated as we think ours is? The way I see it is that their skills were unparalleled for their ecology, and the fact that these early instruments appear to be so sophisticated suggests a far longer pedigree in different, perishable material (Morley 2006; Wyatt and García Benito 2016). This implies that they did understand at least the practical ramifications of hole size and placement, and that any specific size and position was deliberate.

GK3 (the mammoth ivory aerophone) has the largest hole near the embouchure and any one of the explanations discussed above might explain this situation. Given the proximity to the embouchure it is likely that the hole size relates to the pitch and ease of producing sound. The placement, so close to the end makes it probable that sounding of the top hole was difficult, due to the high velocity of the air passing it. The models in Figure 3.6 were made to explore the nature of the top hole. Being elderwood, the bores have natural discrepancies, but they are a good match, and after all, we are really only concerned with the top hole.

The sonic visualiser image (Fig. 3.7) shows the representation of sound of the smaller hole on the left, and it is clear that any note is masked by the presence of harmonics and hiss. The larger hole, represented by the image on the right, produces not only a relatively clear pitch, but I find it easier to create and maintain the tone. The note with the smaller hole is neither pleasant to play nor to listen to, to my ears, but we must be wary of relying on our personal taste when interpreting such a sound. We may hypothesise that the hole was made larger than the others perhaps for ease of play, but it is most likely that clarity of sound was also sought, rather than an ambiguous timbre. A purer tone was desired?

On the swan artefact from Geißenklösterle, it appears probable that the intact end is the distal end and that we are missing the embouchure fragment. The bottom hole would have been exceptionally close to the embouchure if this were the blowing end, and based on the comments about GK3 it would have to have been larger to create a clear tone. The two lower holes are significantly smaller in relation to the one closest to the break. It is plausible that the largest hole may have been made bigger to enable it to be placed closer to the lower holes and lessen the stretch, if all three holes were covered by the fingers of one hand. The model that I made from a whooper swan-radius shows that this is at the limit of a comfortable holding position for me, when covering the three holes with the fingers of one hand. If the logic of this observation has any merit, and the hole was made larger to enable it to be placed further down the bone, it would support an interpretation that the instrument was held in one hand. Conversely, as a two-handed instrument, the initial hole might have been placed in the wrong place and increasing the size sharpened an otherwise flat note, if such a distinction was recognised and desired. Yet again, if too close to the embouchure, a larger hole may have been required to affect the pitch at all, but without the proximal end, we will never know. We may note though

that a swan radius is significantly longer than the extant instrument and it may have been at least twice as long.

Towards a total archoustemology

We have examined three widely differing themes related to the organisation of sound during the Aurignacian, the relationship of experience to sound, agency and self, the relationship of self to ecology and the relationship of artefact form to acoustics. Yet, in essence, they are each part and parcel of epistemology: they relate to the construction of the self. I advocated the value of Bateson's (2000) double description at the start, and what we have examined is the nature of the self-described from different perspectives relating to sensory integration, sound, ecology and artefacts. Indeed, Bateson argued that whether we examine religious or economic categories of a culture, or varieties of behaviour within psychology, we are not looking at real subdivisions but convenient abstractions, each of which is "simultaneously relevant" (Bateson 2000, 64 and footnote 2). It is interesting to compare to Chomsky, who wrote that "History does not come neatly packaged into distinct periods, but by imposing such a structure upon it, we can sometimes gain clarity without doing too much violence to the facts" (Chomsky 1992, 1). Both Bateson and Chomsky highlight that the abstract nature of classification is constructed within our heads, we must be aware that we impose our concepts upon the world and other people. For example, here we have discussed the concept of modern acoustics, but this is not how the Palaeolithic population conceived of sound and more holistic or anomalous explanations may have been closer to their world view (Tuzin 1984). Failure to recognise that the classification is an abstraction of the real world is known as the "fallacy of misplaced concreteness" (Whitehead cited in Bateson 2000, 73–74).

While archoustemology may lack the immediacy of ethnography, the very essence from which Feld developed his model (Feld 1996; 2017), it expands the relational concepts of sensory anthropology by presenting evidence that the senses are themselves entirely relational. At the level of the neuron, the senses are modulated by one another, and by the concepts formed from them. We observe that Steven Feld charged his acoustemology with explaining how the dynamism of sound indexed social immediacy (Feld 2017). It is suggested here that at least part of the reason behind this process is that acoustic experience of synchronised action and auditory sensation of place drives sensory integration, recognition of self-agency and construction of self. This subsequently promotes group cohesion and self-other bonding, and perhaps also a sense of bonding to our lived ecology. Our very interaction with the world, including through musicality, creates our sense of agency, self and niche. The conceptualised sense of self and place recursively feeds back into the cultural model of identity, further substantiating its sensory construction. This includes cultural concepts of the group as much as the environment and choice of material. This process is reflected in our reaction to music as though it is a person, and not simply because we recognise the

living pattern of mind in music. Following Bateson (2000), we ought to consider the interaction of sound and person as a reflected manifestation of mind and self. Yet sensory delay caused by the acoustic of place, in addition to extreme environments or bereavement, may hamper perceived self-agency leading to sensory disintegration, which would be felt to be associated with sound and place. Thus the feeling that music is a manifestation of a mind may be bound up with the temporary fragmentation of one's own perceived self. Such experiences should be considered in any exploration of how sound and acoustics of place affect experience. "Body and mind, after all, are not two separate things but two ways of describing the same thing – or better, the same process – namely the environmentally situated activity of the human organism-person" (Ingold 2002, 171).

Furthermore, the interpretation presented above supports the idea of complex and sophisticated acoustical knowledge during the Aurignacian, which had developed over a long history through practical observations. Distinct finger holes mean distinct pitches, which imply distinct timing, and timing and ideas, in turn, drive a construction of a distinct self in a distinct context. With this discussion in mind, we may consider that the use of ivory to harness the mammoth presence further bound the population into Hussain and Floss's (2015) conceptualisation of the mammoth steppe, where the sound called to the self, the group and the ecological niche, vicariously through the mammoth. If the mammoth-ivory aerophone from Geißenklösterle represents any attempt at harnessing some mammoth essence, then the rather shrill sounds of these aerophones paradoxically embodied the chill of the environment, rather than the furry bulk of the creature itself. Yet as we have discussed above, there is a possibility that such sounds mimicked calls between parent and infant as part of the ongoing relational mammoth steppe.

This world is, and was, a sensory construction aided and driven by rhythmic patterning of sound, the perception of natural environmental sounds, the communal calls of the creatures, and the patterned socialised sounds of the humans and their understanding of the acoustics of objects. At a more abstract level, Gregory Bateson (2000) hoped to tackle, through epistemology, the problem of how we experience any "thing", if our senses sit between the world and the experience. The validity of our perceived model is manifest in our ability to interact physically with the world (Cashmann 2008), and the use of the mammoth ivory is the sonic bridge between the self and the ecology of the mammoth steppe. Engaging with the mammoth ivory instrument reifies the model of self, the relationship to the lived ecology and the acoustic concept of the structured sound, even if the mechanism is not entirely clear to us.

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Note

1 Youtube hosts a film of a female elephant calling to Young (https://www.youtube.com/watch?v=EG3OemglGN4).

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Chapter 4

The sounds are audible: Fabricating ancient instruments – what more can we learn?

Neil Rusch

Abstract

There is a view of archaeology promoted by the Oxford historian and philosopher Robin G. Collingwood (1889–1943), who argued that knowing the past means re-enacting it. This idea is alive today in experimental archaeology. In this chapter, I revisit the concepts of "re-enactment" and "actualisation", drawing on my experiences creating musical instruments for archaeoacoustic purposes. Further, I investigate Material Engagement Theory (MET) and the hypothesis that material engagement and musical instrument making are intertwined and should be traceable in the archaeological record. Five case studies inform this enquiry. The result suggests that 4E cognition – embodied, embedded, enactive and extended – as it is theorised by MET can be applied to archaeoacoustic instrument fabrication. As a method of enquiry, MET structures the actualistic approach I take to making archaeoacoustic instruments, and the results deliver insight into the cognitive aspects of mind-material engagement.

Keywords: material engagement, 4E cognition, working memory, archaeoacoustics, actualistic

Introduction

Ostensibly, this chapter is about results generated by actualistic[1] experiments conducted over 13 years for archaeoacoustic purposes (Scarre and Lawson 2006; Both 2009). Equally informative are the inherent processes that, when reflected upon, reveal the cognitive aspects involved in mind-material engagement and actualistic experimentation. Immersion in the procedures and processes of making and what

these engagements reveal are not the archaeoacoustic results *per se* and, for that reason, are generally not reported. The angle this chapter takes, therefore, aims to extend the previous archaeoacoustic research undertaken (Rusch 2017a; 2021; Kumbani *et al.* 2019; Rusch and Wurz 2020; Rust *et al.* 2022). The commitment will be to link an analysis of actualistic activities (techniques and procedures) with Material Engagement Theory (MET), which "lies in the conviction that minds and things[2] are continuous and inter-definable processes rather than isolated and independent entities" (Malafouris 2019, 13). Here I will investigate MET and the hypothesis that material engagement and musical instrument making are intertwined in the archaeological record. If this is the case then 4E cognition – embodied, embedded, enactive and extended – as it is theorised by MET, should be detectable in instrument actualisations. From this hypothesis, I reason that my instrument fabrications are materialisations of the possibility of MET.

MET has an inbuilt utility when applied as a method because the material engagement focus of MET, in any practice-lead investigation, foregrounds the processes that give rise to the item/instruments created by the processes. Importantly, MET "diverts from the classical phenomenological programme that prioritises subjective experience over situated action" (Malafouris 2019, 13; note also Ihde and Malafouris 2019). The action-based methodology of MET is particularly attractive for actualistic endeavours and it distinguishes MET from epistemological models characterised as "embodied knowledge" (Csordas 1990), "know-how" (Ryle 1945) and "tacit knowledge" (Polanyi 1962). MET research provides a record of applied studies, situated in art, sculpture, drawing, lithic tools and pottery making (Malafouris 2019; 2020; 2021; March and Malafouris 2023; note also Mosley 2021; Wynn *et al.* 2021). These MET examples provide a distincive phenomenological approach and exposition, which informs the focus of this chapter.

The MET approach places attention on the processes of co-production and in theory stands opposed to "the fallacy of misplaced concretness" (Whitehead 1978, xiii). The methods of a "process archaeology of mind" (Gosden and Malafouris 2015) is in tune with other enactive and distributed approaches to cognition and study of mind (Hutchins 1995; 2010; Ingold 2012). According to Whitehead and Collingwood (as we shall see), the world is not an assembly of abstracted things but, rather, things and bodies are embedded in and are enactivated by extensive processes of becoming (Whitehead 1978) and the situatedness of being-in-the-world (Heidegger 1962, 78–90). The co-production of things and thinking is a recursive processural activity characterised as "thinging" (Malafouris 2014). Thinging is "an ecological-enactive vision of participatory mentality where bodily acts and materials act together to generate rather than merely execute thought processes" (Malafouris 2021, 107). According to Lambros Malafouris, "I coined the term *thinging* to articulate and draw attention into the specific varieties of cognative life instantiated in 'actual occasions' of thinking and feeling *with*, *through* and *about* things" (Malafouris 2019, 7, original emphasis).

In the context of actualistic experimentation, we can say that the maker weaves and is woven into the fabric of things. Accordingly, the fabrication of archaeoacoustic instruments fits and is underwritten by the ontological implications of the MET and the priority given to "continuity of mind and matter" (Malafouris 2021, 107). Cognition, as per the 4E model, emerges in thinging and the practices of making because they are embedded in the vitality of materials (Bennet 2004; 2010). For MET, the question "what things are" and the question "what minds are?" are inseparable (Malafouris 2019, 12).

Five case studies are presented in this chapter. Each case follows a phenomenological approach and assumes continuity between cognition and material culture. Accepting that ontologically there is continuity of mind and matter provided the methodological baseline for this study plus the MET has directed the analytical strategy that I apply, taking cognisance that: "acts of making, become the new analytical unit for the study of mind" (Malafouris 2021, 98). Moreover, in each of my cases I follow closely the thinging procedures of a clay sculpture-making experiment in which "the framework of MET [...] structures a phenomenological account that extends beyond the first-person" (March and Malafouris 2023, 585). Going beyond the first person in my case(s) is a crucial element of the actualistic strategy because my aim includes an attempt to understand "thinging" as makers in the past may have approached the task of making instruments. This is an exercise Collingwood characterised as re-enactment, as we shall see.

At the outset I summarise the intersecting vectors as a question. What connects head with hands, mind and materials?

This is not a simple issue. It is an ongoing enquiry that has inspired experimental archaeology to undertake investigations that have proven fruitful (Coles 1973; 1979; Carrell 1992; Reynolds 1999). However, how we approach the problem and its implied conflation, linking actualistic experimenters and makers in the distant past, can be approached from a MET perspective. In the first instance, the maker actualiser draws on individual capacities, engaging material knowledge, skill and dexterity. Simultaneously, the experience bifurcates because, in some mysterious way, actualisation is re-enactment that includes the "other", i.e. cross-temporal corresondences can occur in acts of thinking and feeling with, through and about things, which were made by a maker, or makers, in the past.

In this chapter, there are two linked sections. In the first, I highlight key elements of Robin G. Collingwood's re-enactment framework (Collingwood 1938; 1939; 1946), especially where his conceptualisations appear to anticipate MET, i.e. in instances where re-enactment, thinging and actualistic experimentation become reflexively elucidating. The second section considers five instrument fabrication experiments, which, in line with MET, assume continuity between cognition and material culture. In this layout, section one describes the method and theory. Section two presents the materials and experiments that provide a lens through which to reflect upon section one, and vice versa.

Theory and practice

Question-answer

An actualistic experiment, such as making an instrument, is hypothetical because the exercise is an attempt to understand a process, or refute it (Outram 2008). Recreating ancient sounds for archaeoacoustics purposes is an important aim but there are other avenues of investigation that are equally interesting. Collingwood insists on the hypothetical approach and a "question-answer" logic that sets the actualistic experiment (re-enactment) on scientific footings (Outram 2008).[3] Answers might lead to further enquiry because materials begin to act. Other unpredictable phenomena allow space to arise and reveal insights that were not foreseen by the previous hypothesis. Such is the method that leads to greater resolution.

In several respects, R. G. Collingwood's "re-enactment", "question-answer" method and his idea of "incapsulation" (sic) anticipated later developments and his insights[4] foreshadowed what we have come to understand about the nature of materiality and becoming within the MET paradigm (Renfrew 2004; Overmann 2017; Malafouris and Koukouti 2018; Overmann and Wynn 2019). Collingwood set forth the nature of making and materials in the following way: "The person who makes these things is acting voluntarily; he is acting responsibly; but he need not be acting to achieve any ulterior end; he need not be following a preconceived plan [mental template]; and he is certainly not transforming anything that can properly be called a raw material" (Collingwood 1938, 129, parentheses added). The final phrase suggests that material is not inert. On the contrary, materials are imbued with significance and affordances (Gibson 1977). Assemblages of matter are vibrant (Bennett 2004; 2010) and materials act resonantly when their inherent sound-vibration is released. Materials "call" to be transformed by virtue of their qualities and character(istics) which engage and collaborate with a prehensive and predictive attentiveness (Whitehead 1978; Clark 2013; 2016)[5] in the maker. Once transformed and resonant, the materials are played and, in turn, play back to the maker.

Overall Collingwood's formulation is made in respect of expressive behaviour that is co-constituted by people and material things inter-acting with one another. Moreover, he conceives "re-enactment" as conjoining (conflating) activities separated in time. This is plausible within the 4E cognition model (Ihde and Malafouris 2019), notably by way of fabrication processes and the neuropsychological working memory model (Coolidge and Wynn 2005; Coolidge *et al.* 2013). Thus, for Collingwood, fabricated objects and material things have the potential to act in assonance and across time in a construct that he calls the living past. As I understand Collingwood, re-enactment is driven by question-answer reasoning, and can achieve greater resolution within the rigor of that process. Figured into this process by way of a living past is the notion of temporality. The past and the present enter into dialogue because: "The past which a historian studies is not a dead past, but a past which in some sense is still living in the present" (Collingwood 1939, 98).

The danger of reading the present back into the past, or confusing experiential and experimental, is mitigated by the differential of time and "incapsulation". The difference is one of context. "Historical knowledge is the re-enactment of a past thought incapsulated in a context of present thoughts, which by contradicting it, confined it to a plane different from theirs" (Collingwood 1939, 114). Collingwood elaborates, saying:

> a question arising in that primary series may act as a switch into another dimension. I plunge beneath the surface of my mind, and there live a life in which I not merely think about but am [...] this secondary life is prevented from overflowing into my primary life by being what I call incapsulated, that is, existing in a context of primary or surface knowledge which keeps it in its place and prevents it from thus overflowing (Collingwood 1939, 113).

In summary, a cross-temporal construct can be established through re-enactment, linking the experimental archaeologist with the maker of the archaeological model.

Cross-temporality

Following Collingwood, consciousness is not at any time static but rather is always becoming for individuals and for the hominin species (becoming human) because the living past is: "primarily a study of the nature and implications of process or becoming" (Collingwood 1939, 98–99). Collingwood reveals his inclination for processual understanding by adding: "history is concerned not with 'events' but with 'processes'; that 'processes' are things which do not begin and end but turn into one another" (Collingwood 1939, 97–98). Challenging the intellectual atmosphere that he found himself in (20th-century Oxford realism) Collingwood comments favourably on Whitehead, saying:

> his "philosophy of organism" commits him [Whitehead] to the view that everything which forms an element in a given "situation" is connected with everything else in that situation, not merely by a relation of compresence [sic.], but by interdependence (Collingwood 1939, 45).

I understand these statements by Collingwood as a caveat against facile knowingness and a caution against the fallacy of false concretness. In other words dispense with the idea of a blue-print, existing pre-formed in the head of the maker vis-à-vis Collingwood: "The person who makes these things [...] need not be following a preconceived plan" (Collingwood 1938, 129). This is very much the method of an actualistic experiment when the experimental archaeologist enters a process of thinking with materials and earlier makers.

MET recognises that material/archaeological remains act as catalysts for actualistic proceedures because such items enliven what took place in a living past:

> things play an important part in the integration and coordination of processes that operate on radically different time scales (e.g. neural, bodily, cultural, and evolutionary). Through their physical persistence, they help us to move across the scales of time and to construct bridges between temporal phenomena that operate at different experiential levels [that] often escape the temporal limits and rhythms of individual experience (Malafouris 2019, 8).

At this juncture, the intersecting priorities connecting Collingwood's ideas and MET becomes clearer. Re-enactment, as a means, 'bridges' time. Actualistically fabricated instruments offer a portal to processes of mind other than our own.

Re-cognition is the moment of realisation when re-enactment finds empathy with patterns of cognition imbricated in the materialisation processes of former makers. This is surely "thinking with and through" in the 4E model. It could also be Collingwood's re-enactment of the "context of thought" (Collingwood 1993, 299) and an ability to "see what the person who made this [...] was thinking" (Collingwood 1939, 110).

Thinking with

What is the cooperative connection linking head and hands, materials and mind? *Sensu* Collingwood, what are the dynamics of independence, dependence and interdependence that mediate the potentiality of the in-between? Hands are extensions, mediating between inner and outer. Phenomenologically they are continuous with being-in-the-world, knowing and doing. I turn to my hands as a measure of my interdependence with materials and the vitality of materials acting towards an outcome of their own making.

Hands are active, but they are also perceptive (Mäkelä 2007). As we grasp the world, the world grasps us because engagement in the world implies reversibility (Merleau-Ponty [1945] 2005; Shusterman 2008). The skill-knowledge that hands impart to the maker arises from the capacity of hands and body to function together, equally well, as transmitters (active) and receivers (passive). This type of skilled trans-active body intelligence is hard, if not impossible, to impart since it mostly abides in the realm of somatic proprioception (Paterson 2007) and/or tacit knowledge (Polanyi 1962). Much remains unvoiced and mute (subliminal) even to the maker (unless like now an attempt is being made to voice it). For example, I drop a cup and before it hits the ground I catch it, without thinking. Action and intention are synonymous. The experience is tangible but much of what took place remains invisible. What is seen is the action, or action sequence, which is but a gestural trace of that which resides in the realm of a liminal response (limbic, paleomammalian cortex), ready to mobilise should en-activating circumstances of a similar nature arise again.

Another example: A maker lifts a beam of wood. One hand steadies the beam while the other hand feels down the length of timber. The steadying hand flips the wood through 180 degrees. The other hand lifts a cutting tool and begins shaping the wood. The physical motions represent the collaborative action of head and hands, mediated through working memory situated in the pre-frontal cortex (Alloway and Alloway 2013). A co-extensive head-hand connection resides in the know-how (Ryle 1945) of wood grain and what going with and against the grain implies.

A functional magnetic resonance image (fMRI) would illuminate different parts of the brain in the first and the second example. This is fascinating but limited until the activations and neural responses are situated in a context. In an ecology of

en-activating circumstances (Hutchins 1995; 2010; Ingold 2012) an embodied, extended intelligence (Malafouris and Koukouti 2018) is pivotal, although seldom admitted into explanatory frameworks. This is unfortunate, because omitting unspoken body intelligence elides from evidence material explorations and related cognitive processes (Wynn *et al.* 2017).

Thinking with hands, I suggest, is an invite *sensu* Collingwood to "plunge beneath the surface of the mind". The move on the part of the experimental archaeologist is not unthinking, nor is it without reason, but the method anticipates moments of "methodological naiveté" (Bennett 2010, 17). Methodological naiveté is a learned technique that allows unforeseen phenomena an opportunity to act (Outram 2008, 2). From the foregoing perspective it is reasonable to acknowledge that the instruments created for the archaeoacoustic experiments, described below, are not the products of thinking but rather they provide a portal into a way of thinking.

Free aerophone *!goin !goin*

The *!goin !goin* is a free aerophone (Hornbostel and Sachs 1961 (1914)) also known as a bull roarer, except that in the case of the *!goin !goin* the string is attached to a short stick at one end and is not held in the hand as most other bullroarers (Kirby 1965; 2013; Rusch 2017a). Of all the fabricated instruments described here the *!goin !goin* should have been the easiest to create because there is an illustration of the instrument (No. 19) with dimensions (Fig. 4.1) published in *Specimens of Bushman Folklore* (Bleek and Lloyd 1911, 353–359). In addition, there is a type model (KK052) archived in the Kirby Collection of Musical Instruments, curated by the College of Music at the University of Cape Town. With this information at hand, the first examples that I created were not inaccurate but they were, nonetheless, misleading. The first actualistic instruments were biased because of a predisposition embedded in the experimental archaeologist, i.e., myself, the author. This was an unanticipated discovery but was foreseen in an observation made by Collingwood, namely that re-enactment is not exclusively about the past but is equally a self-reflective procedure in which I, the researcher, "think about myself"[6] (Collingwood 1939, 113) and my impact on the experiment.

Upon reflection, my mistake was a small but critical oversight in material choice; in the MET idiom, my material choice succumbed to my mind. It is necessary at this juncture to make a disclosure, subjective, of course, but the relevance is evident because it impacted on the outcome of the fabrication process, which was ultimately striving for an objective result. Prior to any archaeoacoustic research, I arrived on the scene having built two sailing vessels and two ocean-going kayaks, all in timber. Before this, I received an education at a technical school and over a period of five years was exposed to and practiced a range of artisanal skills including motor mechanics, sheet metal work, electrical work, woodwork and tool-making. Disclosure is two-fold. First, it circumscribes a certain skillset and secondly it demarcates the limitations imposed

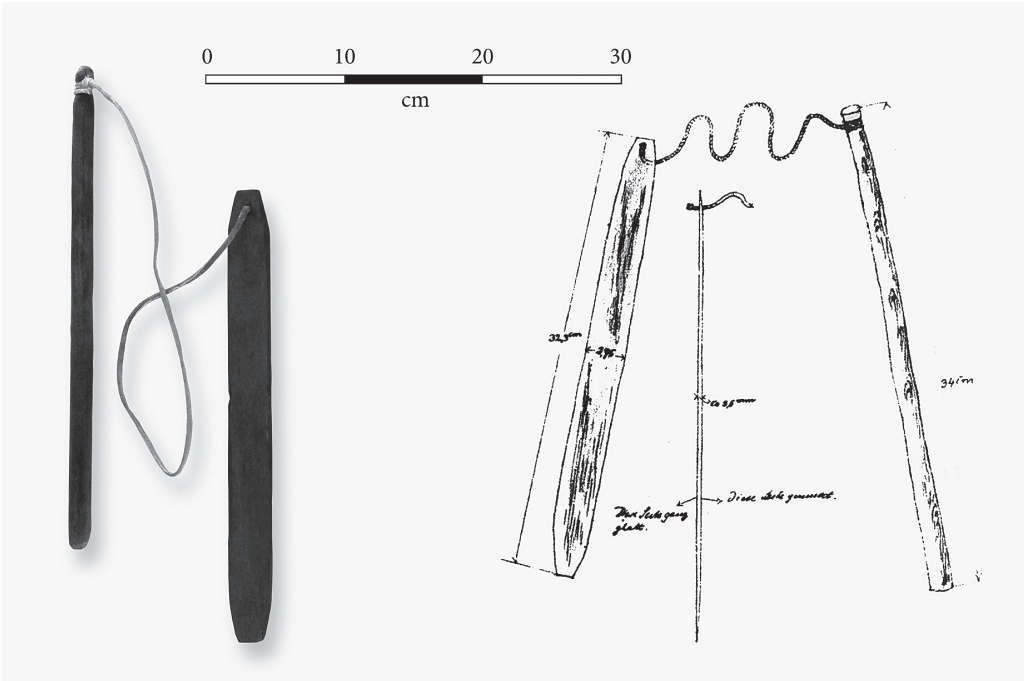


Fig. 4.1: Free aerophone of the !goin !goin *type alongside the illustration reproduced from* Specimens of Bushman Folklore*. Illustration by author.*

by those capabilities. In practice-led experiments, these features are acknowledged, because embodied traits "guide us in material exploration even before physical manipulations start" (Groth and Mäkelä 2014, 1). Moreover working memory mediates performance (Ericsson and Moxley 2013). How does the experimenter "combine critical body awareness with the smooth spontaneity of action? Are there special principles or methods of somatic introspection for improving body consciousness and sensorimotor performance?" (Shusterman 2008, xi). I do believe that Collingwood's injunction to "think about myself" points in this direction, i.e., for experimental archaeologists to question their default skills, awareness and self-perceptivity. Said otherwise, a pre-requisite for actualistic experiments is a willingness to unlearning.

So, how did the above disclosure affect the aerophone experiment? Influenced by previous forms built for the marine environment, I unthinkingly chose to make the "blade" of the instrument from a West African hardwood species. I suppose durability was at the back of my mind. Equally influential in this unthought selection was undoubtedly the easy affordances provided (in Gibson's sense of ecological interactive possibilities) by a stockpile of marine-grade timbers left over from previous boatbuilding projects. Neither the timber's promise of longevity nor its near-at-hand access was good for the outcome of the experiment, although the resultant instrument did provide a starting point and it did produce sound!

Collingwood, as a matter of practice, made a point of asking obvious questions. Would Stradivarius create a violin using marine-grade timber? Both *!goin !goin* and violin are musical instruments. Rather than durable, the timber needed to be light and resonant. This made me wonder about choices and affordances (Gibson 1977). Material in the hand is a multi-modal experience, simultaneously stimulating enactivating sensations and thinking. Tapping, knocking, pulling, banging are tactile acts to solicit sound; "thinging" the aural possibilities of materials into existence. Deliberating on the possibilities of sound is an extension of mind, from materials to music and instruments, and vice versa. With these thoughts my search for "resonant" timber took a turn towards cognitive ecology as explained by the anthropologist Edwin Hutchins in *Cognition in the Wild* (Hutchins 1995). His approach and my search for "resonant" timber encouraged me to expand the scope of investigation to other materials. It had become obvious to me that the actualistic experiment should include the situational context – cultural and ecological – out of which the the *!goin !goin* emerged in the first place.

To cut a long story short, I then constructed a new "blade", using the same dimensions as with the first blade but this time using *Searsia pendulata*, a medium-sized tree that grows along the *boomlope* (Afrikaans: tree paths/walkways) that follow the occasionally flowing river beds in Bushmanland.[7] I realised that what I had enacted fell in line with material ecology (Ingold 2012) and the methodology of MET. Material ecology, like cognitive ecology, stresses relatedness of mind in context. The resultant blade weighs 10 g less than the first one, a 40% difference which in turn translates into an audible difference. This is visually illustrated in comparative spectrograms (Fig. 4.2). My conclusion is that an understanding of MET and cognitive ecology, in this case, resulted in an empirical outcome, measurable by the change in sound and the weight of the instrument.

The effect that 10 g has on the haptic characteristics of the second instrument was transformative and by phenomenological method provided evidence for "the

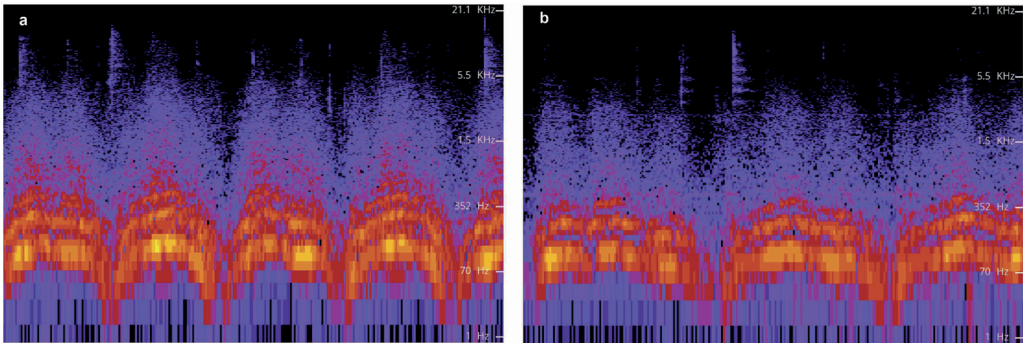


Fig. 4.2: Comparative sound outputs produced by the !goin !goin *type aerophone KK052. Spectrograms illustrate a 10 g weight difference between heavier blade (a) and lighter blade (b). Maximum sound intensity (yellow) occurs between 70–150 Hz for both instruments. The heavier blade spins faster than the lighter blade, which is indicated by the dissimilar pulse rates. Photograph by author.*

study of mind" (Malafouris 2021, 98), my own mind and the minds of the people who made these instruments. As a player rotates the blade (free aerophone) and as the blade circles, restrained by the string, it begins to flutter. This feature is unlike the heavier blade, which more strictly maintains a constant trajectory, without the flutter. The flutter feeds back through the string and is communicated by way of the stick to the player's hand. The sense of inter-animation between player and instrument is palpable. The instrument gives the impression of being alive in its own right (mind-material continuity, somatically reinforced). In |Xam culture where cosmology is animated by relational ontology (Guenther 2016; 2020) this result cannot be overstated. The conclusion that I draw from these results are compatible with MET: the *!goin !goin* is not just an instrument; it is a way of thinking. Thinking with and through the implement initiates entry into the situational ecology and cosmology in which the instrument is embedded. Said another way: by re-enacting the processes of material engagement the actualiser entered into an enactivated way of thinking (as an-other)[8] that influenced the understanding of relatedness and relationship.

Sequential procedure

The procedural nature of the actualistic experiment, described above, highlights key elements of method touched on in section one: i) thinking with is important, if not more so than thinking about; ii) one-off experiments often require subsequent actualisation with modification to experimental parameters, as first set out; iii) a procedural experiment may require more time than is allocated for completing a PhD; iv) factoring into the experiment an anti-method (methodological naiveté) contributes immensely to procedural success. The delay (indeterminacy) that I see as a fundamental part of methodological naiveté is that it allows things to render themselves manifest. According to Bennett, to "render manifest" is "both to receive and to participate in the shape given to that which is received" (Bennett 2010, 17). In these circumstance what plays out, in summary, is the: "Recursive cognitive coupling between people and things-in-the-making" (March and Malafouris 2023, 585).

!goin !goin rock painting

A rock painting added previously unknown chronological information about the *!goin !goin* aerophones instrument (Fig. 4.3). What the painting revealed was that *!goin !goin* aerophones were used around or before 2000 years ago (Rusch and Wurz 2020). With digital image recovery techniques (Decorellation-Stretch, D-Stretch) it was possible to up-scale the depicted instruments for actualistic experiment.

Scaled full-size and re-created, the painted instruments are morphologically similar to an extant ethnographic model. The actualisic recreation demonstrates remarkable continuity in the practice of *!goin !goin* music playing. The painting also affirms the

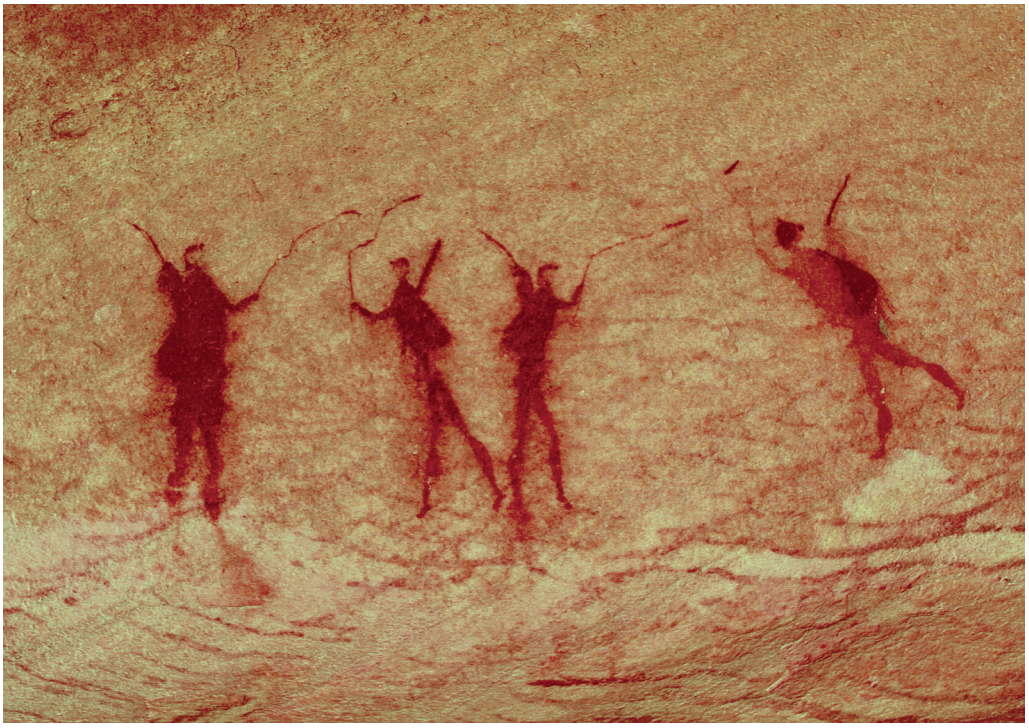


Fig. 4.3: A section of a rock painting depicting !goin !goin *aerophone playing, digitally enhanced to emphasise red-ochreous colours. Photograph by author.*

authenticity of the lighter blade. The variable and angled detail of the painted blades relative to the string (see Figs 4.3 and 4.4) is identical to video footage that shows an actualised model being played.

Pendant or woer woer?

The next example MR40 (Fig. 4.5) served dual purposes, i.e. it functioned as a bullroarer musical instrument and as a pendant (Kumbani *et al.* 2019). This makes the item particularly interesting from the embodied MET perspective. MR40 was fabricated in bone with mass and morphology conforming to the archaeological artefact, which was excavated at Matjes River on the southern Cape coast, South Africa. MR40 was recovered from layer C with dates ranging between 9580 ± 85 and 5400 ± 250 BP (Protsch and Oberholzer 1975, 40; see also Sealy *et al.* 2006, 99).

The fabricated version of MR40 was spun, and the resultant use-wear was compared to the use-wear on the artefact (Kumbani *et al.* 2019, figs 15 and 16). Functional analysis supports the conclusion that the pendant served a dual-purpose. Wearing a sound-producing instrument as a pendant implies embodiment that is

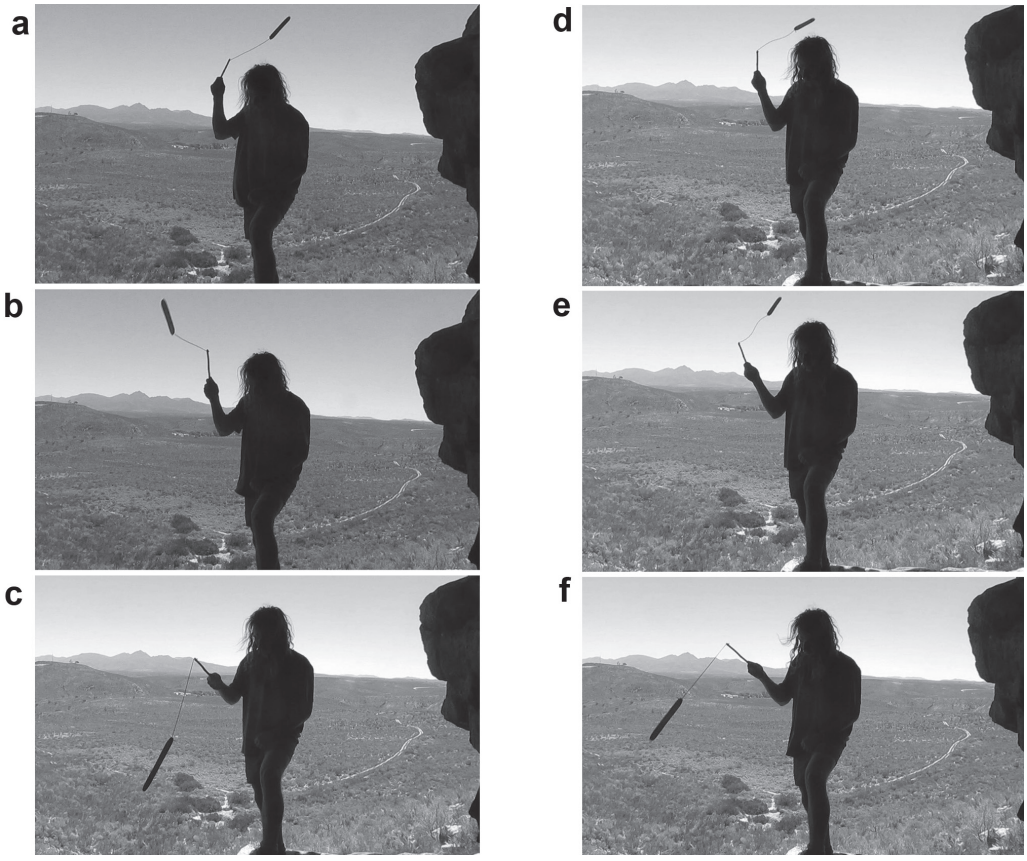


Fig. 4.4: A frame-capture composite image showing the blade, string and stick relationship when playing a !goin !goin *type bullroarer. Photograph by author.*

co-extensive with sound, or sound that augments embodiment. Worn as body adornment the pendant likely carried associations that will have played a role in social signalling. Both visual and audible aspects inherent in the object form part of an embodied signification.

Both KK052 and MR40 produce sound and are categorised as aerophones, but they are very different instruments (Fig. 4.5). For comparison, MR40: blade length 88.2 mm, width 26.9 mm, thickness 5 mm. KK052: blade length 323 mm, width 29.5 mm, thickness 3.5 mm (Rusch and Wurz 2020, figs 6, 7, 8). It is likely the *!goin !goin* had one



Fig. 4.5: Two free aerophones, the ethnographic model KK052 on the left and archaeological model MR40 on the right. Photograph by the author.

function, to produce sound, unlike MR40 where the function is apparently more complex because the instrument, also an pendant, has strong corporeal connections (Joyce 2005).



Fig. 4.6: The KRM woer woer type aerophone, excavated on the southern Cape coast, South Africa, fabricated in bone to match the original. Photograph by the author.

Klasies River woer woer

Corporeal associations also adhere to the Klasies River woer woer (KRM),[9] a two-holed aerophone that is spun on a looped string (Hornbostel and Sachs 1961 (2014)). The KRM instrument (Fig. 4.6) was recovered from the Later Stone Age (LSA) upper midden II, which dates around 4800 BP (Singer *et al.* 2016). The emphasis I wish to make is that the instrument was made of rib bone, with species unspecified (Singer and Wymer 1982, 127; Kumbani *et al.* 2019, fig. 2). There is an implied connection to breath and breathing (Chris Low. pers. comm.; see also Low 2007) through the choice of material (lungs and rib cage). Also the sound produced by the instrument is reminiscent of inhalation and exhalation (Fig. 4.7). Sound emanating from the instrument could be construed as amplified breathing. If this line of reasoning is right, then the woer woer becomes a form of body extension (prosthetic augmentation). It is interesting to consider these observations from the point of view of cognitive ecology (Hutchins 2010). The KRM woer woer illustrates how the functional dynamics in a complex system of cognition is embedded and embodied in the socio-material environment. Thinking with and through the Klasies River woer woer allows consideration of the reciprocities between the body as an alive, sensual locus of expression and the body inscribed by its socio-material environment.

Sound-vibration, by extension, from person through instrument and into a person's surroundings provides a powerful proxy for "transient systems that include somatic activity that lie beyond the body itself" (March and Malafouris 2023, 596).

Several attempts were made to fabricate this instrument, all engaged with the characteristics of bone and the specificity of ribs. Larger and smaller species of animal rib bone were used. What was determined is that KRM aerophone vibrates the air in a unique way. The internal structure of the rib, exposed along its edge (Fig. 4.6) disturbs the air in a distinctive manner. Instruments without the edge exposure sounded but their sound was not the same. The source material (large herbivore) was important, however the possibility of human rib bone being used for the purpose cannot be ruled out.

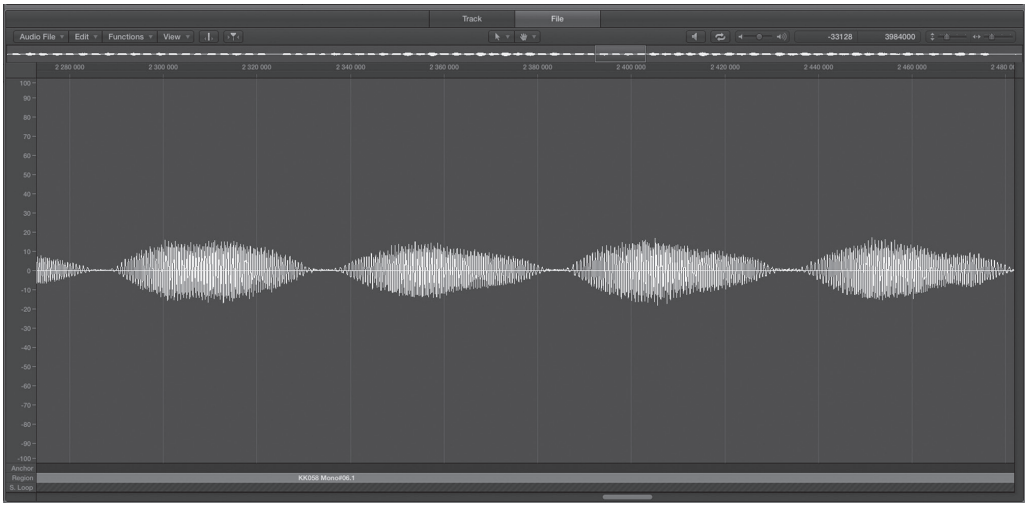


Fig. 4.7: KRM aerophone wave pattern, captured in Logic Pro. Source: author.

Beyond the bounds of these determinations the significance of MR40 is the place of deposition, in a noteworthy Later Stone Age burial ground. Moreover the embeddedness of MR40 owes much to the acoustic enhancing architecture of the rock shelter in which it was found: "The sounds recorded in the studio represent an objective measure, but this only approximates what would have been a dynamic multisensory experience, enacted in context" (Kumbani *et al.* 2019, 709).

Matjes River woer woer

Examples of sound-making instruments are relatively rare in the archaeological record but where they do occur their specificity can reveal vestiges of cognition. An example of this is MR5135, which is a free-aerophone of the two-hole woer woer type. In many ways it is similar to the Klasies River model, except that MR5135 is made of solid bone (Fig. 4.8a) rather than a rib bone. MR5135 has a comparable provenance to that of MR40 because it was recovered from Matjes River layer C – 9580 ±85 and 5400 ± 250 BP.

When strung and spun MR5135 did not produce sound. After modifications the instrument did make sound, which led to conjecture about possible fabrication procedures. There are two probable explanations. Both are plausible and fascinating from a material engagement perspective. Figure 4.8a illustrates the two modifications that were made to correct the implement's asymmetry. With both modifications sound could be produced. Having gone through the making process and having thought through each modifiction I am inclined to believe that MR5135 was a work in progress, left unfinished. Two lines of evidence support this supposition. "Firstly, the manufacturing procedure would probably have been to first produce a blank

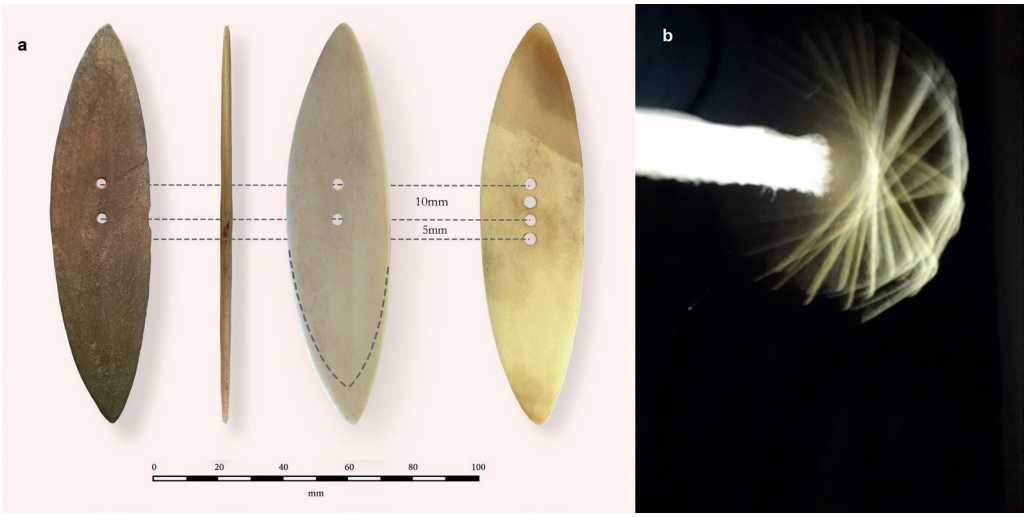


Fig. 4.8: a: A two-holed spinning disc type aerophone (MR5135) fabricated in bone to match the archaeological item (left). Subsequent modifications were made (middle and right) in an attempt to understand the chaîne opératoire. b: Stroboscopic effects of a spinning disc instrument photographed during an actualistic experiment. All photographs by the author.

and then bore the holes, leaving final shaping of the implement to last, allowing for the requisite symmetry to be achieved relative to the holes. And secondly, no significant use-wear was identified along the perimeter of the holes" (Kumbani *et al.* 2019, 697–699).

Information about the holes in MR5135 was edited out of the published article (Kumbani *et al.* 2019). What was observed, however, raises questions about the technique and the tools used by the early maker. Examples are plentiful that show a puncture/perforation technique resulting in holes with bi-conical shape, viewed in cross section (Talamo *et al.* 2021). This method stands in contrast to the holes in MR5135, which appear as if a present-day mechanical drill press was used to bore through the bone, 2.2 mm thick. Whatever technique or tools were used, they left parallel-sided holes that are perfectly perpendicular to the ventral and dorsal surfaces.

MR5135 is an informative item from the point of view of the procedures of production. The conclusion arrived at is that the item is an unfinished aerophone of the spinning-disk type. The beguiling issue that remains unresolved is: How were the holes made? Were they made with a bow-operated drill? Nothing like this has been recovered in archaeological context in South Africa in the timeframe in which MR5135 was deposited. This might be a consequence of preservation but it might not. The actualistic copy of MR5135 raised unexpected issues but the experiment provided an unanticipated explanation that takes into account the mind of the maker. What was demonstrated in this case is that the dead ends, reformulations and failures are

just as important to the outcomes of experimental archaeology as is positive data. Negative results can contribute to an enhanced understanding.

Stroboscopic and aural

Experimentation with the woer woer and *!goin !goin* type aerophones delivered results outside strictly acoustic parameters. The animated haptics of *!goin !goin* bullroarer KK052 are mentioned above. These instruments, it was discovered, also produced stroboscopic effects, which is a visual phenomenon that occurs when a flashing light illuminates a moving object. This outcome came as a real surprise (Fig. 4.8b). The experiment showed that free aerophones have an acoustic as well as a visual aspect, i.e. they create a stroboscopic effect when played at night in flickering firelight (Kumbani *et al.* 2019). This is a reminder that there are aspects of material ecology (Ingold 2012) that are ephemeral and transitory because they are aural and visual.

Lithophones

The creation of two lithophones for heritage educational purposes at the Living Landscape Project and at Khwa ttu produced their own challenges because of the considerable physicality and material mass involved (Fig. 4.9a). Comparative evaluation of the actualistic instruments facilitated a progressive understanding about how these dolerite rocks may have worked as "gong rocks". Critical to their "sounding" is how each rock is placed and "grounded" (Rusch 2017b; 2021). I emphasise both sounding and grounding because I have begun to suspect that the vibration generated when these rocks are struck may include ground vibration in addition to the audible component (Rusch and Wurz 2018; 2019).

Vibroacoustics, frequencies all-told, which include vibrations that are heard and unheard, was brought to my attention shortly before I received a commission to create a gong rock for the Khwa ttu San Heritage and Education Centre. Dolerite rocks for the first gong rock at the Living Landscape Project were selected purely on their acoustic "ringing" quality. Sound recordings of this gong rock were made and the results were incredible. Sound studio reconstructions of the original recordings are included in a film soundscape; a theatre play; a puppet production and an art installation. Nevertheless, following the first actualistic lithophone created, I began to have doubts about the authenticity and accuracy of the recreated gong. The second gong rock created at Khwa ttu is composed of larger rocks, 8 tonnes in total. I see the second gong rock as more in keeping with what we observe in the archaeological examples (Figs 4.9b and 4.9c). Larger "grounded" dolerite rocks are congruent with the infra-sound hypothesis that poses the question: do gong rocks produce sound that is audible as well as vibrations not heard but received? From this point of view could vibrating rocks be exemplary precursors to the amped bass speakers installed in a motor vehicle, pumping out sound and vibration? Adding incentive to this line of

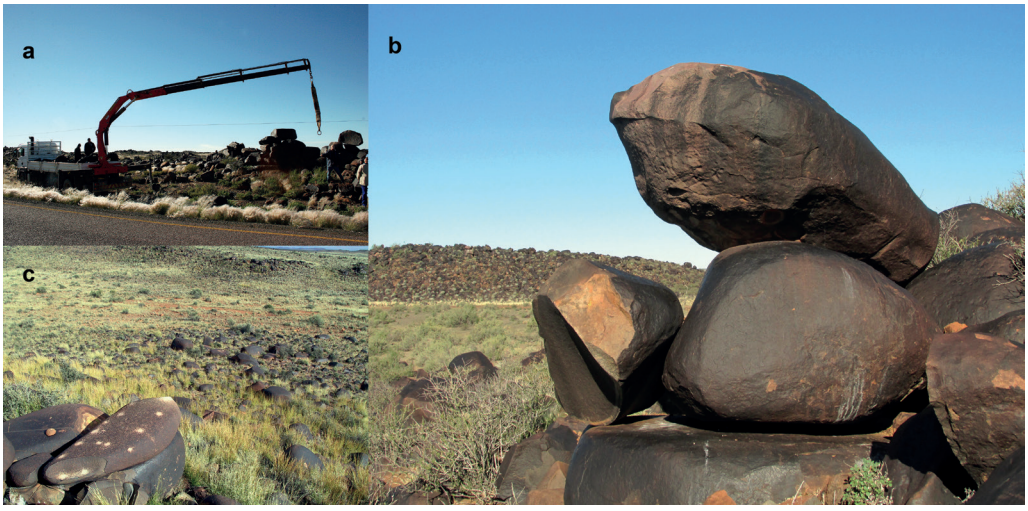


Fig. 4.9: Lithophones. a: First step in the process of creating a lithophone, lifting dolerite boulders. b: The high metal content of the igneous rocks is an element of the instrument. c: High metal content of the igneous rocks in extant archaeological examples located in the Karoo region, southern Africa. Photographs by the author.

enquiry is a rich and extensive vocabulary of words in the now extinct Xam language, referring to vibration, primarily as an embodied experience (Rusch 2016).

Conclusion

> The dress of a woman of Lhassa, / In its place, / Is an invisible element of that place / Made visible (Wallace Stevens 1997, 41)

Writing this chapter I faced challenges, not least language itself, committed as it is to a grammar of subject and object. At issue are "the dualisms that arise from any attempt to analyse process in static terms" (Goodwin 1994, 106). What is written on the page does not adequately convey the "invisible element" involved in the re-enactments I undertook, although the instruments actualised are visible and the sounds are audible. Agency and causation, in the MET idiom, is distributed in a cognitive system that is phenomenologically continuous and interactional. With these observations in mind I have montaged into this conclusion, short impressionistic descriptions for each actualisation.

The case studies and results presented in this chapter challenge the notion of thinking per se, construed as exclusively cerebral. Cognition is not abstracted nor isolated because cognition is understood as immersed and interactive and never static. Consequently, the actulasitic processes in the examples described are not "in the head" but are enacted across time in complex re-enactments involving the vitality of materials and past makers in the construct that Collingwood termed the living

past. In this scenario, re-enactment, material engagement and living pasts become inter-communicative.

At the outset, it was hypothesised that embodied, embedded, enactive and extended cognition might be detected in instrument actualisations. This proposition lies in the conviction that materials and minds are continuous, and therefore 4E cognition would be open to detection in the archaeological instruments and their recreations. The cases studied demonstrate this to be the case, some more convincingly than others. Refinement of the *!goin !goin* aerophone reveals the instrument's entanglement in a regionally situated material ecology, informed by a culturally specific ontology. The rock painting adds an age determination and importantly the depiction confirms physical attributes and details about the instrument. <<With the !goin !goin I feel how it enfolds, gathering into itself the landscape that surrounds it; sparse rain, tree pathways, stillness … and breaths out sound in regular pulses. The enactivating influence of the landscape and the vitality of the materials only become obvious when I plunge into the instrument and play a part in its active becoming.>>

KRM and MR40 demonstrate evidence of embodiment. Sounds from KRM are similar to breath and breathing, which leads to the conclusion that the instrument is beholden to the body as a form of body extension (prosthetic augmentation). The body does not stop at the skin. In both cases sound vibration extends and distributes embodiment through breath-like sound. MR40's dual purpose, functioning as instrument and as a pendant adds further evidence that links body and sound. <<With MR40 I felt the somaesthetic (Shusterman 2008) appeal of the object immediately. Any sense of it-and-me is permiated by the good-to-feel contours of its three-dimensional morphology. There is no surprise that it was a pendant and that it had pressed and rubbed against some body. The surprise is the sound it makes and the low frequency (40Hz) that it emits implants sound in my body.>>

<<Shaping the KRM rib bone, there is a smell of marrow, a distinct oiliness on my finger tips. Increasingly, I allow the material to generate its own form. More hard cortical bone removed exposes the trabecular honeycomb-like structure beneath. There is a strong sense of interiority, penetrating the surface and exposing bone inside. Linked to this, alterations of the sound.>>

MR5135, producing no sound, was an enigma to begin with. Finding reasons for the instrument's silence led to technical investigation and an enquiry into the thought process of the maker. Attempts to play MR5135 highlighted the instrument's asymmetry, which led to the conclusion that it is a work in progress. The procedure appears to follow the same method used to manufacture ostrich eggshell (OES) beads (Miller and Wang 2022). First, OES is broken into fragments and blanks made. Then, holes are drilled. This is followed by final finessing to achieve a circular form, symmetrical to the hole. MR5135 appears to follow a similar procedure – blank, followed by holes, with finishing and shaping left to the final stage. In the case of MR5135 the final finessing was never completed, and the absence of use-wear around the holes supports the work-in-progress conclusion. Decoding the process provides

insight into how the maker engaged and thought with the material. <<MR5135 becomes an obsession with hole-ness. Wholeness and hole-ness in the sense that without sound the instrument seemed incomplete. And then falling into hole-ness, a phenomenology of roundness. As a form holes impart symmetry. MR5135 is shaping me. For how long have holes shaped us?>>

The discovery that free aerophones produce stroboscopic effects was a sharp reminder that the fabrication of musical instruments is, in many respects, a multisensory endeavour. The aerophone's agency does not reside solely in their sound. Aural and visual effects are not isolated in a multisensory world, they correspond. The makers of the instruments probably appreciated audio-visual effects of these instruments. <<First impression, roundness amplified. Bone and pulsating light joined at the centre. And later, dynamical forms materialised by movement.>>

Work is underway to measure the infra-sound component of lithophones. The aim is to establish whether infra-sound is a feature that is ubiquitous to gong rocks or if it is specific to some but not all archaeological lithophones. If this dual property of the gong rocks is correct it would add another level to the understanding of dolerite rocks and their use as lithophones in the Karoo region, South Africa. <<The ancient rocks are present to me. They appreciate my ears, they notice my hands and they recognise my dexterity; while I in turn feel obligued to bring forth their sound.>>[10]

Collingwood was prescient in his observations. He might have foreseen that his assessments would give rise to the field of experimental archaeology. It is less likely that he would have envisaged material engagement theory and the growing scope of MET applications. In the language of process philosophy he did not privilege finality. He believed in duration and the transformations of time and he did not pass over in silence what lies in-between.

Acknowledgements

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Notes

1 Actualistic scenarios, "investigate activities that might have happened in the past using methods and materials that would actually have been available" (Outram 2008, 2). In this sense replica

and replication is misleading because 100% exactitude is not guaranteed, i.e. a replica is never an original.

2 In the context of MET, "the term 'things' is used in the broad sense of material forms, socio-material assemblages and techniques" (Malafouris 2019, 7).

3 For Karl Popper (1889–1943) science proceeds by what he calls "conjectures and refutations". At the core of scientific method is the attempt to refute or disprove theories, which is called the "falsification principle" (Popper 1953).

4 Collingwood arrives at these formulations having worked them out as a philosopher, who made significant contributions to aesthetics, the philosophy of history, metaphysics, the philosophy of language, and the understanding of philosophical method (Monk 2019) but equally as a practicing archaeologist having arrived at the conclusion that "what one learned on a dig depended not merely on what turned up in one's trenches but also on what questions one was asking" (Collingwood 1939, 24–25).

5 Prehension, is a term first used by Alfred Whitehead to explain a form of attention that binds memory and time awareness (Whitehead 1978).

6 Collingwood expands the observation saying: "If what the historian knows is past thoughts, and if he knows them by re-thinking them himself, it follows that the knowledge he achieves by historical inquiry is not knowledge of his situation as opposed to knowledge of himself, it is a knowledge of his situation, which is at the same time knowledge of himself" (Collingwood 1939, 114).

7 The region of lxam-ka !au in central southern Africa became known in colonial times as Bushmanland and remains so named on contemporary maps to this day.

8 Consider the conflation linking actualistic experimenters and makers in the distant past: "The knapper fist thinks through and with the stone before being able to think about the stone and hence about himself as a conscious and reflectively aware agent" (Malafouris 2013, 176–177).

9 Klasies River is a prominent archaeological site in the southern Cape, South Africa, with an occupation spanning the Middle and Late Pleistocene into the Holocene.

10 Reversibility, as indicated earlier, is a quality defined by the ability for an entity to become something else. Reversibility may be experienced as toggling, back-and-forth, between maker and materials. Intensified, reversibility is an oscillation, a resonance. In the context of this chapter the resonance metaphor extends and includes the relatedness of musician and instrument. In enactivating circumstances it is not possible to draw a line between maker and materials. Likewise, there are times we cannot distinguish instrument and musician: who makes the sound?

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Chapter 5

Methodologies to explore the cognitive effects of music in rituals: Implications for studying ancient ritual activities

Raquel Aparicio-Terrés and Carles Escera

Abstract

Music is present in all human societies and has long been related to rituals. Our definition of ritual follows Nicholas M. Hobson and includes predetermined behavioural sequences that are rigid, formal and repetitive, with elements that have no clear instrumental purpose and are part of a broader system of symbolism and meaning. There are sacred and not sacred rituals. Despite the connection between ritual and music, the examination of music in ritual contexts has been neglected in most scientific disciplines related to neuroscience and psychology. In this article, we review studies on the cognitive effects of present-day ritualistic music. By emphasising the methodological characteristics of these studies, we propose several considerations for future scientific investigations on the topic. Specifically, we observe that the function of music in modern rituals may be reduced to modulating emotions during the event and/or inducing alterations in the participants' mental states. Based on this observation, we suggest a series of target cognitive and physiological measures to lead future research on the subject. Also, we suggest ways in which brain activity can be measured and analysed in response to different ritualistic musical stimuli. We argue that exploring how music in present-day ritualistic contexts affects brain activity, cognition, behaviour, and physiology will deepen our understanding of ancient ritual activity.

Keywords: rituals, music, emotions, altered states of consciousness, neuroscience

Introduction

Sound is an ephemeral signal from a vibrating source, which conveys a communicative meaning when produced intentionally in the form of specific bursts or vocal tract

utterances, whether through rhythmic patterns or melodic structures such as in music. For many animals, sound is their main form of communication. For example, the male bullfrogs from the *Rana catesbeiana* species emit multicroak, quasiharmonic calls that are key for neighbour recognition and their reproductive function (Simmons 2004). In humans, the process of structuring auditory stimuli seems to be the result of both old evolutionary abilities that allowed humans to react to noises, and the emergence of higher-level functions of the brain (Reybrouck 2013). Related to sound is the question of music, whose origins are still a matter of debate. Some researchers have suggested that music and language share a common origin, a protolanguage consisting of song-like strings with holistic meanings (e.g., Fenk-Oczlon 2017). Whether music has evolved from language or whether it is grounded in our biology is still unknown. Nevertheless, it is a fact that music is one of the universal cultural elements of all human societies (Mehr *et al.* 2019). Its ubiquity and antiquity have inspired considerable discussion regarding its function.

Scholars from many different disciplines, including psychology, anthropology and philosophy, have proposed a countless number of theories about the purpose of music (e.g. Fitch 2006; Peretz 2006; Schäfer and Sedlmeier 2010). Some hypotheses concerning its ancient functions have received more attention in the scientific literature. An example is put forth by Miller (2000), who argues that music-making served as a plausible indicator of biological fitness and represents a manifestation of sexual selection, similar to the peacock's tail. This idea has inspired empirical investigations into the subject (Grewe *et al.* 2009; Guéguen *et al.* 2013; Lebuda *et al.* 2021). The most promising approach concerning the role of music suggests that music might have already played the role that music still serves today. By analysing individuals' behaviour related to music in modern societies, Schäfer *et al.* (2013) suggested that the most important role of music in human experience is to regulate arousal and mood and enhance self-awareness, possibly by shaping identity and self-perception through music-evoked emotions. This finding aligns with neuroscientific evidence indicating that music can evoke strong and diverse emotions, even in infants as young as four months old (Zentner and Kagan 1996; 1998). It also indicates that music can engage multiple cognitive functions and their underlying neural networks in the brain (Vuilleumier and Trost 2015). However, the majority of these studies have systematically left out a universal and crucial behaviour that seems to have been central to humanness: spirituality (d'Errico and Henshilwood 2011) and, associated with it, rituals (Pettitt 2011). Anthropologists and ethnomusicologists have maintained that music is always present in ritual activities worldwide (Tuzin 1984; Bloch 1989; Nettl 2000; Trehub *et al.* 2015; Killin 2018). In view of this gap, we aim to elucidate the human experience, in terms of brain activity, cognition, behaviour and physiology, that emerges from sounds used in rituals.

Ritual has been an inspiring topic in the social sciences for a long time (e.g., Durkheim 1915; Geertz 1973; Bell 2009; Pettitt 2011). Therefore, definitions of ritual

abound and change depending on the focus given by scholars. In this article, we aim to explore the human experience that emerges from sounds used in rituals. As a consequence, we will use a definition that addresses the ritual's psychology at the individual level and that is compatible with the majority of previous studies on the topic. In a recent review, Hobson *et al.* (2018) defined rituals as predetermined behavioural sequences that: (a) are rigid, formal and repetitive, (b) contain elements that have no clear instrumental purpose, and (c) are part of a broader system of symbolism and meaning. The authors also emphasised three key regulatory functions of rituals, namely, the regulation of emotions, performance goal states, and social connection.

Research on the rise of symbolic and spiritual culture has predominantly centered on the visual art of the Upper Palaeolithic in Europe (for a review on the emergence of symbolic culture, see Henshilwood and d'Errico 2011). For instance, widely recognised evidence pointing towards advanced cognitive and symbolic behaviours in *Homo* are the patterns etched into ochre pieces from Blombos dated to c. 60 ka (sixty thousand years) and ostrich eggshell fragments from Diepkloof also dated to that time (Henshilwood *et al.* 2002; 2009; Hodgson 2014; 2016; but see Tylén *et al.* 2020), both of which are located in South Africa. Nonetheless, musical activities can also be significant but may leave no archaeological evidence. Despite some noteworthy debates on the presence of musical activity (d'Errico *et al.* 1998; 2003), its contextualisation within early expressions of symbolic and religious practices is strikingly scarce. In humans, physiological adaptations to producing complex vocalisations seemed to be already present 400,000 years ago in *Homo heidelbergensis* (de Boer 2017). Therefore, it is highly plausible that humans already possessed the ability to produce music through the use of their bodies or materials that have since been lost to time. The oldest musical instruments are found in Europe and consists in aerophones found in Germany and France dated from c. 40,000 years BP (Buisson 1990; Conard *et al.* 2009; for a summary, see Jiménez-Pasalodos *et al.* 2021).

In this article, we review some studies exploring the cognitive effects of music in ritualistic contexts. We emphasise the methodological aspects of a series of publications that have explored this area. Subsequently, we draft methodological approaches for future scientific investigations. Importantly, we target procedures that allow for a mechanistic understanding of human cognition related to ritualistic music. Lastly, we discuss some limitations and potential challenges of our approaches.

The cognitive effects of music during ritualistic contexts

Evidence from various fields, including anthropology, psychology and neuroscience, suggest that rituals have deep biological roots in human evolution and that they have fulfilled important functions in human social and cognitive development (for a review, see Tonna *et al.* 2019). Notably, music and dancing likely played a central role in early

human ritual practices (Morley 2009). Psychedelic (Sterelny 2018; Winkelman 2019a; 2019b; 2021a; 2021b) and other mind-altering techniques such as meditation (Rossano 2007) are also thought to have significantly contributed to emergence of ritual activity. Even though these elements play a role in the human experience involving rituals, only some of them have received attention in neuroscience and psychology. Specifically, only the role of psychedelics on cognition, behaviour and physiology in ritualistic settings has been systematically studied, both in naturalistic contexts (e.g., Harner 1972; Kensinger 1973; Descola 1996) and under laboratory conditions (e.g., de Araujo *et al.* 2012; Carhart-Harris *et al.* 2016). Therefore, little is known about the role that other elements play in the human experience during rituals, such as sound, or the interplay between them. This contrast is probably due to the vast scientific knowledge available about the mechanisms of action of many psychoactive drugs and the little knowledge about the physiological mechanisms that underly individual human auditory experiences in general.

What is the role of particular drugs in enhancing engagement with music? Psilocybin and lysergic acid diethylamide (LSD) are typical psychedelics that alter fundamental brain processes related to perception, emotion, cognition and the sense of self (Swanson 2018). Research examining the interplay between the effects of drugs and music on cognition showed that music enhances the cognitive effects of LSD, such as self-referential processes (Preller *et al.* 2017) and visual hallucinations (Kaelen *et al.* 2018). Studies investigating drug use in the context of musical performances have shown that psychedelic drugs influence time perception during these performances (Fachner 2011) and the performances themselves (Fachner 2012). These findings suggest the existence of a cultural practice involving drug usage in specific settings, which is not associated with problematic use but rather serves defined purposes. Moreover, psilocybin consumption enhances engagement with music (Kaelen *et al.* 2018). Some have suggested that environments with characteristics such as specific artwork, colour-changing lights, or music falling into the genre of psychedelic trance, may elicit experiences similar to those induced by psychedelic substances (Vitos 2017; Olson *et al.* 2020). All these findings convey the idea that the cognitive effects emerging during rituals cannot be reduced to the effects of drugs. Rather, other elements such as the sensory environment, cultural symbolism, social interaction, and their interplay should be considered to explain and understand human experience, including music. It has been observed that the strategic use of psychedelics is now largely absent from most human cultures (Arce and Winkelman 2021). The vanishing of drug-culture among the general population suggests that more convenient and safer ways to access altered states of consciousness (ASCs) are now an integral part of the human niche, highlighting again the scientifically overestimated role of drugs in rituals. Alternatively, it could simply imply a reduced prevalence of ASCs in the population.

A few studies explored the effects of sound on cognition during ritualistic contexts. Funeral rituals within some Western traditions, for example, can be characterised as

secularised and individualised ceremonies (Venbrux *et al.* 2009). The music that is played in these types of rituals has three main functions (Bruin-Mollenhorst 2020). First, music acts as the building block of ritual, because it stylises and formalises the ceremony. For example, in funerary rituals, music is often used to separate the mourner's speeches. Also, the chosen music is often related to the deceased, presenting part of its identity. Lastly, music during funerals helps mourners gain time and sphere to control their emotions, which is a key aspect of human cognition. At the same time, music during funerals may evoke other complex emotions commonly associated with music listening (Zentner *et al.* 2008).

The cognitive characteristics mediated by sound have also been explored in ritualistic settings as illustrated by a study related to ayahuasca ceremonies. Ayahuasca is a hallucinogenic beverage that can modulate mood, memory and emotions, and might evoke perceptions similar to LSD and psilocybin (Schultes *et al.* 1992). According to the organisers of the events in which ayahuasca is consumed, two key elements seem to be extremely necessary: the ritual context and the songs performed during the ritual (Moreira and MacRae 2011). These songs are typically simple instrumental music or medicine songs known as *icaros*. These icaros are typically sung by healers with precise therapeutic intentions tailored to the unique inner experiences of the participants during the ceremony (Giove Nakazawa 1993; Bustos 2008). While the basic structure of icaros is often consistent, their adaptability is a key feature due to their method of usage. Defining characteristics of icaros include their association with healing in Amazonian medicine and shamanism in a broad sense, their primary vocal nature, monophonic melody, and their rendition by healers conducting healing ceremonies (Graham *et al.* 2023). However, the ongoing globalisation of ayahuasca and Amazonian medicine has introduced new instruments, harmonies and musical elements into rituals (Labate 2014).

During ayahuasca ceremonies, distortions in time perception might occur. Interestingly, this cognitive alteration seems to be related to the music that plays during the event and not to the ingestion of the drug, which has other purposes related to hallucinations (Campagnoli *et al.* 2020). Other studies that explored the use of ayahuasca in non-laboratory settings, namely in real-world contexts, did not provide any description concerning any musical stimuli present during the ceremony (Ruffell *et al.* 2021).

The most studied musical stimuli in terms of its effects on cognition and behaviour is drumming and drum-like stimuli (Oohashi *et al.* 2002; Szabó 2004; Gingras *et al.* 2014; Kjellgren and Eriksson 2010; Hove *et al.* 2016; Lanzilotti *et al.* 2019; Rogerson *et al.* 2021). Moreover, previous anthropological studies have revealed that unconnected cultures around the world use repetitive auditory stimulation as facilitators to induce ASCs (Winkelman 1986; Harner 1990; Vitebsky 1995). From a neuroscientific point of view, a series of studies measuring brain activity during rituals in which drumming was involved have been conducted. Oohashi *et al.* (2002) recorded brain activity with electroencephalography (EEG) from one participant

during a possession ceremony that takes places in Bali, Indonesia, known as "Calonarang". In general terms, these ceremonies are conducted to achieve a state of possession, during which an individual's behaviour is commonly attributed to the influence of an external entity taking control of their being (Kua *et al.* 1986). During the "Carlonarang", as described by Oohashi *et al.* (2002), participants of the ceremony, excluding the possessed individual, vigorously beat a bamboo musical instrument with a stick during the whole event. At the ceremony climax the music is played very loudly. The description of the acoustic environment during the ritual indicates a significant role for rhythmic auditory stimulation in the ceremony. However, the experimental design did not provide a means to disentangle the specific impact of rhythmic music on memory distortions, brain measurements, and automatism-like actions exhibited by the possessed individuals. Oohashi *et al.* (2002) early study led the way for further exploration of the cognitive characteristics and brain configuration during ASCs in ritualistic settings. In a subsequent investigation (Kawai *et al.* 2017), more participants were included, but the descriptions of the music were still not comprehensive.

In contrast to early field research, the more recent study by Huels *et al.* (2021) has been conducted in an experimental setting. It aimed to investigate the phenomenology and electrophysiological characteristics of trance states by using drumming stimulation. Notably, trance is associated with the experience of separation of an individual's soul from their physical body, either to embark on a journey or due to an abduction of the body (Ember and Carolus 2017). Therefore, in contrast to possession states as those analysed in the Oohashi *et al.* (2002) study, in that of Huels *et al.* (2021) it was resolved that during trance states the loss of one's typical sense of self was not typically attributed to being overpowered by an external entity. In Huels *et al.*'s experiment, experienced (i.e., shamanic practitioners) and inexperienced participants were exposed to two distinct auditory conditions, namely 25 minutes of drumming and 25 minutes of classical music, serving as the control condition. However, only the experienced group was asked to enter an ASC. The phenomenological experiences of the participants while listening to drumming and classical music was measured with the retrospective OAV questionnaire that measures ASCs characteristics in phenomenological experiences (Studerus *et al.* 2010). Also, the participants' brain activity was recorded with electroencephalography (EEG) and was characterised in terms of the spectral components of the brain signals, their functional connectivity (i.e., the functional relationship between brain areas), signal diversity (i.e., the number of different patterns in the brain signal), and criticality (i.e., the balance between order and disorder in brain network processing). The results revealed different brain activity patterns between practitioners and naïve participants across all auditory conditions. First, the brain activity patterns of shamanic practitioners during drumming, compared to inexperienced participants, were distinguished by enhanced gamma power that correlated with the degree of visual alterations. Also, the brain activity was characterised by decreased signal diversity in the gamma band

that inversely correlated with insightfulness. Second, both during drumming and classical music, shamanic practitioners displayed a decreased low alpha and increased low beta functional connectivity, and increased criticality in the low beta, high beta, and gamma bands, with increased criticality in the low beta band correlating with complex imagery and elementary visual alterations. Overall, these findings suggest that shamanic practitioners can enter an ASC characterised by a specific brain activity profile that correlates with self-report changes in subjective experience when listening to musical stimuli. They also indicate that shamanic practitioners have a trait-specific brain activity profile compared to inexperienced participants, when listening to musical stimuli. Another study using drumming stimulation in laboratory settings to induce trance in experienced participants did not allow to disentangle the effects of the repetitive music on the cognitive measures gathered due to methodological limitations (Hove *et al.* 2016). In this study, both the control and experimental conditions employed the same repetitive music, with the primary distinction being the instructions given to participants (i.e., to enter a trance state in the experimental condition and to rest in the control condition). Consequently, the design of this study rendered it unfeasible to effectively isolate and evaluate the precise impact of music on the induction of trance.

Some of the previous studies discussed above (Oohashi *et al.* 2002; Kawai *et al.* 2017; Huels *et al.* 2021) were conducted with the objective of characterising the neural activity of ASCs, namely possession and trance states. However, further investigation into the underlying neural signals is necessary to gain a deeper understanding of the mechanisms involved. Brain activity is oscillatory in nature. It is comprised by a series of periodic and organised changes in the electric signals of the brain originating from large populations of neurons. Thus, as with any other oscillatory signal, brain activity can be analysed in the frequency domain. In the series of studies exploring rituals involving drumming (Oohashi *et al.* 2002; Kawai *et al.* 2017; Huels *et al.* 2021), the electrophysiological data were decomposed in its major frequency bands, namely delta (0.5–3 Hz), theta (3.5–7.5 Hz), alpha (8–12 Hz), beta (13–20 Hz) and gamma (21–50 Hz) bands (Berger 1929; Jasper and Andrews 1936; Hoagland *et al.* 1937a; 1937b; Dustman *et al.* 1962). These frequency bands have been found to be linked to broad perceptual, sensorimotor and cognitive operations (Basar *et al.* 2001) and ASCs (Lehmann *et al.* 2001). However, when measured alone, EEG frequency bands only provide descriptive and broad data. In other words, the information provided about the changes in frequency bands during ASCs and resting states in these studies do not allow for a mechanistic explanation of the observed behaviour during possession and trance rituals. Moreover, exploring EEG activity in terms of frequency bands originated in the pre-computer era, in which technical limitations did not allow for more sophisticated types of analyses (Newson and Thiagarajan 2019). Although more modern computations on the brain signals, such as functional connectivity, signal diversity and criticality provide important information about the patterns of brain activity associated with behaviour, these measures on their own do not provide a

mechanistic explanation for why certain behaviours occur. To fully understand the relationship between brain activity and behaviour, additional information about the specific neural circuits and processes involved is needed. We believe that the study of ASCs would benefit from recent analytical approaches that exploit the rich temporal information of the EEG, as consciousness has been suggested to be a highly dynamic process (Tononi and Edelman 1998). Examples of such approaches include EEG source localisation techniques, that allow to see the propagation pattern of the origin of activity in brain networks (He *et al.* 2018; Michel and He 2019).

Shamanic drumming and electronic music share the common feature of using intense and repetitive beats as a fundamental musical element that has long been associated with inducing altered states of consciousness (Winkelman 1986). Although the specifics of the repetitive elements in electronic music and shamanic drumming may differ, the impact of rhythm on the human brain remains constant. However, in the literature from psychology and cognitive neuroscience on electronic music, this kind of auditory stimulation is not often studied in isolation, but rather as part of a larger ritual context, such as rave parties or electronic dance music festivals. It is suggested that ASCs induced by the characteristics of electronic music events are the result of what Newson *et al.* (2021) call the "4Ds": (1) dancing, (2) intense rhythmic drums, (3) sleep deprivation and (4) drugs, particularly psychedelics. Newson *et al.* (2021) conducted a retrospective online survey to explore subjective experiences at raves and illegal underground parties, where drug use is relatively uninhibited. The results of the survey showed that the 4Ds are crucial to how events are perceived as ritualistic and transformative, particularly in fostering communal feelings. However, the cognitive alterations produced by music in raves and free parties remain unknown. Again, the neuroscientific literature focuses mostly on the effects that drug consumption has on human experience in raves (e.g., Lyvers and Meester 2012; Millière 2017; Nour and Carhart-Harris 2017).

Experimental considerations

In an attempt to take a step further in the investigation into the causes of altered behaviour, cognition and subjective experience during rituals, here we draft a series of methodological considerations for the study of the cognitive effects of music in ritualistic settings. First, the studies on funerals, ceremonies related to ayahuasca, possession trance and rave parties reviewed above suggest that sound is able to serve very distinct functions depending on the target ritual. During rave parties and possession trance, the selected music has very specific characteristics. It is drum-like stimuli that is supposed to entrance the listener or aid in the production of an ASC (Vaitl *et al.* 2005). In contrast, the characteristics of funeral music and music used in ayuahuasca ceremonies can vary substantially between these types of rituals, as funeral music typically aims to mirror the identity of the deceased (Bruin-Mollenhorst 2020), whereas in the context of ayahuasca rituals, it adapts to the specific

requirements and experiences of the participants (Giove Nakazawa 1993; Bustos 2008). In view of these observations, the selection of the analytical approach for studying the cognitive, physiological, and neural effects of sounds used in ritualistic settings should be contingent on the specific function that the sound serves within the given ritual. Therefore, the first methodological consideration is to analyse the role of music in the ritual by asking organisers and participants about it or by conducting a literature review on the topic.

Exploring the human experience related to emotions induced by music

Music can be used during rituals to evoke emotions, regulate emotions, and/or regulate mood, distinctively (Bruin-Mollenhorst 2020). Traditionally, the study of music-evoked emotions has been conducted by asking participants to rate their feelings in response to different musical stimuli (Zentner *et al.* 2008). Therefore, emotions evoked by ritualistic music can be measured directly via self-rating questionnaires. However, self-rating questionnaires, by their very nature, provide subjective data that might be biased. To not rely purely on subjective measures, previous research on the neuroscience and music has also used chills (for a review, see de Fleurian and Pearce 2021) and electrodermal activity, i.e., changes in the electrical conductivity of the skin (e.g., Steinbeis *et al.* 2006), as objective indicators of emotion.

To gain a more comprehensive understanding of emotions evoked by music, it is important to explore brain activity in addition to self-report questionnaires and measures of chills and changes in electrodermal activity. Brain activity can be analysed in different ways to gain insight into the neural mechanisms underlying cognition and behaviour. Two common approaches are temporal and spatial analyses. Temporal analysis involves examining the timing and frequency of neural activity, often using techniques such as electroencephalography (EEG) or magnetoencephalography (MEG). This approach provides information about the timing and synchronisation of neural activity across different brain regions. Spatial analysis involves examining the spatial distribution of neural activity across different brain regions, often using techniques such as functional magnetic resonance imaging (fMRI). This approach delivers information about the specific brain regions and networks involved in cognitive and emotional processes. Music played in ceremonial contexts to evoke emotions may vary greatly in its specific musical characteristics depending on the cultural and social context. As a result, the effects of this type of music on the brain are likely to be more closely associated with spatial patterns of activation across different brain regions. A spatial analysis of brain activity may therefore provide a more comprehensive understanding of the neural mechanisms underlying the emotional and cognitive effects of music played in ceremonial contexts.

Pioneer studies using fMRI – a neuroscientific technique "illuminating" brain regions involved in a particular cognitive or subjective experience – have repeatedly shown that music producing joy and happiness engages brain areas that are different

to those active when listening to sad music. Specifically, music that makes us feel joy and happiness recruits the ventral striatum –a brain structure involved in reward, while music that makes us feel sad activates the hippocampus, amygdala and neighbouring medial temporal lobe areas (Mitterschiffthaler *et al.* 2007). All of these brain areas are involved in emotional and remembering processes. By combining fMRI with pharmacological positron emission tomography (PET), it has been found that the higher pleasure during music listening is related to dopamine release in the ventral regions of the striatum (Salimpoor *et al.* 2011). These traditional neuroimaging studies have mainly focused on dichotomous categories of musical emotions, only focusing on the valence and arousal of the targeted emotion. This reductionist and binary approach might be explained by the strong influence of the discrete emotion theory (Ekman 1992; Izard 2007) on the science of emotions. The discrete emotion theory postulates the existence of a set of universally shared innate basic emotions. While this theory does not disregard the existence of other human emotions, it has profoundly influenced the focus of research within the field of neuroscience of music. In contrast, the emotions that we typically experience in our day-to-day lives are very rarely felt in response to music. In particular, many negative emotions habitually experienced in daily life, such as guilt, shame, jealousy, disgust, contempt, embarrassment, anger, and fear, were virtually never elicited by music (Zentner *et al.* 2008). Moreover, music during rituals might elicit "higher-order" feelings that do not correspond to the more "complex" emotion categories studied, such as wonder, nostalgia, tenderness or transcendence. Therefore, we believe that ritualistic music might be a window to unravel the underlying mechanisms related to higher-order emotions, that still remain unknown. To comprehend the significant relationships between brain regions involved in ritualistic music and the ritualistic music-evoked emotions will be the first step to the comprehension of ritualistic behaviour related to music.

Exploring the human experience related to altered states of consciousness induced by music

During an ASC, there is a qualitative change in conscious experience compared to usual mental states (for a review, see Revonsuo 2009). While in these states, the contents of consciousness do not reliably reflect the surrounding environment. For example, dreaming and sleep-related hallucinations are ASCs that are commonly experienced by the general population. Meditation, flow, lucid dreaming and other mystical states are not so commonly experienced. However, these states are sometimes desirable and voluntarily provoked during rituals.

It has been suggested that ASCs are characterised by transient hypofrontality in the brain, i.e., a decrease of activity in the prefrontal cortex (Dietrich 2003). The prefrontal cortex is one of the last brain regions to mature (for a review, see Nelson and Guyer 2011). It also has a greater degree of specialisation in humans compared to other animals (Miller 2000), and it is often referred to as the "personality center"

of the brain (Hathaway and Newton 2021). The idea behind transient hypofrontality is based on two fundamental assumptions: (a) that the brain has finite resources and that different brain systems, regions and structures compete for them; and (b) that consciousness is a process. Regarding the first assumption, the brain does not receive additional blood flow compared to resting when activity in the brain increases. Rather, a physiological mechanism down-regulates certain brain regions to increase blood flow to areas that are relevant at that moment. In this line, it has been shown that the frontal cortex and the prefrontal cortex are consistently down-regulated when other regions in the brain increase their workload (Dietrich 2006; Del Giorno *et al.* 2010). Assuming this physiological mechanism, different methods of inducing ASCs would target different prefrontal circuits, explaining the uniqueness of each type of altered state.

During transient hypofrontality, a set of cognitive functions have been found to be consistently disrupted: time perception, social inhibition and attention (Dietrich 2003). These cognitive functions are key for general human functioning. Time perception is essential for everyday life and normal processing of the stimuli surrounding us (Fraisse 1984). One's ability to perceive time can be measured by estimating the length of a certain time, also known as subjective time measurements (Allan 1979). The ability to inhibit inappropriate actions is also crucial to human behaviour and life in society (Rae *et al.* 2015). In psychology, alterations in inhibition abilities are traditionally measured using executive function tasks such as the go/no-go task (Diamond 2005). Lastly, attention is the ability to focus the processing system on specific available information, ignoring other stimuli (for a review, see McDowd 2007). Attention has been exhaustively studied in the neuroscientific and psychological literature, and many tasks have been carefully curated to collect information about the many types of attention (e.g., the spatial cueing task for measuring attentional orienting, Posner 2007; the attention network test for measuring attentional control, Fan *et al.* 2002). Although a disruption in this set of cognitive functions has not been directly linked to music used in ritualistic settings, we believe that future research should prioritise them over others.

A direct test of hypofrontality in the context of music-rituals could be examined by using fMRI. However, the music used in rituals to induce ASC is specifically curated for that purpose. That is, this type of ritualistic music might have certain sonic characteristics that affect our brain in specific manners to produce alterations in cognition. Therefore, we believe that in order to explore the ritual music's ability to produce ASCs, it is better to exploit the temporal characteristics of the brain activity with EEG. Specifically, the ritual's music should be characterised in terms of rhythm, melody, harmony, timbre, dynamics, texture and form. The most relevant musical elements for inducing the ASC could be assessed by directly asking the ritual's participants and musicians' experiences. Once the key elements have been detected, EEG responses can be measured as a response to the selected sonic characteristics.

The drumming stimuli used during possession trance rituals (Oohashi *et al.* 2002; Vaitl *et al.* 2005; Kawai *et al.* 2017) stand out by their repetitive elements. To study the brain activity patterns related to rhythmic auditory stimuli, EEG responses have been analysed using a frequency tagging approach (e.g., Nozaradan *et al.* 2012; Nozaradan 2014; Lenc *et al.* 2018). The EEG frequency-tagging technique emerged from the evidence that populations of neurons can synchronise their activity with the temporal envelope of sounds (e.g., Galambos *et al.* 1981; Galambos 1982; Pantev *et al.* 1996; Picton *et al.* 2003; Ross *et al.* 2003). This is, when presenting a repetitive stimulus at a fixed rate, the brain generates periodic activity that is reflected in a periodic change in the amplitude of the signal measured with EEG (Adrian and Matthews 1934). This periodic change can be quantified by computing a mathematical transform of the signal, also known as the Fourier Transform (Regan 1966). This transform allows measuring the peak of brain activity at the frequency of repetition of the stimuli and its harmonics. This approach objectively relates the characteristics of the stimuli and the neural responses. Currently, it is mainly being applied to the study of beat perception (Nozaradan *et al.* 2018). In this regard, we have recently conducted an empirical study to investigate the impact of music with a marked beat at different beat frequencies, trance music, on brain activity as measured with EEG (Aparicio-Terrés *et al.* 2024). Previous research suggested that the brain's activity exhibits the strongest synchronisation with external auditory stimulation at a repetition rate of 2 Hz (120 bpm; Will and Berg 2007). To explore this further, we exposed participants to 1-minute-long trance music extracts at three tempos: 99 bpm, 135 bpm and 171 bpm. Our primary objective was to manipulate the tempo of the songs to modulate the level of synchronisation between brain activity and the beat of the music. Specifically, we wanted to examine whether increased synchronisation would lead to dysfunctional brain function, potentially attributable to excessive brain activity resonance occurring at a low, theta frequency range. To assess brain function, after listening to each song extract participants conducted cognitive tasks and retrospectively filled in questionnaires to capture their phenomenological experiences during music listening. Overall, our results showed that the degree of synchronisation between brain activity and the beat of the songs was related to participants' performance in cognitive tasks. We believe that this approach will be successful in the study of drumming-like stimuli in shamanic rituals. Exploring the relationships between the brain activity dynamics and the perturbations in cognitive function in response to ritualistic sounds will be an important beginning to deepen our understanding of ritualistic behaviour related to music.

Methodological considerations regarding other physiological measures

A series of studies have revealed that ritualistic music affects not only some aspects of cognitive function, such as emotion (Bruin-Mollenhorst 2020) and time perception (Campagnoli *et al.* 2020). Rather, ritualistic music might also affect hormone levels and heart activity that might add to the human experience during rituals.

Previous studies have shown that music and synchronous movement releases endogenous opioids and stimulates brain circuits related to dopamine and norepinephrine (Launay *et al.* 2016; Tarr *et al.* 2016). The "Dance of Souls" is an annual event that takes place in Phoenix, Arizona, lasting for approximately 3.5 hours. During the event, participants undergo temporary piercings, to which weights are attached, and then proceed to dance to the beat of drumming music. The "Dance of Souls" was influenced by two cultural traditions, namely the Plains Native American Sun dance (also known as the O-Kee-Pa ceremony) and the Hindu Thaipusam festival of the Tamil communities (Catlin 1867). These traditions involve participants piercing their own flesh to induce a state of ecstasy through physical stress. In the "Dance of Souls", pierced participants show increases in cortisol compared to non-pierced participants (Lee *et al.* 2016). Cortisol is a hormone related to physiological stress that has been shown to change as a response to both positive and negative experiences (Kirschbaum and Hellhammer 1994). Also, cortisol can be measured via salivary samples, which has the advantage of being non-invasive (Blair *et al.* 2017). The reported increases in cortisol in pierced participants during the "Dance of Souls" might be explained by the pain produced by the piercings. However, these same participants also showed decreases in psychological stress. The discrepancy between the physiological and psychological states might characterise the ASC produced during extreme rituals. The rhythmic drumming, that accompanied the entire ritual, may have a role in the observed reduction of cortisol levels. However, further research is necessary to elucidate the exact contribution of drumming to this effect.

Due to the non-invasive nature of salivary cortisol and its link to music, it can be argued that salivary cortisol is a measure that should be considered in future research exploring the human experience related to ritualistic sounds. It has also been shown that, at least in laboratory conditions, music can reduce blood pressure levels and cardiac rate, producing relaxation and stress reduction (Crowe 2004). Heart rate can be recorded non-invasively by placing electrodes that can register the heart's electrical activity during myocardial contraction and relaxation. Although the direction of these findings might depend on the type of music that is being listened to, we believe that the music's ability to modulate the cardiovascular system might be key to explaining music-evoked emotions and ASCs. Thus, we suggest that future research on the topic should take into consideration the role of music in modulating the cardiovascular system.

Challenges

Despite the potential advantages of our proposed methods to investigate the role of music in ritualistic settings, several challenges need to be considered. The major difficulty when exploring the human experience in ritualistic contexts is that, usually, most rituals are typically considered sacred (Kua *et al.* 1986). Getting access to sacred settings can be problematic, and conducting neuroscience experiments in such contexts may pose significant ethical challenges, including issues related

to informed consent, participant safety and the potential disruption of the ritual experience. Furthermore, the inclusion of advanced neuroimaging techniques may also introduce logistical challenges, such as the need for specialised equipment and trained personnel. Another major challenge is related to the participants' body posture and movements. The measures of brain activity that we have proposed should usually be carried out with participants sitting and minimising movement so as to not produce noisy artefacts in the brain signals. However, in ritual settings participants usually use movement, such as dancing, to fulfil the function of the ritual (e.g., Oohashi *et al.* 2002; Lee *et al.* 2016; Kawai *et al.* 2017). At present, this difficulty requires studying the patterns of brain activity produced by ritualistic music detached from its ritualistic context, although this surely decreases the observed effects in brain function, narrowing our comprehension of the complex interactions between music and ritualistic experience. Cognition and behaviour can still be described and measured in natural settings. Advances in technology are allowing the development of portable EEG devices (e.g., Rey *et al.* 2012) that will allow measuring good quality brain activity in naturalistic ritual settings in the near future.

Exploring the effects of music in present-day ritualistic contexts on cognition and brain activity can deepen our understanding of the ancient ritual activity and guide future investigation on the topic. In this chapter, we have reviewed a series of experimental studies investigating the effects of present-day ritualistic music on behaviour and the brain. This review has provided insights to guide future investigations in this field. Critical to the study of ancient human experience, we have found that, overall, modern ritualistic music can play two roles at the individual level, namely evoking emotions or inducing altered mental states in the participants of the rituals. By extrapolating from our understanding of contemporary rituals, we can postulate that similar functions and effects may have been attributed to music in ancient rituals.

On the one hand, music can be used in ritualistic contexts to evoke emotions. In this case, the characteristics of the music adapts to the specific emotions intended to be evoked and align with the culturally associated characteristics of those emotions. As a result, generalising the findings reported in these studies to other cultures and historical periods may present several challenges. Regarding the impact of this proposal in advancing our understanding on ancient ritual activity, it is important to acknowledge the culturally sensitive nature of investigating emotions within the context of rituals. While certain music might elicit comparable emotions in modern-day listeners to those experienced in the past, the cultural meanings attributed to these emotions are likely to diverge significantly. Consequently, a comprehensive understanding of emotional responses necessitates an appreciation of cultural nuances and interpretations. Despite these limitations, exploring emotional responses within present-day rituals can still provide valuable insights into the study of the past. By leveraging the knowledge derived from contemporary emotional experiences, we can establish a framework for understanding the emotional landscape of ancient rituals,

while acknowledging the contextual factors that shape these emotions within different cultural and historical contexts.

On the other hand, if the purpose of ritualistic music is to induce altered mental states, we hypothesise that the acoustic stimulation employed in these rituals is deliberately structured, albeit not necessarily as a conscious decision, to affect biological mechanisms that facilitate the desired altered state. The cerebral cortex, which plays a crucial role in cognition (Imam and Finlay 2020), exhibits common underlying attributes despite evolutionary changes and diversification in the mammalian lineage (Mars *et al.* 2018; Heuer *et al.* 2019; Xu *et al.* 2020). This is, the organisation of the cerebral cortex in mammals follows certain principles of structure and function that are independent of culture and evolution. Therefore, investigating the impact of music in present-day ritualistic contexts where the objective is to induce altered mental states, holds significant potential for enriching our understanding of the past. By examining the effects of ritualistic music on the human brain within contemporary settings, we can gain valuable insights into the universal biological mechanisms that underlie altered states of consciousness. These insights can then be extrapolated to shed light on the role of music in ancient rituals, providing a window into the cognitive and experiential dimensions of our ancestors. This may ultimately provide valuable insights into the evolution and function of music in human societies throughout history. Such research can potentially aid in understanding the role of music in the development of human cognition, social behaviour and cultural practices. For now, the use of modern-day psychological proxies is a necessary means of studying ancient human experience from a psychological perspective, as direct observation of psychological processes in ancient populations is not possible.

Conclusions

Music is one of the universal cultural elements of all human societies (Blacking 1995) and has long been related to rituals (Tuzin 1984; Bloch 1989; Nettl 2000). However, the study of the role of ritualistic music has been neglected in most scientific disciplines. We argue that exploring how music in present-day ritualistic contexts affects brain activity, cognition, behaviour and physiology will deepen our understanding of ancient ritual activity and general human experience. Therefore, we first reviewed available studies relating to the effects of music and cognition in ritual settings. We found that music in rituals serves different purposes at the individual level, mainly modulating emotions or inducing alterations in mental functioning. Then, we proposed some methodological considerations for future research in three cases: for exploring the human experience related to emotions induced by music, to altered states of consciousness induced by music, and to other physiological processes. Overall, we suggest that it is important to combine measures of cognitive function, physiology and brain activity to provide with mechanistic explanations of human experience. To this aim, we propose targeting specific cognitive functions and brain activity analyses

depending on the function of the ritualistic music. Specifically, if the music serves to modulate emotion, we recommend combining subjective and/or objective measures of emotion and information about related brain regions. In contrast, if the music in the ritual has special characteristics to induce ASCs, we advocate focusing on those cognitive functions that have been related to transient hypofrontality (Dietrich 2003) and conduct analyses of brain activity measures at the temporal level. Lastly, we argue that exploring the effects of music in present-day ritualistic contexts on cognition and brain activity can enhance our understanding of ancient ritual practices and guide future investigations on the topic. While the characteristics of music used to evoke emotions may vary across cultures, studying emotional responses in contemporary rituals can still offer valuable insights into the emotional landscape of ancient rituals. Similarly, investigating how music is intentionally structured to induce altered mental states in present-day rituals can provide insights into the universal biological mechanisms underlying altered states of consciousness, offering a window into the cognitive and experiential aspects of ancient rituals.

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Chapter 6

Methods for psychoacoustic and emotional evaluation of archaeological soundscapes with auralisation

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Abstract

In this chapter, the most cutting-edge approaches in psychoacoustics used in archaeology are critically examined, with an emphasis on the study of rock art locations. The capturing of reverberation with a measured impulse response is presented as a crucial methodology for recording the acoustic properties of rock art sites, extracting numerical parameters and conducting statistical analyses, and performing auralisations. In archaeology, auralisation has numerous uses, including the study of psychoacoustics and the preservation of acoustic heritage. Regarding psychoacoustics, several behavioural scales used in the research about the perception and emotional responses to soundscapes are discussed, along with the studies that implement them. The need for the creation of new instruments specific for the recently born field of psychoarchaeoacoustics is debated, as well as the best strategies to overcome cultural biases that studying the sound of the past in the present inevitably entails.

Keywords: acoustics, emotion, psychoacoustics, archaeoacoustics, behaviour

Introduction

Over the past few decades, prolific research in the field of psychoacoustics has focused on unravelling how humans relate to sound in space in terms of emotional responses (Barron 1971; Schroeder *et al.* 1974; Västfjäll *et al.* 2002a; Farina *et al.* 2007; Lokki *et al.* 2010; Pätynen and Lokki 2011; Kuusinen *et al.* 2014). Emotional reactions are more strongly triggered when listeners feel immersed in the soundscapes (Västfjäll 2003; Fan *et al.* 2015). The latter are understood as acoustic environments – the

combination of acoustic resources, natural and artificial – as perceived by humans, in context (Southworth 1969). Because of these strong emotional reactions, the use of spatialised sounds and auralisation (Vorländer 2008) have gained interest among psychoacousticians. Key to these approaches is the impulse response technique (Farina *et al.* 2007) for the recording of the acoustic print of sonic spaces. The technique has been implemented for years in the field of archaeoacoustics and, more recently, for auralisation and psychoacoustical investigation (Manzetti 2016; Ferrando 2020), giving birth to the field of "psychoarchaeoacoustics" (Valenzuela *et al.* 2020).

Nevertheless, to make psychology and archaeoacoustics work together, non-technical challenges must be sorted out. One of such challenges is the ability to explore the emotional dimensions in listeners while they are immersed in an auditory environment. For this to be possible, the use of validated scales is necessary in order to evaluate subjects' affective responses. Spanning from graphical models (Russell 1980) to semantic differential scales (Susini *et al.* 2012), it is possible to employ a large number of instruments for self-reporting of emotion, although only a few are specifically developed for the evaluation of music-evoked affection and behaviour (Sandstrom and Russo 2013; Zentner *et al.* 2008). A second challenge is even more significant if the experiment aims to explore non-content features of sound, such as the acoustic characteristics of a space.

In this chapter an overview of the current state of the art is presented in relation to behavioural research focused on the evaluation of emotions evoked by external stimuli, mainly auditory. Several proposals for the study of psychoarchaeoacoustics from the affective point of view will be discussed.

Archaeoacoustics

Over the last four decades some archaeological research has focused on the study of sound in the past (Lubman and Wetherill 1985; Waller 1993; Scarre and Lawson 2006), giving rise to the field of archaeoacoustics. Its main objective is to understand how sound modulated human experience (Scarre and Lawson 2006), which entails the study of the sounds present in the soundscapes of the past. In the case of hunter-gatherer and early agricultural and pastoral societies, researchers are interested in the sounds produced by sonorous objects including bullroarers, bone flutes and drums, as well as the human voice (Morley 2013). The field of archaeoacoustics also includes the study of the acoustics of landscapes and how these modulate sound (Díaz-Andreu *et al.* 2019; 2022a; 2022b; Farina *et al.* 2019; Fazenda *et al.* 2017; Jouteau 2021; Santos da Rosa *et al.* 2023). In the case of the rock art sites produced by hunter-gatherers and early agriculturalists and pastoralists in which the ERC Artsoundscapes project has been working for the last five years, these are usually considered to be special places. In a world inhabited by humans and non-human beings, scholars usually consider at least some of these sites reserved for important social events and transcendental communication. Rock art specialists argue that the imagery was part of a community's

ritual expression with many of the motifs representing mythological scenes and spiritual beings (Gilette *et al.* 2014). Indeed, when available, most ethnographic accounts support this hypothesis (Lewis-Williams 1987; Whitley 1992; Devlet and Devlet 2002; Cole 2011) although in the past the distinction between the sacred and the profane was not as clearcut as it is today. Since there is no ritual without music (Tuzin *et al.* 1984; Nettl 2000), it is reasonable to think that in these places where social and spiritual events took place there was a linkage between sound and rock art in ritualistic contexts. Several studies have examined the possible connections between acoustics, rock art and the sacred in numerous places of archaeological interest, focusing on acoustic effects such as echoes and audibility of distant sounds. For example, in Quebec (Canada), rock art sites are, according to the First Nations, occupied by mythical human-like creatures (Arsenault 2004), and studies revealed that these spots are characterised by distinct acoustic properties, such as echoes (Waller and Arsenault 2008). Prehistoric rock art paintings in Finland, near the canyon lakes of Julma-Ölkky, Somerjärvi and Rotkojärvi, are located in the cliffs that act as the most efficient sound reflectors (Rainio *et al.* 2018).

A method to study the acoustic signature of a space is by recording a set of so-called impulse responses (Mattioli *et al.* 2017; Álvarez-Morales *et al.* 2020). An impulse response, in acoustics, is a physical-mathematical model for the study of sound propagation between an emission point and a receiver point located within the same environment. It contains both time-domain effects, including echoes, discrete reflections and reverberant tails, and frequency-domain effects, including frequency colouration (Farina *et al.* 2007). The system for making impulse response measurements includes a sound source for the generation of a test signal, which reverberates in the space, and is captured by a microphone. The recorded signal is later deconvolved with the test signal to substract the acoustic contribution of the space (Farina *et al.* 2007).

The most common methods for registering an impulse response involve an omnidirectional sound source. The test signal can be impulsive (e.g., a balloon exploding) or a more sophisticated signal, such as a sine sweep (Farina 2007). Using an omnidirectional microphone, the omnidirectional impulse response can be recorded, from which most of the acoustical parameters of interest listed in the ISO 3382-1 (Asociación Española de Normalización y Certificación (AENOR) 2010) can be calculated. However, to calculate spatial acoustic parameters, like the interaural cross-correlation or IACC (Rafaely and Avni 2010), other recording formats are needed, such as high-order Ambisonics. This type of format offers a higher spatial resolution for sound field reconstruction and a more comprehensive characterisation of the acoustic signature of the sonic space (Valenzuela *et al.* 2020).

An impulse response can be used for more than just extracting numerical acoustic parameters. It can be employed as an acoustic filter to convolve any particular sound recorded in anechoic conditions – thus, containing no spatial acoustic information – so that it can be presented to listeners. This process is called auralisation (Vorländer

2008). Auralisation is used in analogy with visualisation to describe the renderisation of audible sound fields, in such a way as to simulate the listening experience at a given position of the modelled space (Kleiner *et al.* 1993). Once the sound is convolved, the resulting signal can be rendered through a decoder to be presented in any type of audio array (for example, binaural, through a pair of headphones). Auralisation is a very powerful technique for evaluating sound and acoustics perception in the laboratory (Lokki 2002; Pätynen 2011; Pätynen and Lokki 2011; Postma and Katz 2015; Vorländer 2015; Valenzuela *et al.* 2020). One of the advantages of recording impulse responses in high-order Ambisonics formats is the possibility to feed large arrays of loudspeakers and perform auralisations with 3D audio systems surrounding the listener (Farina *et al.* 2007).

Auralisation in archaeoacoustic research

In some areas of the world, studying archaeological sites from an acoustic point of view can help us explain some phenomena associated with the myths that may remain from previous periods and were recovered by ethnologists in the modern period (Díaz-Andreu *et al.* 2022a). The use of auralisation can extend the applications of recording impulse responses of archaeological places of interest, from historic buildings to rock art sites. Auralisation in high-order Ambisonics formats allows the recreation of the acoustic environment of places, including archaeological sites. Some examples of recent works in this direction are the acoustic study of the church of Hagia Sophia and the use of its acoustic signature on live performances of Byzantine chants (Abel *et al.* 2013), and the reconstruction of the lost church of the Order of Saint Jerome monastery in Alzira, in Spain (Sender *et al.* 2018). Also, some repositories have been created to make acoustic resources, such as recorded impulse responses of historic buildings, available to anyone, for example, the OpenAIR library (Murphy *et al.* 2017).

The objectives of acoustic reconstruction of archaeological places are diverse. There is an interest in the conservation of historical places using virtual reconstructions to preserve a virtual version in case of loss or damage, as well as to safeguard them from unintentional human modification by offering the audience a virtual version of the places to visit, instead of allowing the general audience to access the original space. An example is the virtual visual and acoustic reconstruction of the Chauvet Pont d'Arc cave in France (Lima *et al.* 2014). The virtual acoustic reconstruction of historical places using the technique of impulse response recordings has numerous applications in historical research. One in which the ERC Artsoundscapes project is particularly interested is the combination of auralisation of the recorded acoustic environments of historical places (rock art sites) with techniques borrowed from experimental psychology. The aim of this approach is to investigate how these acoustic prints modulate the perception of sound and emotions elicited by it in modern-day listeners, giving birth to a new interdisciplinary field of study: experimental psychoarchaeoacoustics (Valenzuela *et al.* 2020).

Psychoarchaeoacoustics

The novel discipline of experimental psychoarchaeoacoustics attempts to reproduce the acoustic conditions from archaeological sites in the laboratory and is interested in how the human experience is modulated when listening to sounds with such acoustic prints, i.e., how sounds are perceived and the type of emotions elicited by them (Valenzuela *et al.* 2020). The recreation of the past human experience of a soundscape involves, first, the recording of the impulse response of our site of interest (e.g., a rock art site). After this, the convolution with a sound recorded in anechoic conditions is needed, to then undertake the rendering of the resulting signal, using a decoder. From the numerical analysis of the acoustic parameters of the recorded impulse responses, it is possible to build hypotheses about the perception of the acoustic environment and using auralisation, testing them on modern-day listeners. This implies the design of behavioural experiments to, ultimately, extract conclusions about how past communities related to sound in those spaces.

There is evidence that the aural component of environments is important to induce a sense of presence in virtual reconstructions (Västfjäll *et al.* 2002a). The way an auditory stimulus is rendered, in terms of the acoustics (Västfjäll *et al.* 2002a) and of the audio system (Västfjäll 2003) affects how emotions are exalted by sound. Spatial audio creates stronger emotional reactions than binaural rendering (Västfjäll 2003). In order to recreate a soundscape, multichannel audio systems are optimal for behavioural experiments to study the emotions elicited by auditory stimuli. Multichannel systems are already widely used to simulate multidimensional sound fields in research, artistic performance or commercial purposes (Guastavino and Katz 2004).

Rating human perception

In the purely acoustic dimension, several scales are useful to assess human perception of acoustics. The basis is the relation between specific acoustic characteristics or phenomena and particular vocabulary of auditory perception. The most evident example is the relation between the sound parameter of *Strength* or *Gain* (G) and the perception of distance from the sound source. If a sound is louder, listeners interpret that the sound source is close to them; if it is quiet, especially if accompanied by a certain amount of reverberation,[1] they interpret that the sound source is far away (Barron 2009, 36). Also, if the reverberation of a space is very short, it is usually described as *dead;* if it is long, it might be described as *live*, because the responsiveness of the room makes listeners give a living entity to it, that can be either dead or alive (Barron 2009, 44).

The short *Subjective Questionnaire* developed by Barron (2009, 44) included several items that listeners had to rate when presented with the acoustics from concert halls, in the context of an acoustic study of British concert halls. These items that listeners had to appraise were *clarity* (from *muddy* to *clear*), *reverberation* (from *dead* to *live*), *envelopment* (from *expansive* to *constricted*), *intimacy* (from *remote* to *intimate*), *loudness* (from *loud* to *quiet*) and *balance* (from *weak* to *loud*) of each frequency range

(high, mid and low). Listeners also had to score the amount of background noise and the overall impression of the hall. Based on this questionnaire, Giménez *et al.* (2011) created the *Acoustic Assessment Scale for Concert Halls*. This questionnaire assesses more than 50 acoustic characteristics of concert halls. However, although some items can be applied to any space indistinctly, the new scale is designed specifically to assess concert halls and not for other types of locations such as, in our case, archaeological or historical sites.

Rating human emotions

Focusing on the study of emotion using behavioural instruments, this section describes some of the numerous scales that exist to evaluate different emotional dimensions. Some scales are designed to assess emotional reactions to general situations, some are specifically designed to assess emotions elicited when a particular stimulus is presented, and some are even more specific, designed for the assessment of emotional reactions to sound and music. Table 6.1 summarises some of these scales, including the *Circumplex Model of Affect* (Russell 1980), the *Self-Assessment Mannikin* (Bradey and Lang 1994), the *Positive and Negative Affect Schedule* (Watson and Clark 1988), the *Activation and Deactivation Adjective Checklist* (Thayer 1967) and the

Table 6.1: Summary of scales employed in emotion assessment, indicating the publications where these were first presented, the type (verbal or visual), if the scales are designed for assessing emotions elicited by stimuli and, more specifically, auditory stimuli, and examples of studies where these have been employed to assess emotions elicited by auditory stimuli.

Scale	*Original reference*	*Type (verbal or visual)*	*Specific for emotions elicited by stimuli*	*Specific for auditory stimuli*	*Studies where it has been employed to assess emotions elicited by auditory stimuli*
Circumplex Model of Affect (CMA)	Russell 1980	Visual	No	No	(Västfjäll *et al.* 2002a; 2002b; Hagman 2010; Nardelli *et al.* 2015)
Self-Assessment Mannikin (SAM)	Bradley and Lang 1994	Visual	Yes	No	Soares *et al.* 2013; Stevens *et al.* 2016; Gatti *et al.* 2018; Yang *et al.* 2018
Positive and Negative Affect Schedule (PANAS)	Watson and Clark 1988	Verbal	No	No	Leupold *et al.* 2007; Emfield and Neider 2014; Pacheco-Unguetti and Parmentier 2014; Campillo *et al.* 2018
Activation Deactivation Adjective Check List (AD ACL)	Thayer 1967	Verbal	No	No	Hirokawa 2004; Binder *et al.* 2005; Lim and Park 2019
Geneva Emotional Musical Scale (GEMS)	Zentner *et al.* 2008	Verbal	Yes	Yes	Lykartsis *et al.* 2013; Kaelen *et al.* 2015; Lopes *et al.* 2019; López-Mochales *et al.* 2022

Geneva Emotional Musical Scale (Zentner *et al.* 2008), and several studies where each of the scales has been used.

The *Circumplex Model of Affect* (Russell 1980) is a visual emotional scale consisting of a double axis of valence and arousal (Fig. 6.1). Valence is a dimension describing pleasure, comprised between the limits of *feeling no pleasure at all* and *feeling great pleasure*. Arousal is a dimension between the limits of *feeling no excitement* or *feeling very relaxed* and *great excitement* or *arousal*. Disposed as axes of a spatial model, they interrelate making affective concepts fall in different points of the edge of circle in the following order: *pleasure* (representing the highest value of pleasure and a middle value of arousal), *excitement* (representing a mid to high value of arousal, and a mid to high value of pleasure), *arousal* (representing the high value of arousal and a mid-value of pleasure), *distress* (representing a mid-high value of arousal mixed with a mid-low value of pleasure), *misery* (representing the lowest value of pleasure and a mid-value of arousal), *depression* (representing a mid-low value of pleasure mixed with a mid-low value of arousal), *sleepiness* (representing the lowest value of arousal and at a mid-value of pleasure) and *contentment* (representing a mid-high value of arousal mixed with a mid-high value of pleasure). This model was offered both as a way psychologists can represent the structure of affective experience, as assessed through self-report, and as a representation of the cognitive structure that laymen utilise in conceptualising affect. Although it is not directly designed to assess emotions evoked by auditory stimuli, it has been employed to fulfil this objective in several studies (Västfjäll *et al.* 2002a; 2002b; Hagman 2010; Nardelli *et al.* 2015). For example, in the study by (Västfjäll *et al.* 2002b), they assessed, using the Circumplex Model of Affect, the affective reactions to interior and exterior binaurally recorded vehicle sounds varying in physical properties. They found that the dimensions of valence and arousal discriminated between affective reactions induced by different qualities of the sounds. In the field of archaeoacoustics, to address the hypothesis that pleasure and excitement could have been experienced during the activities that involved rock art and sound production in specific rock art sites studied, this would be a reliable instrument to assess these feelings in modern-day participants in the presence of the soundscape of those particular spots.

A second model used by psychoacousticians to assess the human perception of acoustics is the *Self-Assessment Manikin* (Bradley and Lang 1994). This is a non-verbal pictorial assessment technique that directly measures pleasure, arousal and dominance associated with a person's affective reaction to a wide variety of stimuli. It is specifically designed to assess reactions to stimuli, although it is not restricted to auditory stimuli. It consists of three rows of drawn manikins, each row with five manikin drawings. Individuals must indicate which manikin of each row represents how they felt most after being presented with a stimulus. The first row corresponds to the rating of pleasure, with five levels, and the element that indicates the level of pleasure of the manikin is its smile. In the second row, which represents arousal, the manikins have a drawn explosion on their stomach, which is very small on the left end of the scale, representing calmness, and large on the right end of the scale, representing high arousal. In the third row, representing dominance,

the size of the manikin changes, with a small manikin on the left end and a large manikin on the right end. Several studies have employed this scale to assess participants' response to auditory stimuli (Soares *et al.* 2013; Stevens *et al.* 2016; Gatti *et al.* 2018; Yang *et al.* 2018). For example, in Yang *et al.* (2018), the objective was to expand existing auditory affective sample databases, such as the International Affective Digitized Sounds or IADS (Bradley and Lang 1999) to sufficiently cover natural sounds. The researchers asked 207 participants to rate 935 sounds, using the Self-Assessment Manikin. The results showed that emotions in sounds could be distinguished on the affective rating scales. Although in this and other cases the object of study is the content of the sound, this could be another example of scale to be used in the study of non-content features of sound (acoustic characteristics).

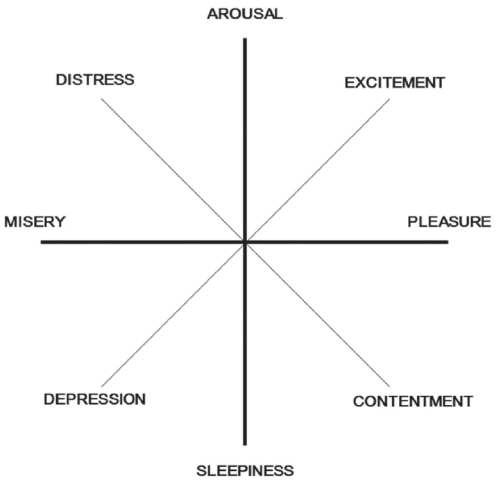


Fig. 6.1: The Circumplex Model of Affect. Based on the original in Russell 1980.

A third model is the *Positive and Negative Affect Schedule* (Hagman 2010), a scale of 20 items for individuals to rate from 1 to 5 (1 being *very slightly or not at all*, 2 *a little*, 3 *moderately*, 4 *quite a bit* and 5 *extremely*). The items included in the scale are *interested, distressed, excited, upset, strong, guilty, scared, hostile, enthusiastic, proud, irritable, alert, ashamed, inspired, nervous, determined, attentive, jittery, active* and *afraid.* The scale is shown to be highly internally consistent, largely uncorrelated and stable at appropriate levels over a two-month time period. The latter makes it unsuitable for studying emotions immediately evoked by the stimulus presented in the moment. However, it has been used in several studies employing stimuli and, in particular, auditory stimuli (Leupold *et al.* 2007; Emfield and Neider 2014; Pacheco-Unguetti and Parmentier 2014; Campillo *et al.* 2018). Nevertheless, all these studies address the effects of long-term auditory stimulation. For example, how does being exposed to a certain environmental sound affect how you feel? None of these studies assess the emotional reactions evoked during or immediately after a short exposure to a sound.

An alternative model to those referred to above is the *Activation-Deactivation Adjective Check List* (AD ACL) (Thayer 1967). This is a multidimensional test of various transitory arousal states, including energetic and tense arousal. Within the broader dimensions of energetic and tense arousal are four subscales: *energy* (General Activation), *tiredness* (Deactivation-Sleep), *tension* (High Activation) and *calmness* (General Deactivation). It consists of a set of 20 items that participants must rate

according to how they are feeling, with four possible values, one indicated with a double tick, equivalent to *strongly agree,* a single tick, equivalent to *agree,* a question mark, equivalent to *I don't know*, and a *no* if they do not feel that emotion at all. The items to rate are: *active, placid, sleepy, jittery, energetic, intense, calm, tired, vigorous, at rest, drowsy, fearful, lively, still, wide awake, clutched up, quiet, full of pep, tense* and *wakeful.* Although this scale is not explicitly designed to rate stimuli, again, several studies employ it to evaluate listeners' emotional reactions to sounds (Hirokawa 2004; Binder *et al.* 2005; Lim and Park 2019). For example, Lim and Park (2019) examined the relationship between arousal and cognitive performance after a musical experience. They examined music-induced arousal, measuring the participant's level of arousal before and after performing a musical task. To do so, they employed the AD ACL scale described. In psychoarchaeoacoustics, it is interesting to measure listeners' level of arousal when presented with the acoustics from a rock art site, especially if there is some association of the place with activities that involved sound production.

The first model and instrument specifically designed to capture the richness of musically evoked emotions is the *Geneva Emotional Musical Scale* (Zentner *et al.* 2008). It comprises nine categories of musical emotions: *wonder, transcendence, tenderness, nostalgia, peacefulness, energy, joyful activation, tension* and *sadness.* In these nine categories are classified the 45 emotional items of the original scale, but there are also two shorter versions available, the GEMS 25 (of 25 items) and the GEMS 9 (of 9 items, in which participants directly rate the emotional categories described before). Listeners rate each item from 1 to 5, 1 being *not at all* and 5 *very much*, according to how they felt during the listening. This scale has been widely used in recent studies about music and emotion (Lykartsis *et al.* 2013; Kaelen *et al.* 2015; Lopes *et al.* 2019; López-Mochales *et al.* 2022). López-Mochales *et al.* (2022) used the GEMS 9 scale so listeners could rate the emotions evoked by two musical pieces from the English Renaissance convolved with the impulse responses recorded in several cathedrals from the UK, to compare if the same musical piece was experienced differently and evoked different emotions when presented with different acoustics. This scale could be a good instrument to use in psychoarchaeoacoustic studies, but it is limited to music and not extensible to other types of sounds, such as natural sounds.

Customised behavioural scales

The objective of validating a behavioural instrument such as a scale is to ensure that the results obtained from that scale applied to a sample can represent the population where the sample was extracted. However, this is not strictly necessary when the comparison is done between the same item or scale in different conditions (for example, in the presence of different sound stimuli), and if the interest rests in the results of the sample itself solely, and not in extrapolating our results to a population. Instead of employing whole psychological scales, some studies select the items most suitable for their objectives and ask participants to rate them in the shape of bipolar scales. For example, a scale of *expressiveness* from *expressive* to *expressionless*

(Västfjäll 2003; López-Mochales *et al.* 2022), a scale of *sleepiness* from *sleepy* to *awake*, or scales that correspond to items borrowed from other scales, such as *pleasure* from *displeased* to *pleased,* or *activation* from *passive* to *active* (Västfjäll 2012).

Some other studies use the method of individual vocabulary profiling (IVP), in which participants directly assign any words they want to the sounds presented, and with statistical techniques such as clustering analysis, the attributes can be classified (Lokki *et al.* 2010) or consensus vocabulary profiling (CVP) in which the first group of participants do individual vocabulary profiling, and then a second group finds consensus between the terms apported by the first group (Susini *et al.* 2012).

A study by Kawakami *et al.* (2013) developed a list of 62 emotional items to rate from 1 to 4 according to how listeners perceived a series of musical excerpts, both considering how the music transmitted each emotion, and how they felt themselves during the listening. The objective was to explore the pleasure exalted by music considered sad, although sadness is considered a negative and unpleasant emotion. In this study they created their own scale borrowing items present in all the other scales described. For example, the item *relaxed,* present in the Circumplex Model of Affect (Russell 1980) and the Self-Assessment Manikin (Bradley and Lang 1994). Also, the item *energetic,* present in the Activation Deactivation Checklist (Thayer 1967). Also, the items *nervous* and *inspired,* present in the Positive and Negative Affect Scale (Watson and Clark 1988). Finally, the items *sad, fascinated, tender, nostalgic, allured, feeling transcendence, moved, tearful, tense* among others, all present in the Geneva Emotional Musical Scale (Zentner *et al.* 2008).

A similar method to that employed in Kawakami *et al.* (2013) was applied in the experiment conducted by López-Mochales *et al.* (2023), in the framework of the European Research Council project Artsoundscapes, involving the auralisation of the soundscapes from several rock art sites in the Republic of Altai (Russia). The experiment was conducted using spatial audio rendering, in a system of 16 loudspeakers installed in the auralisation room of the Immersive Psychoacoustics Laboratory of the project Artsoundscapes, located in the Faculty of Psychology of the University of Barcelona (Fig. 6.2). The study aimed to analyse the modulations in the perception and the emotions elicited by sound on listeners caused by the acoustic prints of several rock art sites of Altai. The study rated a series of 10 psychoacoustical and emotional descriptors after listening to a series of natural sounds convolved with the recorded impulse responses. The set of descriptors was a selection of elements from several of the behavioural scales presented in this section. It included items from the Barron's *Subjective Questionnaire* (Barron 2009) to study the psychoacoustics, and from the *Circumplex Model of Affect,* (Russell 1980) and the *Geneva Emotional Musical Scale* (Zentner *et al.* 2008) to study the emotional responses. Sounds were rated as significantly more *present* when convolved with the impulse responses from some of the rock art sites, compared to those convolved with impulse responses recorded away from the rock art panels. This result matches those obtained from the acoustic analysis of the sites (Díaz-Andreu *et al.* 2022a), which concluded that the locales



Fig. 6.2: Auralisation room of the Immersive Psychoacoustics Laboratory funded by the Artsoundscapes project, located in the Faculty of Psychology of the University of Barcelona. Source: Samantha López-Mochales. © Artsoundscapes project.

where there was presence of rock art were characterised by a total lack of late sound reflections. A way to overcome the inexistence of specific behavioural instruments for the field of psychoarchaeoacoustics is to create new scales and questionnaires based on those applied to other sub-fields of acoustics, such as the study of theatres or concert halls.

Limitations and prospects

In this chapter, the most advanced techniques in archaeoacoustics have critically been appraised, starting with the recording of impulse responses as a way to capture the acoustic print of open spaces, such as rock art sites. It has been pictured how the impulse response is recorded and how it can be later used for extracting the acoustical parameters and performing statistical analysis of those, as well as for convolution with anechoic sounds and auralisation. The advantages of this technique have been highlighted, focusing on its applications in archaeology for both preservation of spaces

and research, and how convenient is also the use of multichannel audio rendering to study what we call psychoarchaeoacoustics. Finally, a series of behavioural scales have been inventoried, all of them widely used in the study of emotions evoked by auditory stimuli, also presenting several studies that employ them with this objective, and detailing how each scale could be used in the field of psychoarchaeoacoustics. Nevertheless, even if there are cutting-edge techniques for recording and rendering soundscapes of rock art sites and validated behavioural instruments, there are numerous limitations in this field of study.

The first limitation of studying soundscapes in the past is that impulse responses are recorded in rock art sites thousands of years after the moment the rock art was produced. During this long time, several elements of the landscape might have changed, both naturally or by human intervention, such as vegetation or the composition of the soil (that can change the absorbance of the floor), and some of these could affect the acoustic character of the space (Álvarez-Morales *et al.* 2020). To overcome this problem, recent sophisticated solutions have been proposed, such as those of archaeoacoustics relying on 3D modelling of the sites, to virtually simulate the acoustic reflections and to obtain a highly accurate impulse response of the place, taking into consideration the original structure and materials. Nevertheless, this approach has only been put into practice in the reconstruction of buildings, for example, the reconstruction of the Roman theatre of Gortyn (Manzetti 2016) but in the case of natural landscapes such as rock art sites, this is more difficult to deal with.

Another limitation is the lack of repositories of anechoic recordings of different characteristics to convolve with our desired impulse responses for auralisation. There are some anechoic repositories with classical music available, but it is challenging to find vocal capella music, music with traditional instruments from different cultures. One of the few examples of the latter is the Artsoundscapes repository of anechoic sounds (López-Mochales and Jiménez-Pasalodos 2021). This repository was created in 2021 to provide a collection of vocal sounds as well as recordings of percussion, wind and string instruments. Many of the instruments recorded were reconstructions of archaeological instruments of different cultural origins.

Some psychoacoustic studies may require non-musical anechoic sounds, such as animal sounds, which are very difficult to obtain since these must be recorded in an anechoic chamber. However, some methods have been proposed to overcome that issue. Quasi-anechoic recordings can be obtained with the deconvolution of a recorded signal with the impulse response from where it was recorded (Gemba 2014). If auralisation is done with non-anechoic sounds, the sounds may carry acoustical information from where the recording was done and, therefore, not provide an accurate representation of the soundscape of interest.

There are many behavioural instruments, validated and applied to several studies in auditory research employing auditory stimuli, that could be adopted and used in the field of psychoarchaeoacoustics. However, there are no instruments for the study of emotions evoked by the non-content features of sound, even though numerous studies show its effect on listeners' affective reactions to sound (Barron 1971; Schroeder

et al. 1974; Farina *et al.* 2007; Lokki *et al.* 2012; Pätynen and Lokki 2016). Therefore, it is necessary to develop specific instruments to evaluate the affective reactions to non-content features of sound, such as loudness, reverberation, clarity, etc. to effectively study psychoarchaeoacoustics.

Finally, a major problem is the lack of knowledge about the cultural understanding of the people who produced and used the rock art. When designing experiments involving auralisation, a sound must be chosen to convolve the impulse response of interest with. When studying rock art sites, in most cases, there is no record of the nature of the soundscapes that the groups of individuals who took part on the production of the rock art were exposed to. Did they employ any instruments in their practices? Which ones? Did they sing? Our knowledge gap extends to the actual undertakings occurring during the production or revisiting of rock art. The use of static acoustic recreations has limitations since it does not encompass the dynamic character of certain acoustic cues that may become apparent as individuals move about the area during these activities. Also, nowadays, listeners are very different from the communities that inhabited the landscapes studied thousands of years ago. Modern-day listeners are exposed to very characteristic soundscapes and acoustics. In what concerns sound and music, and the way listeners engage with it, cultural background cannot be ignored, as not even the definition of music itself is universal (Nettl 2000). Also, regarding the acoustic exposure, the acoustic characteristics of a cave or mountain shelter where rock art paintings or carvings can be found, are characterised, for example, by slightly longer reverberation times in comparison to the free field. However, these are not salient at all for Western individuals who live in buildings characterised by much longer reverberation times.

So far, in the studies conducted in the framework of the ERC project Artsoundscapes, two strategies have been designed to overcome cultural biases. The first one was implemented, after much discussion between the psychologists and the ethnomusicologists in the project, in the study by López-Mochales *et al.* (2023) that analysed the perception and emotions elicited by the acoustics of the rock art landscapes of Altai (Russia). In this study, on the advice of the ethnomusicologists the sounds selected were from natural sources, to avoid the cultural bias that music could cause. The second one is currently being implemented in the newest study by López-Mochales *et al.*, that investigates the perception of the acoustics from Cuevas de la Araña, a rock art site located in Bicorp, Spain (Santos da Rosa *et al.* 2023) using an individual vocabulary profiling technique. Here, the set of sounds selected includes musical excerpts from songs that are aesthetically appealing for the listeners that take part in the study, according to a survey previously conducted. This strategy is being implemented to facilitate the emotional reactions to music, that will be hypothetically modulated by the impulse responses from the rock art site. The main disadvantage of this strategy is that it does not reproduce all the elements of the listening experience endured by the individuals that took part in the activities involving rock art production. In the future, performing experiments with participants from different cultures and with very different lifestyles is crucial to separate the

cultural component of sound and acoustics exposure from the unbiased emotional reaction that the acoustics of interest could elicit.

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Note

1 Reverberation: Series of sound reflection paths, where each individual reflection is very close in time to its neighbours and thus arrive at the listeners as a dense set of reflections (Howard and Angus 1996, 286–287).

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Chapter 7

Ethnohistorical sources in archaeoacoustics research: A case study from South-Central California

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Abstract

This article explores the use of ethnohistoric data for the understandings of the acoustic and sound-world of rock art sites. A discussion on the complexities of using ethnohistorical documents in the study of rock art and archaeoacoustics is made using Yokuts rock art as a case study. The analysis follows five lines of evidence: the placement of rock art, first, in sonorous landscapes and, second, in places with "special" acoustics; the representation of musical practices and sound-producing instruments; the evidence of musical instruments in the period under study and, finally, the production of rock art at or near lithophones. It is concluded that critically reading ethnohistorical sources may reveal conceptual inadequacies when approaching the cultural understanding of sound in other cultures and assist the research questions followed in fieldwork. Finally, the analysis of ethnohistorical sources makes archaeoacousticians undertaking fieldwork aware of possible sites and lines of research that could be sensitive and/or restricted to certain members of the society involved.

Keywords: archaeoacoustics, rock art, ethnohistory, Yokuts, California, landscape, sound, music, musical practices, lithophones

Introduction

In 1998, Paul Taçon and Chris Chippindale distinguished the study of rock art based on formal methods from analyses that followed informed methods. Formal methods refer to the systematic measurement and evaluation of a set of features without the assistance of ethnographic knowledge. In contrast, informed methods require cultural knowledge of the art acquired through insights "passed on directly or indirectly from

those who made and used the rock art" (Taçon and Chippindale 1998, 6). The division between formal and informed methods, however, is not as clear-cut as it seems. On the one hand, the interpretation of the results of analyses based on formal methods is, more often than not, inspired by ethnographic sources. This is because they may provide clues on how to culturally interpret rock art sites and/or landscapes. On the other hand, as Taçon and Chippindale acknowledged, there are only a few rock art traditions that continue into the present and the ethnographic information on them is scant (Morwood and Hobbs 1992; Keyser *et al.* 2006; Blundell *et al.* 2010). Therefore, it could be said that the analysis of rock art areas where informed methods are possible thanks to knowledge obtained "through ethnography, through ethnohistory, through the historical record, or through modern understanding known with good cause to perpetuate ancient knowledge" (Taçon and Chippindale 1998, 6) may often require to be assisted by formal methods of analysis.

In the last two decades archaeology has experienced a renewal in the way past communities are examined. In rock art studies this has led specialists, among others, to an attempt to go beyond materiality and recover less evident and intangible cultural signs such as those related to the senses, including hearing. This is because pre-industrial societies around the world give special importance to places where distinctive acoustic effects are generated. As some ethnographic sources hint, these sonorous places are ontologically related to supernatural beings and embedded with agency (for examples of this and a global overview on this see Díaz-Andreu *et al.* 2021, 3–14). Formal and informed methods are two perspectives to be used in the analysis of the relationship between sound and rock art (Rainbird 2002; Waller 2005b; Devereux 2008; Lahelma 2008; 2010; Loose 2008; Waller and Arsenault 2008; Zawadzka 2011; Arsenault and Zawadzka 2014; Äikäs 2015). In some areas, historical and ethnohistorical sources are unavailable and formal methods are the only way to assess the extent to which acoustics and soundscapes were at all relevant for the location and creation of rock art (Díaz-Andreu *et al.* 2021, 14–18).



Fig. 7.1: Map of the Yokuts ancestral area, with indication of where the site of Rocky Hill is. Author's own elaboration.

Nevertheless, other rock art traditions are today (or they were until very recently) lived and experienced by populations culturally connected to those who created the depictions. Thus, insights about the relationship between landscapes and acoustics can be traced both in ethnohistorical sources and in recent ethnographies.

In this article we present our informed analysis of the ethnohistorical sources on the different Yokuts tribes of south-central California in terms of how these sources can shed light on archaeoacoustics inquiries. In particular, we will refer to the area where acoustical fieldwork is planned under the auspices of the Artsoundscapes project (www.ub.edu/artsoundscapes).[1] This will be undertaken in the Rocky Hill area near Exeter, California. In this boulder-strewn hill (Figs 7.1 and 7.2) paintings are located in alcoves, shelters and caves. In them a series of polychrome painted motifs in red, black, white and yellow/orange are found (Fig 7.3). Figures include anthropomorphs, zoomorphs and geometric shapes (Whitley 1996, 158–159). The presence of riders and cattle indicates that, at least in some cases, the art was produced during the historic period (Grant 1981, 23). The central role of Rocky Hill for local Yokuts meant that, despite being privately owned for the last century or two, its ritual use continued. As Whitley explained, for the Yokuts "the pictograph motifs not only represent supernatural spirits symbolically, but are themselves sacred objects in a concrete sense" (Whitley 1996, 160). Sites excavated in the area are dated from 300 CE (Robinson 2006, 94).



Fig. 7.2: A view of the Yokuts ancestral site of Rocky Hill (Exeter). Acquired in the historical period by Euro-American settlers (Whitley 1996, 159), a portion of Rocky Hill was bought in the 1990s by the NGO The Archaeological Conservancy (TAC). Yokuts tribal members have continuously used the site and, moreover, tribal knowledge about the rock art panels has been passed through generations (ibid.). Photo by David S. Whitley, reproduced with permission.



Fig. 7.3: Rocky Hill. Panel. Photo by David S. Whitley, reproduced with permission.

The ethnohistorical sources referring to the different Yokuts tribes cover a period related to the final years of the 19th century and the early decades of the

20th century. Despite their shortcomings, we argue that these sources may be helpful to inquire into how rock art may have been entangled with Yokuts soundways, i.e. "the paths, trajectories, transformations, mediations, practices, and techniques – in short, the ways – that people use to interpret and express their attitudes and beliefs about sound" (Rath 2003, 2; 2008, 419). We begin below by reflecting on the use of ethnohistorical sources as a methodological tool for rock art research. We discuss some of the approaches to sound, song and landscape that can be found in Yokuts historical ethnographies, and finally, we relate these findings to Yokuts rock art following the five lines of evidence connecting rock art and acoustics proposed by Díaz-Andreu and Mattioli (2019).

The use of ethnohistorical sources on Yokuts' rock art sites

Rock art researchers have widely engaged with both the advantages and problems of taking into consideration ethnographic and ethnohistorical accounts (e.g. Lewis-Williams 1981; 1991; Huchet 1991; Morwood and Hobbs 1992; Solomon 1998; Taçon and Chippindale 1998, 6–7; Bahn 2001; Quinlan and Woody 2003; Keyser *et al.* 2006; Bednarik 2010; Francis and Loendorf 2010; Whitley 2010; Blundel and Woolagoodja 2012; Layton 2012; Pearce 2012; Gillete and Greer 2014; Rozwadoski 2018). In general, these informed methods (Taçon and Chippindale 1998) are considered to be one of the few methodological tools that may provide interpretations of the production, meaning and use of rock art. However, their benefits have been questioned. The main criticisms of this approach are both the apparent implicit denial of cultural change and the defective nature of the ethnographic record. The first concern is closely related to a perceived necessity to recall the ethical problems of 19th-century evolutionistic approaches to non-Western cultures. However, researchers who use informed methods in areas where rock art is still being created (or was until recently) and where a certain cultural continuity is accepted, argue that their perspective does not dismiss cultural change, but simply offers a selection of available sources that may indicate a possible continuity in a particular cultural manifestation, even if change can be demonstrated in other aspects (Bundell *et al.* 2010, 4; Whitley 2010; Pearce 2012). Some authors have even claimed that, in the light of diverse ethnographies, conservatism is not uncommon among traditional societies, particularly regarding ritual and religious beliefs (Whitley 2010, 124). In this respect, Pearce (2012, 141) has stated that both change and continuity must be demonstrated and not simply assumed.

Many voices have called for a critical approach to the historical sources. For instance, Vinnicombe (2010) alerts us to the imposition of Western narratives on fragmentary emic information. Likewise, Monney and Baracchini (2017) acknowledge the need for both a critical analysis of the sources and an awareness of the diversity of the records, including the different ontologies and epistemologies involved. Several others such as Brady *et al.* (2019), Monney and Baracchini (2019), Rogers (2007) and Sundstrom (2012) also underline the problematic contexts of ethnographic

compilations and the bias in the type of materials selected by ethnographers. These authors have also highlighted scholars' subjective interpretations based on problematic translations or on western-centric paradigms such as gender binarism. Moreover, they have been pointed out that female individuals and female narratives are scantly represented in the ethnographic sources, due to both the gender and the mind-frame of the early anthropologists (especially Rogers 2007). Finally, multiple meanings and multivocality within the communities that hold the traditional knowledge are a last challenge for those willing to use ethnohistorical sources to interpret rock art (Rogers 2007; Sundstrom 2012, 331; Brady *et al.* 2019; Monney and Baracchini 2019). Nonetheless, ethnographic information must be reported and carefully considered, as the uncritical denial of any kind of cultural continuity not only undermines native epistemologies and oral histories, but also expropriates indigenous peoples from their cultural heritage and historical narratives (Whitley 2010, 126–127).

The criticisms highlighted above are relevant to our own survey of ethnohistorical sources on the Yokuts cultures, as the texts we have dealt with are "deeply marked by the historical, cultural, and relational conditions in which they were recorded" (Monney and Baracchini 2017, 536). Most of these documents were authored by salvage anthropologists in the early 20th century (Kroeber 1907; 1925; 1939; Gayton 1928; 1929; 1930; 1945; 1948a; 1948b; Gifford 1932; Driver 1937; Aginsky 1943; and the Harrington papers now in the Smithsonian produced between 1914 and c. 1957). They were written in the context of Euro-American internal colonialism and were, therefore, produced under unequal power relations. Moreover, on top of influencing who, where and what was recorded as representative of Native California, salvage scholars also guided the choice of the medium and the audience for which materials were compiled. Tribal stories, songs, languages and dances, among others, were put onto paper, first as fieldnotes and then as organised, analysed, compared and theorised information, for a mostly Euro-American academic audience (Kroskrity 2013, 150). Consequently, as is well known, salvage anthropological sources need to be read critically. This entails taking into account their particular approach to ethnographic representation, including, firstly, the exclusion of the present of the Native American people portrayed in their texts, and secondly, their exclusive focus on Native American memories, material objects and cultural practices that were deemed able to convey "purely aboriginal" knowledge by salvage anthropological standards (Lightfoot 2005, 31; Clifford 2013, 170).

Salvage anthropological sources constitute an important body of literature despite the romanticised and static representation of pre-reservation life highlighted above. On the one hand, Native American tribal members, including the five Yokuts tribes that presently constitute the Central California Yokuts NAGPRA Coalition, are using some of these documents (i.e. the fieldnotes taken by John P. Harrington) in their cultural and language revitalisation programmes. Moreover, the Tejon Tribe, a constituent of the above-mentioned Coalition, has used these fieldnotes to claim

expropriated ancestral lands (Whitley pers. comm. January 19, 2021). On the other hand, ethnohistorical sources have played an important role in the construction of knowledge regarding different historical and archaeological aspects of Native California. In fact, as archaeologist David Robinson pointed out (2006, 21–34), since the mid-1970s archaeologists have used ethnohistorical documents to interpret California rock art (see for instance Bean and King 1974; Blackburn 1975; Hudson and Lee 1984; Whitley 1992; 1994; 2000a; 2000b). These documents provide evidence concerning aspects of the meaning, creation and use of Yokuts rock art, along with place names and terminology related to Yokuts rock art sites (Whitley and Whitley 2012, 258).

Ethnohistorical documents become a valuable research resource when they are cross-referenced with ethnographic, archaeological and geospatial research (Robinson 2006, 34). Nevertheless, the critical reading of published sources must be complemented with archival work and close collaboration with Native American tribal members. Archival research, i.e. reading salvage anthropologists' field notes, field diaries and other unpublished manuscripts should constitute an important step in the revision of salvage anthropological texts in the context of Californian rock art research. Even more important is the collaboration and corroboration with Native American tribal members as both experts on their own cultural practices and histories and as gatekeepers of sacred knowledge unveiled in salvage anthropological materials, but meant to be accessed exclusively by certain tribal members at specific moments and through particular processes (Whitley 2007). This is also important from a wider perspective, especially if one considers that "the future archaeological practice in the U.S. – and many other parts of the world – will be partly based on indigenous knowledge, influencing how we identify and assess sites, how they are managed, and how we interpret their meaning" (Whitley 2007, 8). After all, there is a difference between the consultation of indigenous sources, and indigenous archaeology as a decolonising practice in which indigenous people take part in the archaeological research process (Atalay 2006).

Yokuts rock art, archaeoacoustics, and the ethnohistorical record

In this section we will look at the "lines of evidence" linking rock art and acoustics first proposed by Díaz-Andreu and Mattioli (2019) for the case of Yokuts rock art. These lines of evidence included:

1. the placement of rock art in "naturally sonorous landscapes";
2. the placement of rock art in landscapes where artificially produced sounds, including human musicking, could be perceived to have exceptional acoustic responses;
3. the representation of musical practices and objects in rock art;
4. the presence of sound and musical objects at rock art sites; and
5. the production of rock art at or near lithophones (Díaz-Andreu and Mattioli 2019, 503).

Our initial ethnohistorical survey has provided examples of most of these points of connection.

The archaeological study of such a link between rock art and acoustics is not new. In North America the relationship between rock art and acoustics was first noted in academic archaeological contexts by Jack Steinbring (1992), when he mentioned that there were "doubtless hundreds of sites which invoke unusual sound patterns, or present conditions in which sounds may give striking effect" (1992, 103) citing a few examples in Canada and Wisconsin in the US. Also Ken Hedges (1993) concluded that the existence of rock art in ringing rocks illustrated an unusual feature of petroglyph sites, which adds another dimension to our understanding of rock art. Clearly, senses other than the visual were at work. First of all, there is the rhythmic and tactile experience of making the rck art itself. The ringing rocks show that an auditory component might also be significant in the production of rock art, and that these sites often have many layers of understanding that may be overlooked, awaiting casual discovery of features of the site that are not in the least obvious upon initial examination (Hedges 1993, 124).

Since the 1990s the link between rock art and acoustics, especially echoes, has become the focus of Steve Waller's research, producing a series of publications about ethnographic and historical sources for echoes and the results of his own fieldwork in archaeoacoustics mainly in the United States. These pioneering authors were later joined by an increasing number of scholars. Most comments refer to isolated sites, although the study of rock art landscapes has also been undertaken in Deer Valley and Box Valley in Arizona (Waller *et al.* 1999), Horseshoe Canyon and other sites in Utah (Waller 2000; 2005a; Allan and Waller 2009), Petroglyph National Monument in Albuquerque, New Mexico (Waller 2003), Colorado (Williams 2012) and the Mojave Desert (Liwosz 2014; 2017) (see also Patterson Rudolph 2000; Loose 2008). Most of these authors link the perception of the acoustics of rock art places to religious practices and beliefs, particularly shamanism, and mention some ethnohistorical sources, although in most cases their use has lacked depth (however, see Whitley 2010).

Two notes before we delve into how the "lines of evidence" may reveal new information about Yokuts rock art and acoustics. The first of them is that so far in our survey of early 20th-century ethnohistorical sources on the Yokuts tribes, we have seen that salvage anthropologists tended to impose Euro-centric concepts and ontologies on sound and music when dealing with Native Californian cultural practices. Moreover, indigenous listening positionalities were not at the centre of their concerns. However, their overall focus on documenting Native American rituals and religious beliefs allowed for some issues pertaining to Yokuts soundways to emerge in their scholarship (Alarcón-Jiménez and Díaz-Andreu 2019).

Moreover, it is important to note that early 20th-century Yokuts sonic ontologies and epistemologies were not conversant with a clear division between naturally and artificially produced sounds. Songs, for example, could be learnt from different entities such as lakes, the wind, birds, or fellow human beings (Harrington, Reel 89,

Image 176). Furthermore, songs could not only be acquired from other-than-human-beings, but they were also heard by them. Indeed, salvage anthropological accounts of different Yokuts tribes referred to personal, ritual or ceremonial practices to control (e.g. rattle snakes) or to communicate with different beings through singing and dancing. With or without their agency, animal sounds also mediated communication processes between humans and other-than-human-beings. This was the case of the birds from "Wóluluqaj, (...) down south of (...) Tsunut ot Wowal country", who could share the landscape's songs with certain individuals (in Harrington, Reel 101, Image 174), or the human beating of a dog to make it cry and stop the rain (Gayton 1948a, 158). Other-than-human-beings not only sounded, sang and responded to singing but some of them also talked. Within the framework of Yokuts' creation stories, certain animals, such as specific bears and birds, were classified as "people" and spoke phrases in Yokutsan languages. For example, frogs said *pono'j 'ilik'* (meaning "two waters" in Chunut Yokuts), according to Yokuts tribal member Josefa Damián (of Chunut and Wowol descent) (in Harrington, Reel 91, Image 146). All in all, the division between sound/song, soundscape/landscape and artificially/naturally produced sounds must be reframed in this context. Moreover, it should be taken into account that sources such as Harrington's fieldnotes also reveal the complex and conflicting relationship between different religious powers and belief systems that were present in south-central California in the first decades of the 20thcentury. A brief but telling example about this is found in the testimony of Yokuts tribal member Francisca Lola who, after being baptised by a Catholic priest, lost the ability to dream and bond with dream helpers and thus ceased to learn songs from them. Following her baptism, she was only able to dream with people who had passed away (in Harrington, Reel 89, Image 970).

First line of evidence: The placement of rock art in sonorous landscapes

Yokuts tribal members considered rock art sites to be powerful (Whitley 1996; 2000; 2020; Hector 2009; Robinson 2013) and therefore sonically salient. According to the Yokuts knowledge represented in ethnohistorical sources, the sense of hearing played a central role in the identification of certain locales in the landscape as powerful, "sacred,"[2] or, in the Tachi-Yokuts language, tripni. In Harrington's fieldnotes, for instance, Yokuts tribal members characterised certain mountains, rivers, lakes and ponds as particularly tripni as they either talked, embodied stories, sounded out or sang/had songs on them (Alarcón-Jiménez *et al.* 2021). Particularly tripni places and topographic features such as rock art sites could be heard and sensed by Yokuts ritual specialists and other tribal members. It is important to highlight here that the contrast between the Yokuts and the Euro-American settlers' sensorium – in other words, the ontological difference between these cultural realms – had already been brought up by the aforementioned Francisca Lola in the first decades of the 1900s: "why the Indians see so many tʃr'ip'ni [tripni] things and the Gringoes [sic] never see anything like that. (...) Maybe it is because the Gringoes [sic] are not afraid of anything and always want to investigate" (in Harrington, Reel 94, Image 329).

Yokuts rock art sites, like other salient tripni features and places, were thus perceived as sonorous points in the Yokuts ancestral territories. In a few instances they were specifically portrayed as sounding hollow and being guarded by both visible and audible other-than-human-beings. This is related to at list one type of practice. As the ethnohistorical and ethnographic evidence suggests, at least some Yokuts rock art sites were painted by ritual specialists. Furthermore, they were used as caches to hide personal valuable items like money and ritual regalia (Gayton 1948a, 113; Whitley 1994; 1996; 2000; and Harrington, Reel 94, Image 616). Regarding the hollow sound, Yokuts tribal members Sam Garfield and Mary Pohot (of Wukchumni descent) described a rock art site in Bell Bluff, presently under the waters of the Terminus Dam, as sounding "different" when stepping on it; they told anthropologist Anna H. Gayton that large rooms, only accessible to ritual specialists, extended within the rock (Gayton 1948a, 113). They also referred to other-than-human-beings guarding the site, which was therefore avoided and feared (*ibid*).

Second line of evidence: The placement of rock art in places with "special" acoustics

The placement of rock art in landscapes where sonic and musical practices could be perceived as having "exceptional acoustic responses" (Díaz-Andreu and Mattioli 2019) refer to acoustic effects such as echoes, resonance and reverberation, none of which are addressed in the ethnohistorical sources consulted. While further ethnographic research and formal archaeoacoustics tests are needed to inquire into these issues in the context of Yokuts rock art, it could be argued, however, that the perception of the acoustics of certain Yokuts rock art sites was probably "enhanced" in the context of some rituals and healing practices, as a consequence of altered auditory perception. Ethnographic and archaeological research suggests that certain "quests" and healing practices took place at Yokuts rock art sites like Rocky Hill.[3] Furthermore, ethnohistorical documents highlight the importance of processes such as song acquisition, singing and/or dancing (including bodily percussion movements) for questing and healing, although without specific references to rock art creation, rock art use or rock art sites (see, for instance, Gayton 1928, 32–33; 1948b, 15; Driver 1937, 103, 7). However, a mix-methods approach can be used to link these different kinds of evidence and thus to infer that singing and perhaps also dancing took place at rock art sites during these processes. Along these same lines, it could be further argued that musical and other sound-related practices were perceived to have "exceptional acoustic responses" at rock art places as questing and healing rituals developed. This is because, as the ethnohistorical sources point out, quests involved a disciplined bodily process of fasting, cold bathing and induced dreaming brought on by, for example, the ingestion of the hallucinogenic plant *Datura* (Gayton 1948a, 114, 108–109; 1948b, 150, 158, 173; Robinson *et al.* 2020). The altered state of consciousness resulting from the questers' preparation of their bodies would surely have influenced their auditory perception of the sites where the rock art was already placed or was about to be painted. The same could be

argued, to a certain extent, for the healing practices that took place at rock art sites (Whitley 2020), as the illness in question may also have altered human auditory perception. Hence, in both contexts, music at rock art places was probably heard to have "exceptional acoustic responses" from the singer/listener's bodily experience of the surrounding space.

Third line of evidence: The representation of musical practices and sound-producing instruments

As in the previous section, this line too needs to be further researched in the field and in collaboration with Yokuts tribal members. No musical instruments are known to be depicted in Yokuts pictographs. However, in an alcove used for healing purposes at Rocky Hill, as well as at other Yokuts rock art sites, there are pictographs of concentric circles representing a whirlwind (Whitley 2020). Whirlwinds or *mojak'* (in Wukchumni Yokuts)[4] were described by Francisca Lola as powerful and feared events caused by ritual specialists (Harrington, Reel 92, Image 158). Although different from whirlwinds, strong winds were mentioned in Harrington's fieldnotes on another three occasions: first, as being "people" (Reel 89, Image 397; Reel 91, Image 823); second, as being caused by the flapping of the wings of a bird that lived on top of Mount Whitney (Reel 101, Image 500); and third, as a source of songs, as in the case of Tachi-Yokut ritual specialist Bob Bautista, who was able to obtain songs from the wind blowing above the presently drained Tulare Lake (Reel 89, Image 176).

Regarding musical practices, a blue heron or Huhuna dancer is depicted in a rock art panel on Rocky Hill.[5] Archaeologist David Whitley learned about the interpretation of this pictograph from a Yokuts tribal member who collaborated with him; the panel was painted between the late 19th and early 20th centuries by a late family member (Whitley 2020). Both Gayton's and Harrington's ethnohistorical documents offer accounts of the Huhuna dancer. To begin with, in Gayton's ethnography Huhuna dances are described as being part of the annual mourning ceremony and lasting over eight hours. According to the Yokuts knowledge represented in her texts, Huhuna dancers wore ritual regalia made of long feathers with rattling sticks hanging from the back (Gayton 1948a, 127–128). They also had a net covering their faces, abalone shells for eyes, and two horns protruding from the tops of their heads (Gayton 1948a, 43). Huhuna dancers "never sang" (Gayton 1948a, 41) but were accompanied by singers; they used a bone whistle which they blew repeatedly as they danced. They had a wooden stick in each hand, which they occasionally played against each other. During their dance, Huhuna dancers were ritually killed and revived by a ritual specialist and they also looked for hidden money. In Harrington's fieldnotes, Yokuts tribal members Maria Wheaton (of Koyeti and Yawelmani descent) and her husband Tomás (of Wowol and Tubatulabal descent) referred to similar ritual regalia for Huhuna dancers. They emphasised the fact that Huhuna dancers could not see, as their eyes were covered by abalone shells (in Harrington, Reel 91, Image 823). They did not mention the mourning ceremony, the dance or the sticks.

However, they did refer to the use of the whistle, explaining that "in ancient times" Huhuna dancers blew it throughout the night and that, as a result, there was wind the next morning (in Harrington, Reel 91, Image 823). Moreover, they stated that Huhuna dancers went to "every place just like thunder" and that they were "the same as wind, that is wind's body" (in Harrington, Reel 91, Image 823).[6] Finally, it is important to mention that anthropologist Alfred L. Kroeber translated the Yaudanchi word *huhu'-udètec* as "bullroarer" (Kroeber 1907, 234; 1963, 219).[7] According to him, this ritual instrument was linked to thunder (Kroeber 1963, 214). In the light of the sources currently available it is impossible to say whether or not the bullroarer had a name that was cognate with Huhuna. Nonetheless, with regard to archaeoacoustics, the ethnographic representation of Huhuna dancers does highlight the limited vision resulting from the design of their ritual regalia, as well as the importance of senses such as hearing, to find hidden money during their ritual dance.[8]

Fourth line of evidence: Musical instruments

No musical instruments were found by Elsasser in his 1957 excavation of Rocky Hill (Robinson 2006, 93).[9] From a broader cultural perspective, nevertheless, a number of bullroarers and bone whistles have been found in south-central Californian Chumash caches (Hudson and Blackburn 1986; Whitby 2012, 278–285). In Harrington's Yokuts fieldnotes, the bullroarer (or "*zumbador*" in Californio or Spanish) is repeatedly mentioned by Yokuts tribal members in connection with the "*antap*" (Reel 90, Image 585; Reel 90, Image 586; Reel 94, Image 334). *'Antap* was, "a society of ritual specialists" who "operated throughout much of Chumash territory" in "the protohistoric period" (Robinson 2006, 56). *'Antap* were also known by some of the Native American people interviewed by Harrington at the Tule River Reservation. In fact, according to Maria Wheaton, Yokuts and other tribal members from the then Tejon Rancheria were familiar with *'antap* because they saw them at fiestas (Reel 94, Image 453). The deer tibia bone whistles found in Chumash caches have also been associated with the *'antap* (Corbett 2004; Robinson 2006, 56; Whitby 2012, 287). Corbett has even proposed that a technical improvement in the construction of these whistles during the Middle Period (900–1150 CE) is related to a shift towards greater religious complexity among the Chumash (Corbett 2004; Whitby 2012, 287). Some of these whistles and bullroarers can be found at museums like the Ventura County Museum, the Santa Barbara Museum of Natural History, and the Peabody Museum (see Whitby 2012, 278–313). However, both bullroarers and whistles are sacred objects for south-central Californian Native American people, and so their study must be carried with the explicit authorisation of the pertinent tribal authorities, as well as that of the museums.

Fifth line of evidence: The production of rock art at or near lithophones

South-central Californian rock art sites like Rocky Hill have panels with pictographs, cupules and milling features close by or next to each other (Whitley 2006b; Gorden 2009; Hector 2009; Robinson 2011). Some Yokuts cupule petroglyphs were painted

(Hector 2009, 71, Whitley 2006a, b, 314). Although cupules could be associated with ringing rocks (Hector 2009, 72), further research is needed to confirm whether or not this is the case at Rocky Hill or other Yokuts rock art sites and this resonates with the suggestion above to collaborate and corroborate with Yokuts tribal members. Nevertheless, it is known that cupule petroglyphs in the Yokuts ancestral territories "served functional, ritual, and aesthetic purposes" (Gorden 2009, 25). Despite the fact that ethnohistorical and ethnographic evidence is scarce, Yokuts cupules are known to be made and used by female tribal members for fertility purposes and during puberty initiations, among others. Indeed, through ethnographic interviews conducted in 2008, archaeologist Susan Hector learned that "the Yokuts continue a tradition of women's use of these features [cupules] at (...) Rocky Hill" (Hector 2009, 73). However, puberty initiations contain internal and delicate tribal knowledge. In our view, this line of inquiry should be consulted with tribal members and researchers must be prepared to keep it confidential if deemed appropriate by the tribes involved.

Conclusions

This article has revealed how ethnohistoric data, despite its problems, can bestow new and important understandings of the acoustic and sound-world of rock art sites. It has also highlighted the relevant but complex use of ethnohistorical documents to further our knowledge of both rock art and archaeoacoustics. Using the five lines of evidence proposed by Díaz-Andreu and Mattioli (2019), we have connected Yokuts rock art with ethnographic evidence to reveal the paths open for future formal archaeoacoustics investigations. Our survey of early 20th-century ethnohistorical sources about different Yokuts tribes has been essential to acquire a more detailed and culturally situated understanding of Yokuts soundways. As we have indicated, however, a critical reading of these sources is key, as also is collaborating and corroborating with the Native American people whose knowledge such documents claim to represent.

We started this article by mentioning informed versus formal methods for the study of rock art. In a multi-sited endeavour such as the Artsoundscapes project with a set formal methodology at stake, the informed approach we followed in this text contributes to illuminating the formal methods we are planning to follow in fieldwork. It brings forward conceptual inadequacies, such as separately categorising song and sound in the context of early 20th-century Yokuts soundways. It also points towards culturally relevant practices and perceptual engagements with the acoustics of rock art sites (i.e. the impact of altered states of consciousness in the auditory perception of certain Yokuts rock art locales). Furthermore, even though chronologically speaking the consulted sources might not coincide with all the sites to be archaeoacoustically measured, some of the points raised by such sources could still help to adjust formal tests so as to avoid discarding ontological perspectives that may escape researchers. Consequently, the use of both formal and informed methods is, we argue, the way

forward in the context of Yokuts rock art. Finally, ethnohistorical sources and anthropological research helps archaeoacousticians undertaking fieldwork to be aware of possible sites and lines of research that could be sensitive and/or restricted to certain members of the society involved.

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Notes

1 Archaeoacoustics fieldwork was originally planned for March 2020, but it had to be cancelled due to the Covid-19 pandemic.

2 See, for instance, Mary L. Keller's "Indigenous Studies and the 'Sacred'" (Keller 2014) for a discussion regarding the use of the term "sacred" in the context of Native American studies.

3 Here, we use the word "quests" to refer to the rituals that took place at rock art places and that involved creating and/or using rock art and rock art sites. Whether these rituals were ritual specialists' vision quests that resulted in the creation and use of rock art (Whitley 1994; 2000; Whitley and Clottes 2005, 168) or rather, other tribal members' quests – for whom the rock art functioned as both "an active accompaniment to" and a communication vessel "about the constituent elements of" an induced trance event (Robinson *et al.* 2020, 31035) – is still under debate.

4 For transcriptions and translations of whirlwind in other Yokuts languages see Kroeber (1963, 193).

5 In Gayton's ethnohistorical text, Huhuna dancers are said to have an owl as a dream helper (Gayton 1948a, 110). In fact, Gayton's drawing of the Huhuna dancer's ritual regalia resembles an owl and not a blue heron (Gayton 1948a, 68). However, in a personal communication (11 March 2021), David Whitley stated that, according to contemporary Yokuts knowledge, Gayton had misidentified the associated bird species.

6 The relationship between power, the wind and caves/earth-holes appears twice in Harrington (Reel 91, Image 824; Reel 90, Image 820–821). In this last reference (Reel 90, Image 820-821), a placed called *Shrok'win T'inliw* ("Wind Cave" according to Harrington's translation) is mentioned. This place is said to have wind in it, "if you throw a boulder into it (...) it blows it out furiously" (*ibid*).

7 Harrington asked Francisca Lola about *huhu'-udètec* meaning bullroarer and she stated that that word was wrong (Reel 94, Image 325).
8 The portrayal of eyes was rare in Yokuts rock art, although there are a few red turtles depicted with white eyes at Rocky Hill (Robinson and Sturt 2008, 36). Furthermore, fieldwork and ethnographic research are needed to look into whether or not the small circle shaped figures that are placed on the left and right sides of what might be the head of anthropomorph figures at Rocky Hill are depictions of ears.
9 The Artsoundscapes project will carry out fieldwork at Rocky Hill but our methodology is non-destructive, non-collecting and therefore, no excavations will be carried out.

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Chapter 8

Early rock music: Methodology to identify and analyse portable lithophones. An example from Great Sand Dunes National Park and Preserve in the San Luis Valley, Colorado, US

Marilyn Armagast Martorano

Abstract

A new class of prehistoric artefacts in the western United States of America, portable lithophones, has been identified from Great Sand Dunes National Park and Preserve and in private collections from the San Luis Valley, Colorado. A portable lithophone is a musical instrument consisting of a purposely selected rock that is tapped or rubbed with friction to produce musical notes. Portable and stationary lithophones have been utilised in ancient and modern cultures around the world, but only a few portable lithophones have been formally recognised in North America. Until recently, no such lithophones had been documented in Colorado. Many of the newly identified lithophones were originally thought to have functioned as utilitarian artefacts such as manos and pestles. The acoustical and physical characteristics of the Colorado lithophones were intensively documented. Based on this detailed analysis, a methodology was developed for identifying and formally documenting other portable lithophones in the field or laboratory. This study resulted in recommendations for future research and identification of additional types of potential portable lithophones.

Keywords: portable lithophone, archaeoacoustics, ground-stone artefact, lithophone identification, Great Sand Dunes National Park and Preserve, Colorado, US

Introduction

"Litho" is Greek for stone, and "phone" means sound. A lithophone is a musical instrument consisting of a purposely selected rock, often formally shaped, that is tapped or rubbed with friction to produce musical notes. Portable and stationary

lithophones have been utilised in cultures around the world including Europe, the Far East, Africa, the South Seas and South America (Caldwell 2013; Martorano 2018). According to Duncan Caldwell (2013, 521), stationary lithophones include: natural stalagmitic drapery; adulterated ridges and stalactites; natural rock gongs; natural, but positioned, stationary stones; and manufactured stationary columns. Portable lithophones described by Caldwell (2013, 521) include natural rocks that were suspended; manufactured suspended lithophones; long bifaces and stone slabs; and stone cylinders. Portable lithophones have been utilised in ancient times, during the historic period (Caldwell 2013; Martorano 2018) and today.[1]

Only a few portable lithophones have been formally recognized in North America (Brown 2005, 2009, 2014; Caldwell 2013; Martorano 2018). The majority of these lithophones have been identified in museums or private artefact collections, likely because archaeologists and other researchers have not often been aware of lithophones. In the past, ground-stone artefacts were normally assumed to have functioned only for utilitarian purposes such as grinding and crushing and were rarely considered as potential lithophones. Identification and study of additional portable lithophones is important to expand our current knowledge of archaeoacoustics, prehistoric musical instruments, music, and ritual on the continent of North America and in other parts of the world. One way to accomplish this goal is to identify potential portable lithophones in archaeological contexts, museums or curation facilities by testing artefacts for acoustical attributes and documenting their physical characteristics if they exhibit acoustical properties.

The primary objectives of this article are to describe the Colorado lithophone research and results. Using this data, methodologies are proposed for identifying and documenting additional portable lithophones including acoustical and descriptive analyses. Other information is discussed that may help to identify and understand portable lithophones including documentation of toolstone sources and lithophone toolstone extraction techniques; and lithophone sounds and relationship to rock types, other physical characteristics and types of percussors. Other discussion topics include ethnicity and gender of lithophone makers and users, and the roles of lithophones in ancient cultures. The time span of portable lithophone use, playing, storing and caching of lithophones, and the association of lithophones with rock art are additionally reviewed. Methodology for identification of lithophones in curatorial facilities or museums, and evaluation of other tool types that could be lithophones, such as bifaces, Jadeite axes, celts, adzes, or *tchamahias,* are presented.

Colorado lithophone research

Context

Many years ago, several very interesting and unique ground-stone artefacts were identified in the Great Sand Dunes National Park and Preserve (Great Sand Dunes) museum collections and in private collections throughout the San Luis Valley,

Colorado, US (Fig. 8.1). The artefacts were long and carefully shaped by pecking, grinding and polishing; and made from dense stone (Martorano 2018, 91). Some of these artefacts had been referred to in writing or labelled in museum collections or displays as pestles, roller manos, digging tools, hide-working tools, or thought to have been used for chopping or cutting. Most of the Colorado artefacts had been picked up by local artefact collectors, and a few others had been formally donated to the Great Sand Dunes Museum, Colorado. One artefact was collected as early as 1938, and others were found more recently (Martorano 2018, 34).

After initial analysis of these artefacts in 2005 and 2008, it was determined that they had not been utilised primarily for crushing and grinding because they did not exhibit characteristics similar to those known to have been utilised as pestles or other common grinding implements (Adams 2002, 138–140; Martorano 2018, 10). Also problematic was why some specimens were so long, heavy and very carefully shaped for a simple utilitarian purpose such as grinding or crushing. As a result of these unanswered questions, the function of this unusual artefact class remained unclear, and the artefacts were placed back in the museum collections. Then, in 2013, the archaeologist David Killam shared a YouTube video[2] with the author that described the work of a French researcher, Erik Gonthier of the Musée De L'Homme in Paris, France (Gonthier 2005; 2009). Gonthier's research on long, cylindrical, stone artefacts collected in Africa by French soldiers in the early 1900s confirmed that certain specimens had acoustical properties and established that these acoustically active artefacts were very likely utilised as portable lithophones (Gonthier 2005; 2009).

In 2013 Duncan Caldwell introduced the concept of portable lithophones in North America. He identified two cylindrical ground-stone lithophones from New England, and discussed their characteristics in comparison to others previously identified by Gonthier (Caldwell 2013, 521). Caldwell (2013, 532) suggested that these American lithophones could be a new class of artefacts in the US. He also indicated that the portable lithophones he studied were likely associated with prestige or rituals and were not utilitarian due to their scarcity in comparison to other types of artefacts (Caldwell 2013, 523). In his view, only a few potential portable cylindrical lithophones had been identified in North America including the two he



Fig. 8.1: Map showing the location of the San Luis Valley in Colorado where Great Sand Dunes National Park and Preserve is located. Drawn by Thomas H. Simmons, reproduced with permission.

described in New England, one lithophone from Arizona, and possibly one from New Mexico. He noted that one of the cylindrical lithophones from the New England area may be up to several thousand years old, perhaps as old as 8,000 years before present (Caldwell 2013, 530).

The lithophone characteristics identified by Gonthier (2005) and Caldwell (2013), as well as those found around the world,[3] were compared with the ground-stone artefacts from the Great Sand Dunes and the San Luis Valley (Martorano 2018, 11). This data suggested that many of the latter may have had a primary function other than as utilitarian grinding stones. To test this idea, three of the Great Sand Dunes cylindrical stone artefacts were set up on foam blocks and examined for acoustical properties in a similar manner to that conducted by other researchers (Martorano 2018, 11). A short video of the sounds produced by the three artefacts in the Great Sand Dunes collection was recorded. The three artefacts that were tested yielded acoustical properties similar to a marimba sound, and they each yielded two sound planes (two notes), as described in Caldwell (2013, 529). Two additional artefacts on loan from private individuals were also tested. These two artefacts had definite acoustical properties (ringing), and each played two different notes. The results of this initial testing suggested that these artefacts were lithophones and that others likely existed in the Great Sand Dunes Museum curated collections and in local private collections but had not been correctly identified.

Setting up the project

The Friends of the Dunes obtained a History Colorado Museum State Historical Fund Archaeological Assessment Grant in 2016 (Project 2016-AS-006) that enabled the intensive study and analysis of the Colorado artefacts (Martorano 2018, 12). For this study, 21 potential lithophones from the San Luis Valley and one artefact from another area of Colorado were intensively analysed. These artefacts were chosen for study based on their physical characteristics and acoustical properties that appeared similar to other described portable lithophones from throughout the world (Caldwell 2013). The goals of this Colorado lithophone study included, first, archival research to gather relevant existing archaeological and acoustical data on lithophones from North America and around the world (Martorano 2018, 13–14). Moreover, an inventory was undertaken of artefacts in Great Sand Dunes curated collections and in local private collections containing ground stone that could be lithophones. Tasks included execution of formal loan agreements to study the artefacts, interviews with the original artefact collectors, acoustical analysis of the potential lithophones, and analysis of the physical characteristics of each artefact. The archaeological assessment report included results of the archival research and lithophone acoustical and archaeological analysis; recommended future studies including consultation with indigenous peoples; suggestions for interpretation of the lithophones to the general public, archaeologists and other scientists and professionals including museum staff; and audio/visual recordings.



Fig. 8.2: Example lithophones from the San Luis Valley, Colorado, US. Scale is 30.5 cm. Photo by author.

Colorado lithophone characteristics

The artefacts studied and identified as portable lithophones from Colorado ranged from 23 cm to over 61 cm in length and were primarily cylindrical or a flattened oval in cross section (Fig. 8.2). All of the Colorado lithophones (Martorano 2018, 44–47) exhibited widths between 4 and 8 cm, and a length-to-width ratio averaging 5.6 (Martorano 2018, 135). The weight of the artefacts ranged from 0.9 to 4.5 kg. The rock types were primarily very dense volcanic and metamorphic stones including basalt, andesite, granite and schist. Additional detailed descriptions of the Colorado lithophone characteristics are included in the sections below discussing methodology to identify and document portable lithophones.

Methodology for identification of portable lithophones

Based on the procedures utilised to identify the 22 portable ground-stone lithophones from Colorado, an intensive methodological approach was developed to document and analyse the acoustical properties and physical characteristics of each potential lithophone (Martorano 2018, 132–133). This methodology involves non-destructive techniques to identify if an artefact is a probable lithophone. It was utilised for these investigations and has been used repeatedly since 2018 to identify additional lithophones located in private collections, archaeological contexts and museums and curatorial facilities. This methodology and the described analysis techniques are recommended guidelines to utilise whenever feasible for analysing potential lithophones.

Portable lithophone characteristics and types

Caldwell's basic criteria for identification of portable lithophones (2013) can be used to initially evaluate an artefact. Those physical criteria include diameter between 4 and 8 cm; lengths between 35 and 80 cm; dimensions 4.5 times longer than they are wide; few, if any, signs of being used for vertical grinding or pounding; and the use of such acoustically active stones as chlorite-schists and schist-actinolites (Caldwell 2013, 526). If a lithophone can be easily transported, it is considered a *portable lithophone*, as defined by Caldwell (2013, 521–522). Portable lithophones can be further categorised as three different types: minimally modified and roughly shaped rocks; highly modified rocks; and stone cylinders. Lithophones that are considered minimally modified and roughly shaped rocks include those that are elongated natural cobbles that have been minimally shaped with rough flaking or pecking (Martorano 2018, 39). Some minimally modified lithophones are similar to kiva bells described by Dr Emily Brown (2014). Several of these minimally modified lithophones have rough notches near one end, presumably for suspension (Brown 2014, 62).

Lithophones that are described as highly modified rocks include those that exhibit grinding and pecking and often show polish on the body. They also exhibit highly modified ends (Martorano 2018, 40). Lithophones that are termed stone cylinders are the most highly modified of all of the portable lithophone types. All of these artefacts have been carefully pecked and shaped over the entire body and are basically rounded in cross-section. Many of these artefacts show polish on the body and sometimes on the ends (Martorano 2018, 41–42). Note that some portable lithophones may appear to be cylindrical when viewed from certain directions, but based on a cross-section view, they are sometimes not completely rounded. Of the 22 studied portable lithophones in Colorado, four were considered minimally modified or roughly shaped stones, 14 were highly modified rocks, and four were defined as stone cylinders (Martorano 2018, 39–40).

Acoustical analysis techniques

After the physical characteristics of an artefact are examined and evaluated as per Caldwell (2013, 526), and most or all of the criteria are met or exceeded, it is suggested that the following steps be undertaken to determine if an artefact exhibits acoustical qualities. If so, it can be identified as a lithophone. To test an artefact for acoustical properties, the first step is to locate the two acoustical nodes or dull zones (Fig. 8.3). Sound travels through a lithophone as sound waves when tapped or rubbed with friction. The way the sound travels is based on the physics of sound waves and how sound travels through various materials (Caldwell 2013, 524–525). The sound waves travel in two sinusoidal curves that cross each other twice, and where the sound waves cross are termed the acoustical nodes or dull zones (Caldwell 2013, 524). These are the only two spots where the lithophone can be held, suspended or placed on another medium without muffling the potential sound when the artefact is tapped

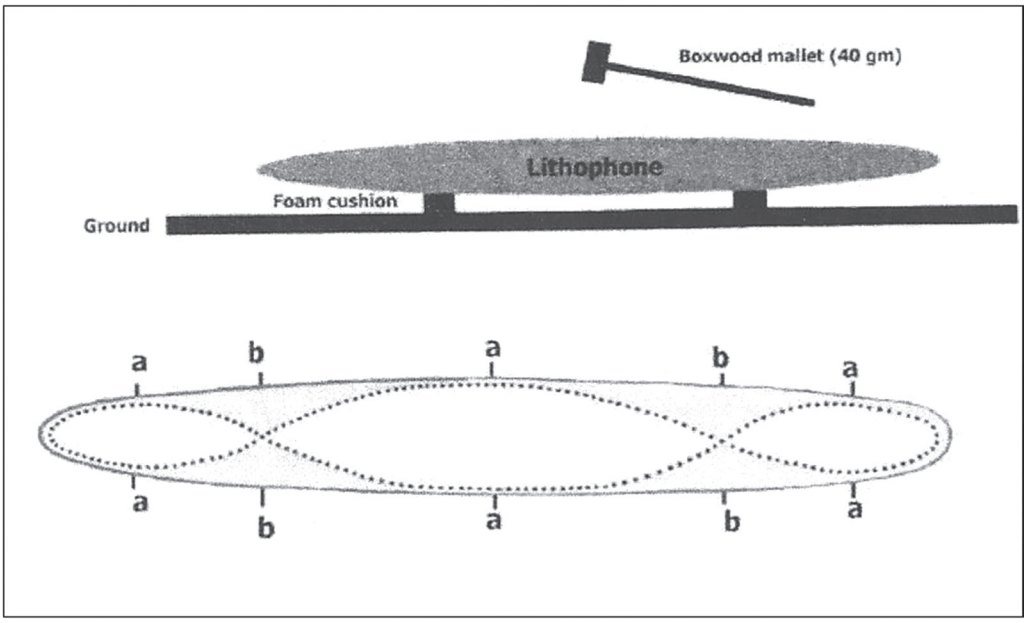


Fig. 8.3: How sound waves travel in two sinusoidal curves through a lithophone. The two points where the waves cross (b) are called acoustical nodes/dull zones. Source: Caldwell 2013, fig. 2, with permission to reproduce.

with a mallet or other percussor. The artefact can also be rubbed along the length of the body to test for acoustical properties using friction.

The two acoustical nodes are located at points approximately 25% of the total length from each end of the artefact (Caldwell 2013, 523–525), so these two locations can be estimated or measured (Fig. 8.4). The nodal points can be identified or refined by ear by tapping along the length of the artefact when it is placed on a narrow rope or other acoustically non-conductive material to raise it above a surface, such as a table. Several methods were tested for playing the Colorado portable lithophones, including placing them on narrow foam blocks, ropes and pieces of wood that had thin strips of foam window insulation attached (Martorano 2018, 101). The best and easiest method to play the lithophones was determined to be laying the artefacts on two pure cotton ropes (with no added chemicals). The ropes can be easily adjusted when locating the acoustical nodes.

The two acoustical nodes can be located by the above-described methods and marked where the lithophone sound is muffled when tapped at these two locations. Small pieces of archival-quality tape can be temporarily placed at these two nodal locations on the artefact. To be tested, the artefact needs to be held vertically, suspended or raised above the ground or any flat surface at one or both nodal locations. It can be held vertically using minimal contact with one finger and your thumb at the uppermost node location (Fig. 8.5). It can also be suspended horizontally or vertically



Fig. 8.4: How to test a potential lithophone using a xylophone mallet. The "X" marks show the acoustical node/dull zone locations where the artefact should be supported above a flat surface or the ground, or where it should be held or suspended if testing in a vertical or horizontal position. Do not tap on these "X" marks. The best locations to tap the artefact to check for acoustical properties are at either end or in the middle of the body. Scale is 25 cm. Photo by author.

on one or both acoustical nodes using leather strips or sturdy string (Fig. 8.6). The artefact can also be positioned horizontally with the two nodes on top of narrow pieces of hard foam, narrow sticks or pieces of rope (see Fig. 8.4). In addition, longer lithophones can be played across the lap or ankles if placed on those body parts at the acoustical nodes (Fig. 8.7).

A hard mallet is needed to tap the artefact to test for acoustical properties. In the field, a small, narrow, elongated pebble made of a dense type of rock, such as granite, basalt, schist or petrified wood (not sandstone), can be utilised. In the lab, several mallet types can be used to test an artefact for acoustical properties: a small, elongated pebble; a mallet made of hardwood such as rosewood or boxwood; or a piece of antler or hard bone (Fig. 8.8). If feasible, the best mallet for testing is a hard composite or plastic (not yarn-wrapped or rubber) xylophone-type of mallet such as a Musser mallet #124 that can be obtained at music stores or online (Fig. 8.9). The artefact is tapped on the top surface using a spring-like motion in the wrist. Even though a rock, bone or antler mallet will produce a good sound on a lithophone, use of a composite or plastic mallet is recommended for testing so that new use wear markings or residue smears from the mallets are not unintentionally created on an artefact. If the artefact produces musical sounds, it can also be tapped on the lateral edges in these same three locations to determine if the sound is the same, higher or lower than the top surface sounds. Most of the lithophones play at least two notes, one on the top surface and another on the lateral edges, unless they are very flattened in shape.



Fig. 8.5: Testing a potential lithophone vertically by holding it at the point of the upper acoustical node (dull zone). The least amount of contact with the hand/fingers provides the most acoustical clarity when tapping on the lithophone. Photo by author.



Fig. 8.6: Suspending a potential lithophone for testing horizontally. It is suspended by thin pieces of leather on the two acoustical nodes marked with white tape. Photo by author.

Some lithophones play several notes depending on where they are tapped. A few lithophones also produce overtones, or extra notes that sound when a fundamental note is played, if the artefact is rounded and can be rolled or turned while continuously tapping it. If the artefact is a lithophone, the sounds produced will be similar to tapping on a wooden marimba, a metal xylophone, glass crystal or a metal bell. The artefact can also be rubbed back and forth with friction along the length of the body. The artefact is being struck numerous times as the mallet hits various surfaces when rubbed with friction. The musical sounds produced by the Colorado artefacts when rubbed varied from a smooth, extended-length sound to a rougher, choppy, extended-length sound, based on the smoothness or roughness of the surface of the lithophone. This sound is somewhat similar to tapping, but in general, friction produces a more rough and continuous musical sound instead of a singular ringing note. If rubbing the artefact with friction, the sounds usually

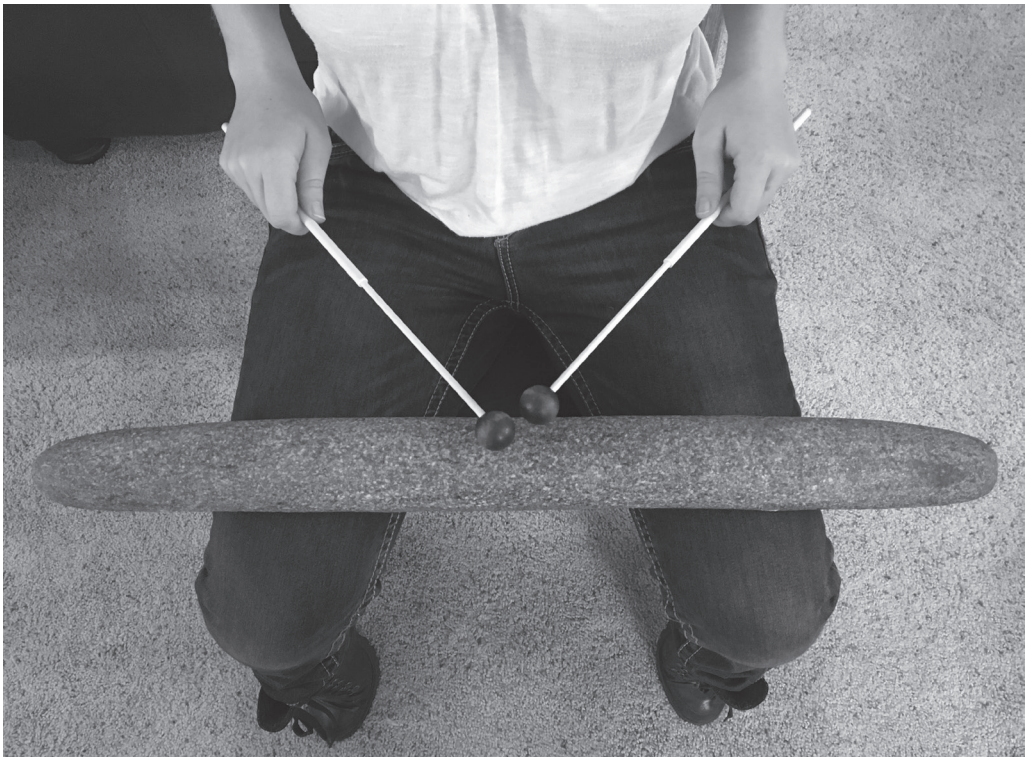


Fig. 8.7: Testing a lithophone by placing it across the knees on the two acoustical node locations. Photo by author.

resonate longer. Oftentimes, if the body of a lithophone is roughened (not smoothed or polished), it will produce more sound when rubbed with friction. If there is no ringing or musical sound produced when the artefact is tapped or rubbed, the artefact is not a lithophone. Note that lithophones may have natural surface coatings such as $CaCO_3$ (calcium carbonate) or hardened clay on some surfaces (Martorano 2018, 71–73). A $CaCO_3$ coating suggests that the artefact was positioned at one time in a moist setting, usually where there was surface-standing water such as in a shallow lake, wetlands or occasional high groundwater. This coating can sometimes be very thick and can affect the sound qualities of a lithophone. If a surface coating is removed from a lithophone, it will have more significant acoustical properties since a heavy coating of any material on the exterior can muffle the sound/vibrations.

Software apps, such as Pitch Analyzer and Tonal Energy Tuner, are easily accessible and reasonably priced tools that can be downloaded on cell phones, computers or other devices and used to determine the specific acoustical characteristics of sounds produced by lithophones. There are several distinctive steps to completing the acoustical analysis. The first of them consists of recording the following information



Fig. 8.8: Mallets made of natural materials that can be used to test potential lithophones; top left to right: antler, bone, and rock; bottom: boxwood. Scale is 30.5 cm. Photo by author.

for each sound from the software apps (Fig. 8.10): the primary and secondary notes, the cents or intervals above or below the standard pitch of each note, the octave(s) played, and the frequency or Hertz (Hz). All of these acoustical characteristics can be documented in a spreadsheet for comparison to other lithophones. Descriptive notes regarding the specific sound qualities of each artefact should be included in the information for each artefact.

The second step is to record and compare the Hz of the primary and secondary notes of each lithophone with the weight, length, width and thickness, and note if the artefact is a fragment or was broken and repaired (glued). For the Colorado lithophones, the Hz produced when the artefact was tapped was not necessarily lower on fragments unless very short or those with a broken, flat-shaped end, or on repaired specimens. It is suggested that the Hz produced when tapped likely depends more on the rock density and body shape rather than on the completeness of the artefact (Martorano 2018, 112–116). The final step is to record the sounds produced by each lithophone. This can be accomplished with a cell phone or with high quality recording equipment. To prevent interference from other sounds when testing or

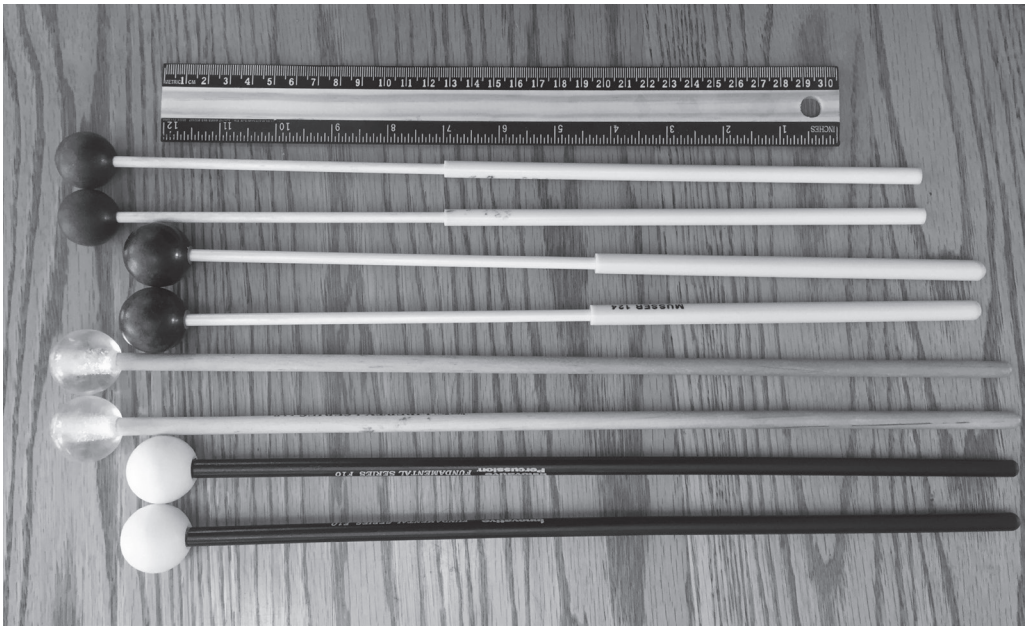


Fig. 8.9: Modern xylophone mallets made of hard plastic and composite materials are highly recommended for testing potential lithophones. A pair of Musser #124 mallets, shown second from the top in this photo, works well for testing acoustical properties without damaging an artefact. Scale is 30.5 cm. Photo by author.

recording potential lithophones, it is best to select a quiet location without fan noise from heating or air conditioning, or distracting sounds from vehicles, people or animals.

Colorado lithophone acoustical properties

When tapped with a percussor, the sounds produced by the Colorado lithophones are similar to tapping on metal bells, glass (crystal), a wooden marimba or a metal xylophone, or a combination of these sounds (Martorano 2018, 117). In general, the longer Colorado lithophones played a lower note while shorter ones played higher notes, similar to the high and low notes produced by a modern xylophone or marimba (Martorano 2018, 117). There are a few exceptions to this generalised statement. The reasons for this difference in sound versus length may be related to a number of characteristics, such as the overall shape of the artefacts, especially cross-section, thickness, and the shape combined with other factors such as rock type, density and weight. As noted by Caldwell (2013, 526), the width does not appear to affect the sound like the length, thickness and rock type.

The sounds produced by the Colorado lithophones were louder and had more acoustical properties (more of a ring) when played with hard percussors such as a hard-composite material like modern xylophone mallets, or a hard and dense

elongated rock. Antler and weathered bone produced a similar, but not quite as musical of a sound. Baked or boiled fresh bone worked better than highly weathered bone. Playing the lithophones with a hard wood percussor, such as rosewood or boxwood, produced a somewhat softer sound. A wooden mallet did not produce a sound that was as musical as harder, more dense materials like rock. In contrast, the sound of each lithophone was muffled when played directly on one or both of the acoustical node locations with any type of percussor. The best sounds were produced near either end or near the middle point along the length of the artefact and on the lateral edges at these locations.

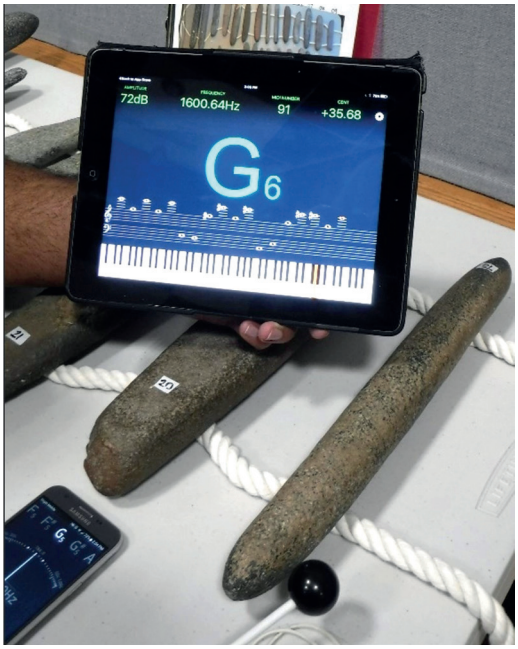


Fig. 8.10: Methodology to test an artefact for acoustical properties. This photo shows a lithophone being tapped on the lateral edge with a mallet. The results of the testing are shown on the Pitch Analyzer app. Photo by author.

The 22 Colorado portable lithophones that were studied played a minimum of 57 notes, and all of the lithophones produced at least two sounds, one on the top surface and one on the sides or lateral edges (Martorano 2018, 117–118). The notes produced by a single lithophone varied from those that played the same note and same octave on the top and lateral surfaces, the same note but different octaves, ½ step to two steps apart, and those that played multiple notes and multiple octaves depending on where they were tapped (Martorano 2018, 117). F#/Gb was played by 10 lithophones; G, G#/Ab and C#/Db were played by more than six; F and A#/Bb were played by five; and C, D, D#/Eb, E, A, and B were played by three or less lithophones (Martorano 2018, 118). Many of the lithophones also played overtones. When the lithophones with cylindrical-shaped bodies were tapped continuously while rolling them with both acoustical nodes lying on a rope, they generally played a clear primary note, then overtones (usually both the primary note and the secondary note at one time), and then a clear secondary note. This pattern was repeated as the lithophones were continuously rolled. The notes played by the lithophones varied from those that were above the standard pitch of a note, ranging from C6 +3.58 cents and D#8/Eb8 +3.58 cents to F#8/Gb8 +47.81 cents; and below the standard pitch of a note, ranging from G#6/Ab6 -0.14 cents to F#5/Gb5 -46.05 cents (Martorano 2018, 117).

The Hz produced by the 22 Colorado lithophones ranged from 192 Hz on an artefact broken into three pieces and glued together, to 8786 Hz on a complete artefact

(Martorano 2018, 118). Some of the lithophones that played a clear, musical sound had a low Hz (235 Hz) when tapped in some locations and were higher in others (1166 Hz). On one artefact, the recorded Hz ranged from 550–6096 Hz, depending on where it was tapped (Martorano 2018, 118). The relevance to the lithophone makers/users of the Hz that is produced and the actual sound qualities of each lithophone is not known. Of all the notes produced by the studied lithophones, 56% were pentatonic (the black keys on a piano) and 44% were not (Martorano 2018, 118). Understanding the meaning of the notes produced by these artefacts is a complex topic. Although it is not known what scales were played by these lithophones, it appears there was a preference to create artefacts that played pentatonic notes. This supports the fact that pentatonic scales, in all their various forms, are the most commonly used tonal structure and have been encountered in music from cultures all over the world (Martorano 2018, 118–119).

Methodology to document the physical properties of portable lithophones

Descriptive data collection

Prior to documenting the physical properties and characteristics of each portable lithophone, detailed background information should be recorded. For the Colorado study, this information was gathered from museum accession data and associated documents, and verbally during interviews with the private owners (Martorano 2018, 34–38). This data can be input into a spreadsheet for comparative purposes and the following information should be recorded: land ownership, current owner(s), specific location where the lithophone was found, and current accessibility status of the artefact, such as in a museum, a private artefact collection or a formal curation facility. The date of the artefact discovery and collection, and the name of the collector and affiliation, including current contact information, should be recorded. Any data obtained through consultation with cultural groups who may have ties to the area where the lithophone was found should be documented.

The spreadsheet should contain a description of the landscape setting including the geographical location and elevation where the lithophone was found. The lithophones from Colorado were found in the following geographical and specific locations: at the edge of an old playa, on a slope in a piñon/juniper wooded area, in deep sand dunes near a spring, found during mechanical sorting of potatoes, and near creeks and other water sources (Martorano 2018, 34–38). In addition, the physical provenience of the artefact when discovered should be recorded. For example, several Colorado lithophones were found lying horizontally on the surface of the ground and two were found buried vertically in the ground with only 5 to 15 cm visible on the surface (Martorano 2018, 34–38). It is assumed the vertically placed lithophones may have been cached upright in a certain location so they could be easily found again, especially when left in sand dunes where artefacts are often buried by the wind or water.

It should be noted if a lithophone was found in certain locations, such as in ploughed fields or stream beds, because they may have been damaged by machinery and/or moved from their original provenience either through mechanical or natural processes. These artefacts may show distinctive marks that can be identified in the laboratory (Martorano 2018, 70). Another issue to be taken into account is to record and describe the landscape setting, i.e., the natural features found in the vicinity of the lithophone such as canyon walls, large boulders, rock shelters, sand dunes or caves. These natural features could have potential acoustical properties that may have been related to where portable lithophones were made, played or cached (Williams 2012). Any other information such as associated artefacts and cultural features including rock art, fire hearths or structural remains should also be recorded. The sediments where the lithophone was recovered and if it was a surficial find or excavated from subsurface deposits should be described. Any dated sediments, artefacts or features located in direct association with the lithophones or nearby should be noted. Some of the Colorado lithophones were found in isolated contexts but many were found in the vicinity of other prehistoric stone artefacts including projectile points, flaked stone materials and other ground-stone tools (manos and metates). Although artefacts of many time periods were found in the general vicinity of the Colorado lithophones, artefact styles generally dated from the Middle to Late Archaic with one lithophone likely associated with a feature dating to the end of the Early Archaic (Martorano 2018, 34–38).

Physical properties data collection

Documentation of the physical properties of each portable lithophone should follow the methodology described below. This descriptive data can be entered into a spreadsheet for comparison to other lithophones and the following basic information should be included at a minimum. First, measurements should be taken using hard and soft metric tape measures. Soft tapes are more accurate for obtaining circumference and metric measurements should be recorded to enable comparison with lithophones found throughout the world. The weight of each artefact should be measured by using a digital scale for accuracy. Hand magnifiers of different strengths (up to 16×) or microscopes can be utilised to view the physical characteristics of the surface of the lithophones when collecting data. Varied lighting, both natural and man-made, can be utilised when the artefacts are described and/or photographed to enhance the identification of physical characteristics, especially small or subtle marks.

The completeness of the artefact (whole or fragment) should be recorded. Very short lithophone fragments with two flat ends often have little to no acoustical properties. If the artefact has been broken and repaired, describe if glue is visible on the lithophone body at the break and repair location(s). Some repaired lithophones may still retain acoustical properties, but it is likely that the sound quality will have been impacted to some extent by the break (Martorano 2018, 115). The maximum



Fig. 8.11: Upper photo: Lithophone #5 (Martorano 2018, 53) top view of the body. Note the white $CaCO_3$ in peck marks on the body and different shaped ends. Scale is 25 cm. Lower photo: Lateral view of Lithophone #5 showing overall undulating curvature of the body, different end shapes, and $CaCO_3$ on the edges. Scale is 25 cm. Photos by author.

length, width, thickness and circumference of each artefact, and the ratio of length-to-width of each artefact should be documented (Martorano 2018, 51). This ratio affects the sound qualities, and based on Caldwell (2013, 526), portable lithophones with the clearest sounds are generally 4.5 times longer than they are wide. The average length-to-width ratio of the 22 Colorado lithophones is 5.6, with 5 averaging less than 4.5, and 17 averaging a 6.2 length-to-width ratio (Martorano 2018, 135).

The overall body shape/curvature (straight, curved, undulating or a combination) should be described. Caldwell (2013, 527) noted that the two New England cylindrical lithophones he studied exhibited a noticeable curvature when viewed laterally. He suggests that they may have been specifically designed with a curve to be played on a person's lap, where the curve gives them more stability. Several of the lithophones studied by Martorano (2018, 52) exhibited slightly curved-shaped and/or undulating bodies, especially when viewed on their lateral edges (Fig. 8.11). It is not known if the curvature of these artefacts is a natural characteristic of the rocks, or in some cases, if a curved or undulating form was purposefully created during manufacture to obtain a certain sound quality, visual appearance or to stabilise the artefact when playing.

The cross-section shape of the lithophone body should be described at both ends and in the middle. Examples of body shapes include cylindrical/rounded, oval and/or flattened or a combination of shapes. The cross-section shapes often vary from one end to the other, especially on longer lithophones. Any overall tapering of the body of the lithophone when viewed from the top and from a lateral edge should be noted. Any concave or flattened areas on the body of the artefact and any differences

in surface characteristics in these areas such as pecking, polish or striations should be described. The shapes of both ends of each artefact should be noted. Typical end shapes include tapered, beveled, conical, rounded, pointed, flattened, slightly bulbous, angled or broken off (Martorano 2018, 76–79). The end shapes often vary from one end to the other on a single artefact (Martorano 2018, 79). Caldwell (2013, 526) noted that columnar lithophones were most sonorous, or capable of producing sound, when their ends were conical or oval, rather than flat or slightly bulbous, like the majority of pestles. The maximum thickness of each artefact should be measured when it is laid on the most flattened portion, except for the cylindrical artefacts that do not have a flattened surface. The exact weight of each artefact should be recorded.

The rock type of the artefact should be identified. Many ground-stone lithophones are made from very dense volcanic or metamorphic rocks such as basalt, andesite, granite and schist (Martorano 2018, 9). Caldwell (2013, 523) noted that identified lithophone rock types from Africa primarily included chlorite-schists and schist-actinolites, with dolomitic limestone, amphibolites, quartzites and smectites also represented. The two New England portable lithophones were made of a porous siltstone and a chloritoid schist (Caldwell 2013, 528). The most common material type of kiva bells studied by Brown (2014, 62) was basalt with other types including argillaceous limestone, phyllite, phonolite and feldspar. A geologist can often assist with rock type identification and may be able to provide information through petrographic analysis (the descriptive and systematic classification of rocks) whether the rock could be locally available or appears to have been obtained from a distant location. Several potential source areas for the Colorado lithophones were identified with the assistance of Great Sand Dunes geologist, Andrew Valdez. He discovered an area on the western edge of the San Luis Valley that contains columnar volcanic rock outcrops (Martorano 2018, 93). A few representative samples of these volcanic columnar rocks, approximately 46 to 61 cm in length, were found to have acoustical properties when tapped even though they are unmodified (Martorano 2018, 93). It is possible that prehistoric peoples may have obtained similar rocks and played them either unmodified or may have formally modified them.

Evidence of manufacturing techniques and surface modifications, such as flaking, pecking and manufacturing/shaping marks and/or intentionally pecked designs, should be documented (Fig. 8.12). Other modifications may include notching, striations, polishing, grinding and evidence of applied residue such as ochre, or other surface coatings like clay or $CaCO_3$. Some lithophones exhibit flaked notches on the lateral edges that may have been utilised for suspension (Brown 2014, 62), and others may exhibit drilled holes. Any physical damage, such as plough or other machinery marks, should be noted. The size, length, width and depth of surface modifications such as peck marks (Fig. 8.13), striations, impact marks and any other visible marks should be described and measured. If feasible, the number of peck marks located on the entire lithophone can be estimated by measuring the number in a sample-sized area and extrapolating the total number on the entire surface of the artefact.



Fig. 8.12: Close-up of two of five sets of pecked zig-zag lines along the body of a lithophone. A circular pecked line around the circumference connects to the zig-zag lines near the visible end of the artefact. Scale is 10 cm. Photo by author.

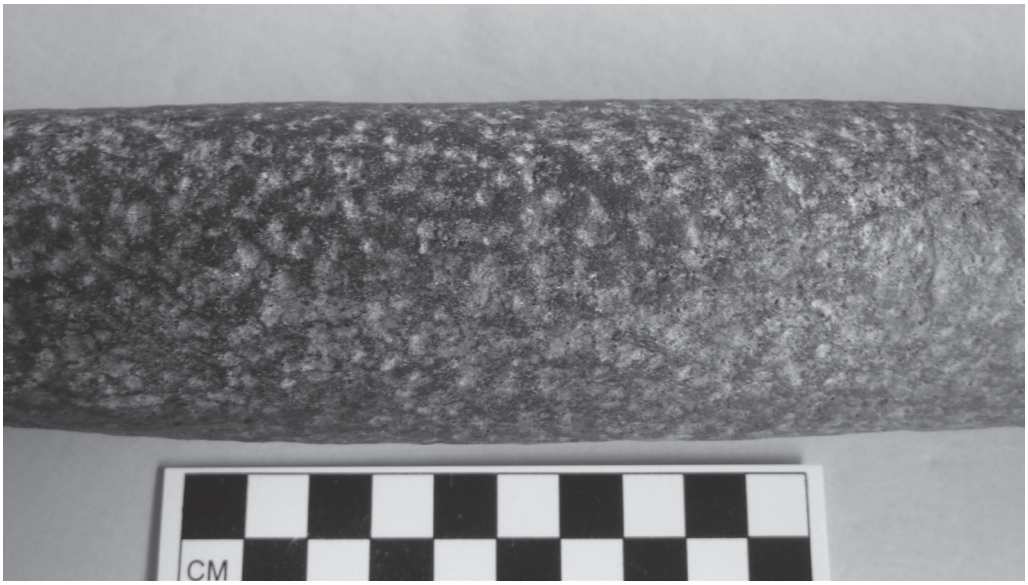


Fig. 8.13: Close-up of peck marks on a lithophone (Martorano 2018, 74). Scale is 10 cm. Photo by author.

If an artefact was played continually with a mallet made from bone or antler, there may be smears of residue from the mallet material (Caldwell 2013, 531). This residue may appear as a darkened area on the lithophone, especially near either end or in the middle of the body. Any residue may be sampled for residue analysis if there is sufficient quantity and it has not been contaminated through natural forces or during handling or storage. Impact marks from playing with a hard mallet such as stone should be documented. According to Caldwell (2013, 531), if a portable lithophone was played with a stone percussor, it may be possible to identify either small, densely clustered conical fractures or multiple small, densely clustered areas of polish. Brown (2014, 62) noted evidence of scarring and polish on kiva bells interpreted to be from being struck with various types of percussors. Several of the lithophones identified by Martorano (2018, 68–69) showed signs of impact marks (Fig. 8.14) and striations on the body or ends of the artefacts that were interpreted as evidence of the use of hard percussors. Post-manufacture damage, such as marks from ploughs or other machinery, and marks from battering should be documented (Martorano 2018, 70). If an artefact is broken, describe the breakage pattern (angled, straight across or rough and uneven) and look for impact marks near the break that may suggest how it was broken. Any visible polish on the surface of the lithophone should be documented. Certain areas on the lithophones may have been intentionally or unintentionally polished during production of the artefact, during use, or possibly some polish may have been created during transport of the artefact. For example, the ends may have become polished if the artefact was transported vertically in a leather bag.



Fig. 8.14: Close-up of probable hard percussor impact marks on the end of a lithophone; the marks are a lighter gray than the remainder of the body. Scale is 10 cm. Photo by author.

Photo documentation

All photographs of each lithophone should be taken with a scale. Detailed photographs should include overviews of the top, bottom and both lateral edges; close-up views of each end (top, bottom and end view); and close-up views of surface modifications such as pecking (shaping and intentional designs), use wear, striations, polishing, flaking, impact marks, notching and visible residue (natural and applied). Varied lighting, both natural and man-made, can be utilised when the artefacts are photographed to assist in documenting all the physical details of each artefact. For example, low side lighting can enhance subtle characteristics and marks, such as pecked designs, for identification purposes and to provide high quality comparative photographs. Photographs of the portable lithophones showing the lateral edges (curvature) can be taken with a graph paper background to better visually depict the curvature of the body (see Fig. 8.11).

Other recommended portable lithophone analysis techniques

Several additional types of analytical methods are recommended for artefacts identified as lithophones and are discussed below. These tests require separate laboratory analysis or special computer software but are non-destructive techniques that can provide additional significant information about each lithophone including data on toolstone sourcing, residue analysis and detailed information regarding physical characteristics and form.

XRF analysis

XRF (X-ray fluorescence) analysis of each lithophone is recommended. XRF is a non-destructive analytical technique used to determine the elemental composition of materials. XRF analysis can determine the chemistry of a lithophone by measuring the fluorescent (or secondary) X-ray emitted from a sample when it is excited by a primary X-ray source. XRF results in a breakdown of the chemical elements making up a stone. Future researchers may be able to use this data to help evaluate the differences in the chemical elements and material types of known lithophones, and the XRF data could be used to answer questions regarding acoustical properties of different lithophone rock types and sources (Martorano 2018, 91–93).

FTIR analysis

FTIR analysis (Fourier-Transform Infrared Spectroscopy) is suggested to test residue on a lithophone. FTIR uses infrared spectroscopy to create an absorbance signature of organic compounds, including those recovered from archaeological artefacts. FTIR analysis has potential to identify residues on a lithophone, such as remnants of bone used as percussors.

3D modelling

It is recommended that 3D computer modelling be conducted for each portable lithophone (Fig. 8.15). Using 3D modelling can be utilised to help understand and compare the physical properties and sound characteristics of known lithophones

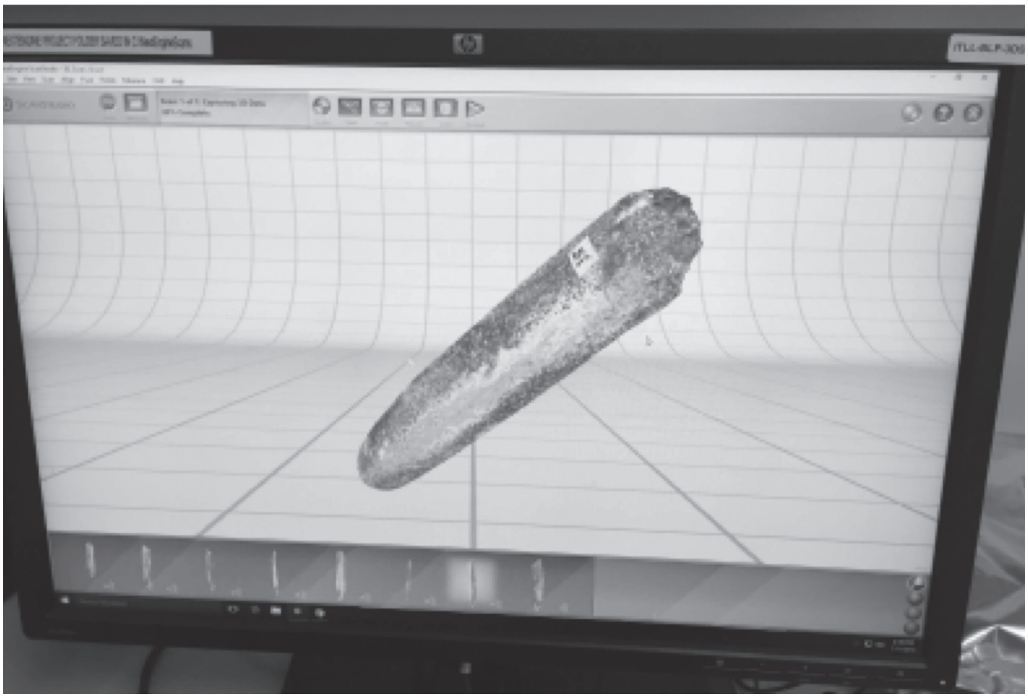


Fig. 8.15: Computer 3D modelling of an example lithophone fragment from Colorado. Photo by author.

(Martorano 2018, 127). Due to the many variations in the shape of the body and ends of a single lithophone, it is difficult to accurately describe and measure these physical characteristics, even by taking detailed photographs. Utilising 3D modelling enables a more precise record of each lithophone and potentially helps to better understand and compare sound qualities with physical appearance and form. Also, 3D modelling is a way to obtain permanent physical documentation of artefacts that may not be available for future study.

Discussion

Although a wealth of new information has been recently collected about ground-stone portable lithophones from Colorado and New England areas of the United States (Caldwell 2013; Martorano 2018), additional research is needed to fully understand how lithophones were utilised over time in North America as well as elsewhere in the world. The primary future research goals are discussed below.

Documentation of toolstone sources and lithophone extraction techniques

It is important to determine the rock source areas for identified lithophones, whether from local or distant locations, or both. It is crucial to determine if the source areas varied over time, and what the natural rock looked like prior to being modified for use as lithophones. For example, it is important to know if the rock was formally

quarried or found as naturally occurring individual stones, such as columnar basalt. Petrographic and XRF analysis may help to determine the potential source areas for the stone. If certain lithophones were made from quarried stone in a process similar to that described for manufacture of Maya manos and metates in Guatemala (Searcy 2011), it should be possible to find lithophone quarry sites with remaining evidence of the quarrying process. In Searcy's descriptions of mano and metate quarries, a photograph depicts grooves made in a boulder to split off pieces of stone, and potential stone quarrying waste material is visible at a currently utilised stone mano/metate quarry (Searcy 2011, 40). The first step in the identification of potential lithophone quarry sites would be to find potential rock outcrops or other strata that are likely to have acoustically active stone in areas where lithophones are found. Then, identifying and examining accessible locations may help to discover potential prehistoric or historic lithophone quarry/extraction sites.

Lithophone sounds and relationship to rock types, physical characteristics and types of percussors

There are a number of relevant research topics related to musical sounds across different cultures and to the concept of notes played by lithophones. Specific questions related to the notes and scales produced by lithophones include how the musical sounds/scales produced by different groups varied over time. Also, it is unknown if and how stones for lithophones were chosen to create specific notes and sounds, or if they were chosen simply because they exhibited acoustical properties and the note played was secondary in the selection process. The differences in lithophone sounds may be related to a number of physical characteristics such as the overall shape of the artefacts (rounded body versus generally flattened oval shapes in cross-sections, and/or shapes of the ends), or the shape combined with other factors such as rock type, density, thickness, length and weight of the artefact (Caldwell 2013, 526). Experiments conducted specifically to test and compare sounds of lithophones made of different rock types and various physical characteristics may help to answer these questions. It is assumed that rocks were specifically shaped/tuned to obtain certain pre-conceived notes such as those in pentatonic scales. It is possible that acoustical qualities had a higher value for selection of raw materials for lithophone manufacture than being able to create specific notes or sounds. Regarding specific sounds produced by lithophones, it would be important to determine the types of percussors that were utilised and how these may have varied through time, in different cultural groups and/or in different geographical areas. Identifying evidence for hard or soft percussors (especially materials like bone, antler or wood) utilised on lithophones would be an important first step. Even though evidence of soft percussors is not likely on surface artefacts due to weathering, indications of the use of hard percussors should be identifiable on any lithophone. Searching for percussors physically associated with lithophones would also provide important data.

Ethnicity and gender of lithophone makers and users, and overall roles of lithophones in ancient cultures

The ethnicity and gender of lithophone makers and users is often not known. It is not clear who was making and using lithophones, if the lithophone producers and users were local inhabitants or outsiders who occasionally utilised certain areas, and if and how the makers and users of lithophones may have changed over time. Investigating gender roles associated with the manufacture and use of lithophones may reveal information similar to the Maya traditions of manufacturing and utilising manos and metates (Searcy 2011). In the Maya areas where Searcy observed the production of manos and metates, the males quarried and manufactured the tools and the females were the primarily tool users (Searcy 2011, 64–65, 93, 138–143). Ethnographic research, consultation with cultural informants, and analysis of lithophones found in specific archaeological contexts may provide insight into how, when, why and where lithophones may have been manufactured and utilised in prehistoric, historic and modern times in different areas around the world.

The role of lithophones in the lives of the users/players and those who listened to them is not clear. Lithophones may have been used for ritual/ceremonial purposes, for everyday activities such as a form of communication, for simple enjoyment of music, or a combination of these purposes. It is not known if and how the uses and purposes of portable lithophones may have changed over time and if different shapes of lithophones may indicate the associated type of use, i.e., whether used ritually or for other purposes. It is not clear if lithophones were sometimes utilised as multi-purpose tools. For example, limited evidence of grinding, battering, striations and crushing may have occurred after a lithophone was discarded and possibly repurposed, or some lithophones could have been created specifically to be used as multi-purpose tools. In addition, questions remain regarding evidence of applied residue, such as ochre, or incised or pecked lines that may suggest the use of a lithophone for ritual or ceremonial purposes. Other possibilities include that certain physical characteristics could have possibly been produced during the manufacturing process or during transport, storage or during use/playing as a lithophone. It is also not clear if portable lithophones may have been carried over long distances through time and were considered significant cultural artefacts that may have been curated and handed down from one generation to the next.

Timespan of portable lithophone use

It is unknown if the idea of creating portable lithophones was introduced through migration, trade, movement of different cultural groups or was it an ancient or more recent local invention, or a combination of those events. For example, it is possible that the tradition of using portable lithophones was carried into North America or other areas of the world by multiple cultural groups at various times resulting in the differing physical forms of the lithophones and varied sounds chosen by the makers. As noted above, Caldwell (2013, 530) suggests that the portable lithophones he studied

may be up to several thousand years old and possibly date as old as 8,000 years before present. Some documented portable lithophones in Vietnam (bifacially worked slabs played like a xylophone) are 5,000 to 6,000 years old (Caldwell 2013, 522). All of the kiva bells from the Rio Grande Valley in the southwestern US are associated with Native American pueblos and dated to post-1300 CE (Brown 2014, 65).

Questions remain regarding how long portable lithophones have been utilised around the world. Based on a few finds in North America (Caldwell 2013, 530; Martorano 2018, 119–120, 130), it appears that lithophones could have been utilised for thousands of years, potentially back to Paleoindian times. It is not known if certain types of unmodified or minimally modified types and highly modified cylindrical lithophones date to different time periods and/or are affiliated with different cultural groups. As noted above, the more recent forms of lithophones in the American Southwest, kiva bells, are either unmodified or minimally modified stones (Brown 2014). It is suggested that more formally shaped lithophones, especially the cylindrical and other highly modified artefacts, are an earlier form in comparison to unmodified or minimally modified types. Additional research, analysis and dating of portable lithophones are needed to test this hypothesis and determine if the more highly modified lithophones found in Colorado and other areas of North America date to a much earlier time and are possibly related to multiple cultural groups (Martorano 2018, 119–120).

Playing, storing and caching of lithophones

It has not been determined if portable lithophones were used individually, in groups of more than one lithophone, or both. All of the lithophones studied for the Colorado project are assumed to have been found as single artefacts and not part of a cache of multiple artefacts; however, several of the lithophones were described to have been found near each other on the western side of Great Sand Dunes (Martorano 2018, 34–38). Since these artefacts were found over a number of years, it is possible that some were originally located together and were picked up at different times as they were uncovered by shifting sands. It is not entirely clear if individual or groups of lithophones were cached by hunter-gatherer groups and whether lithophones were more often cached or stored by sedentary groups. The fact that two of the artefacts from the San Luis Valley in Colorado were found buried in a vertical position (Martorano 2018, 34) suggests they may have been cached similar to lithophones found in northern Africa as described by Caldwell (2013, 526). Caldwell (2013, 526) noted that leaving lithophones cached in a vertical position would make them visible to anyone searching from afar. At Great Sand Dunes, one of the longest and heaviest cylindrical lithophones was found positioned vertically in the sand dunes (Martorano 2018, 34). Due to the strong winds that continually blow the sand in that area, if an artefact was left lying flat/horizontal, it would quickly be covered up by shifting sands and would be difficult or impossible to be relocated. It would also seem plausible for pedestrian hunter-gatherer groups to cache one or more lithophones due to the weight of some of the larger ones, which weigh between 2.7 and 5.0 kg.

Brown (2014, 63–64) described several caches of lithophones from pueblos in northern New Mexico and Dr Joe Ben Wheat (1954, 116) recorded a cache of 12 artefacts from a Mogollon pithouse in Arizona that are potential lithophones dating to c. 100 CE to the late 900s. During excavations of Picuris Pueblo in northern New Mexico, one kiva bell and several stone rods were found in subfloor caches with other artefacts such as bone flutes, miniature pots and other interpreted ceremonial items (Adler and Dick 1999, 101–119). A cache of 23 kiva bells/bell stones was found at the Cuyamungue Pueblo in New Mexico (Adams 2002, 196). These examples document evidence of portable lithophone caching by sedentary prehistoric groups in North America. More information about the musical and physical characteristics of groups of cached lithophones would add significant data to our knowledge about the notes, scales and sounds produced from a set of portable lithophones rather than single artefacts. A description of the physical characteristics of sets of lithophones would add very important data to our knowledge of groups of lithophones. In addition, if associated dates can be determined for North American lithophone caches, it would be very important for comparison with other known lithophone caches found throughout the world.

Association of lithophones with rock art

It is possible that lithophones have been depicted in rock art or associated with rock art sites. A local Colorado San Luis Valley artist, David Montgomery, found a rock art panel west of Great Sand Dunes (Fig. 8.16) that he believes may depict the playing of a group of portable lithophones (Martorano 2018, 126). Numerous petroglyphs have been found associated with what are identified as bell rocks at Cocoraque Butte in Arizona, US (Hernbrode and Boyle 2016). While these bell rocks are considered stationary lithophones, this association is suggestive of a direct tie of petroglyphs to sound and lithophones. Gregory Williams and Carol Patterson (2013) have recorded a probable rasp (a serrated surface that is rasped or scraped with a non-sonorous stick to produce sound) that is carved into a rock cliff wall in western Colorado. The rasp is associated with rock art and acoustically vibrant properties of the canyon walls. This data supports the idea that sound is an element related to the placement of rock art. Williams (2012) also discusses the concept of rock art and prehistoric ritual behaviour as related to soundscapes and landscape setting. Lithophones found near rock art sites or other areas with acoustical properties such as canyon walls or caves, may suggest that these specific locations were chosen for their acoustical properties for the playing of portable lithophones. Other potential depictions of the use of lithophones in rock art may exist and should be documented.

Identification of lithophones in curation facilities or museums and evaluation of other tool types, such as bifaces, axes, adzes, celts or tchamahias, that could be lithophones

In several communications with museum curators, I have been informed that additional unidentified portable lithophones have been found by collectors or are

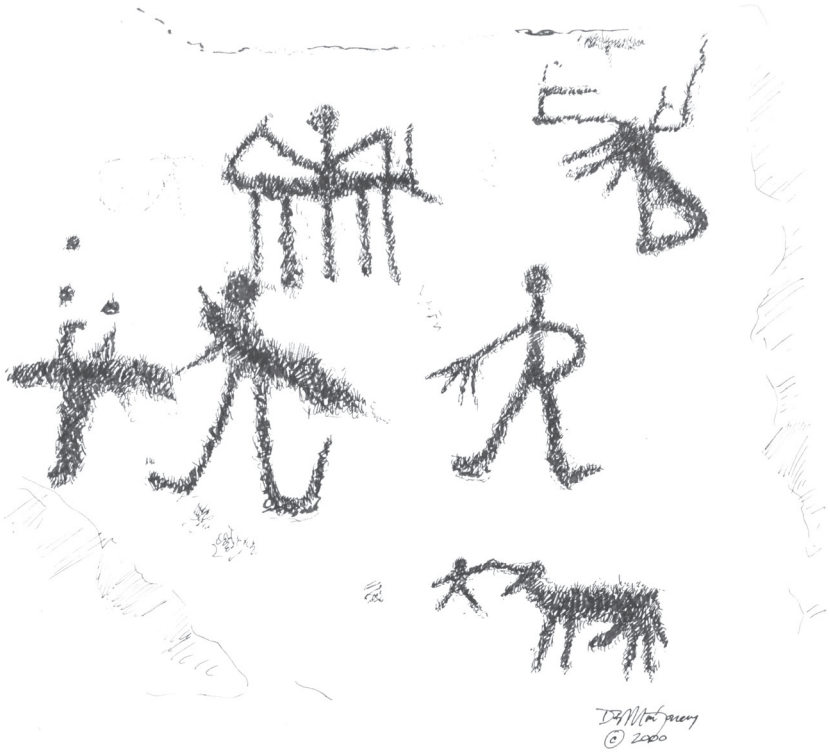


Fig. 8.16: Sketch of a rock art panel at an archaeological site on the western edge of the San Luis Valley, Colorado. The figure on the top, upper left, may be a depiction of a person playing multiple lithophones, and the figure in the center with one arm on its hip and another arm out to the side, may represent a person dancing. Not to scale. Drawing courtesy of David Montgomery, published with permission.

located in archaeological collections in museums or other repositories. For example, one very long lithophone is exhibited in a local museum in the town of Truth or Consequences, New Mexico and was not initially identified as a lithophone (Fig. 8.17). This specimen is displayed next to a smaller artefact that also may be a lithophone. The longer artefact is over 122 cm in length and was reportedly found associated with the mammoth skull shown on the table behind the two ground-stone artefacts. There are many research questions related to this find, such as, if other portable lithophones of this length exist, and if so, who made them and when; where the toolstone material came from (local or distant source); and if the rock to create a very long lithophone like this was quarried or made from a singular rock. Questions also remain such as how a very long, thin lithophone was crafted without breaking it, and if the association of this lithophone with mammoth remains supports the use of portable lithophones during Paleoindian times in North America.

One important question is to determine how other lithophones can be identified in museums and curation facilities when the searchable database does not include the

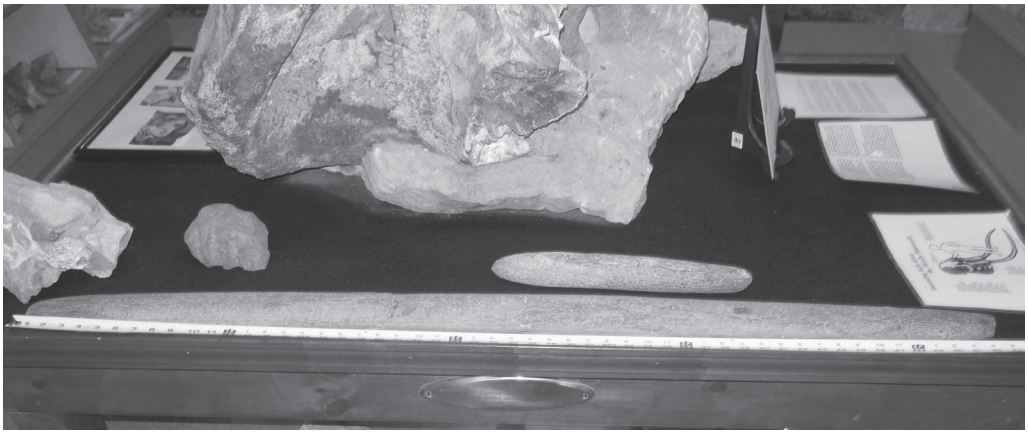


Fig. 8.17: Lithophone from New Mexico that is over 122 cm long and another potential small lithophone that were reportedly found in association with the mammoth skull in the background. Scale is marked in 2.54 cm increments. Photo courtesy of Fred Bunch, published with permission.

term lithophone. I developed a list of alternative artefact terms in museum databases that could help identify potential lithophones in 2021 for a virtual museum confab for the History Colorado Museum. Those terms include pestle, *tchamahia* (*chamahia, tcamahia, tshamahia, tsamahia*), ritual/ceremonial hoe or axe (ax), stone rod (flaked or ground), kiva bell, ringing stone or rock, bell stone or rock, rock gong, kneading stone, hide working stone, roller mano, celt or adze, large biface (example, Turkey Tail points), flaked microblade, spud (stone), and cloudblower. Sometimes these types of artefacts are also referred to as "eccentrics". Utilising these alternative terms during museum and curatorial facility searches will likely assist in the identification of additional lithophones.

Another major research question is whether there are other types of portable lithophones from archaeological contexts, such as large, flaked, biface lithophones. Some biface caches, such as a group of four large bifaces in a cache in Forteau Point, Labrador, have been interpreted as lithophones.[4] This suggests that groups of large bifaces as well as individual artefacts should be tested for acoustical properties. Caldwell (2013, 532–533) noted that some artefacts currently classified as projectile points could have been suspended like chimes. He considered Turkey Tail points to be the best candidates for such lithic chimes, as they are almost always made of acoustically rich Indiana hornstone. Furthermore, their tiny stems make them difficult to haft, and, consequently, hard to use as knives or projectile points. Caldwell (2013, 532–533) pointed out that their small bases would have been perfect, however, for hanging them, while their unusual thinness may have made them particularly sonorous. Martorano received a recording from Doug Schwartz (pers. comm. 2023) tapping on a Turkey Tail point from New England, US, that produced a very metallic ringing sound. All this data suggests that flaked bifaces, especially those found in caches, should be tested for acoustical properties.

In addition, other types of ground-stone artefacts, such as those identified as a celt, adze, Jadeite axe or a *tchamahia*, could have possibly functioned as lithophones. For example, two artefacts, identified as a celt and adze, have been tested for acoustical properties (Fig. 8.18) and their sounds are similar to tapping on metal bells (Martorano 2018, 131). Jadeite axes have been found in prehistoric contexts throughout Europe from southern Italy to as far north as Scandinavia, Ireland and Scotland, and to the east as far as the Black Sea (Klassen 2013; Sumnall 2022). These axes are made from several different types of rock (jadeite, eclogite, omphacitite and some types of amphibolite) that was used for axe production in the western Alps between the end of the 6th and the first half of the 3rd millennium BCE (Klassen 2013, 86). The sources of the raw materials and the Neolithic quarries for these Jadeite axes have been located at Mont Viso (Piemonte, northern Italy) and to a lesser degree at Mont Beigua (Liguria, northern Italy). The stone source area locations and the known finds of Jadeite axes far from the original quarries are of interest regarding their function. The Jadeite axes discussed by Klassen (2013, 88) range in length from approximately 6 to 36 cm. The Jadeite axes exhibit fine craftsmanship and dense rock types, they do not exhibit use wear that would suggest utilitarian artefacts, and they have been interpreted as sacred objects of power or status items tied to specific ritual beliefs (Klassen 2013, 86). Based on these characteristics, it is suggested that careful testing of Jadeite axes could reveal whether they exhibit acoustical properties and were possibly utilised for sound production as lithophones rather than only for a utilitarian purpose.

Questions also arise about the function of *tchamahias* (as mentioned above other spellings include *chamahia, tcamahia, tshamahia, tsamahia*) found in the American Southwest because of their similarity to the Jadeite axes. Interpretations of *tchamahias* vary from hoes to ritual/ceremonial items (Adams 2002, 50, 161, 179). These types of artefacts would be worth testing for acoustical properties since the toolstone is often a very dense material, such as a fine-grained siltstone; the craftsmanship is very high; and like jadeite axes, many of the *tchamahias* show little to no use wear that would be expected if used as an axe or hoe (Adams 2002, 179). *Tchamahias* could possibly have functioned as lithophones and the notches on some examples of these artefacts may have been created for suspension rather than for hafting. If any of these artefacts, such as celts, adzes, Jadeite axes or *tchamahias*, have acoustical properties, it could greatly expand our interpretations and understandings of the role of these types of artefacts in past cultures. If the artefacts exhibit acoustical properties, it will also show the value of not assigning the function of artefacts only by visual assessment.

Conclusions

This article has explained the research undertaken with a series of unique ground-stone artefacts from Colorado. Originally thought to have been used for crushing, pounding/mashing and grinding, it is now clear that they functioned as portable lithophones. Based on the intensive analysis and documentation of 22 lithophones,



Fig. 8.18: Artefacts described as an adze (top) and celt (bottom) from northern New Mexico, US produce highly resonant bell-like sounds when tapped. Scale is 30.5 cm. Photo by author.

detailed methodology for identifying probable lithophones, documenting their physical characteristics, and describing their acoustical properties was developed to assist with future lithophones research. This methodology includes recommendations for testing to initially identify a potential lithophone. Additional detailed methodology includes how to describe and measure physical characteristics, record and document acoustical properties, and photo-document artefacts identified as portable lithophones. A wide range of additional investigative avenues that will enable better understanding of the place of lithophones in the world's cultures are discussed. Topics include documentation of toolstone sources and lithophone toolstone extraction techniques; lithophone sounds and relationship to rock types, physical characteristics, and types of utilised percussors. Questions regarding ethnicity and gender of lithophone makers and users, and overall roles of lithophones in ancient cultures are discussed. Other topics examined include the time span of portable lithophone use; playing, storing and caching of lithophones; and association of portable lithophones with rock art. Identification of lithophones in curation facilities or museums and evaluation of other tool types, such as bifaces, Jadeite axes, adzes, celts or *tchamahias,* that could be lithophones are additionally reviewed.

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Notes

1 https://www.lithophones.com/. Accessed 20 April 2023.
2 Des pierres préhistoriques musicales sorties de l'oubli. https://www.youtube.com/watch?v=fRamnKf6OEY. Accessed 20 April 2023.
3 https://www.lithophones.com/. Accessed 20 April 2023.
4 The Archaic Site at Forteau Point, Southern Labrador. *Inside Newfoundland and Labrador Archaeology – Digging through the files…* https://nlarchaeology.wordpress.com/2015/11/27/the-archaic-site-at-forteau-point-southern-labrador/. Accessed 20 April 2023.

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Chapter 9

Preliminary insights into the archaeoacoustics of cup-marked sounding rocks in the north area of the Gredos mountain chain, Spain

Raquel Jiménez Pasalodos, Martín Almagro-Gorbea and Jesús Caballero Arribas

Abstract

This chapter discusses the results of an ethnoarchaeological survey undertaken in the highlands on the north face of the Gredos mountain range, in the provinces of Ávila and Salamanca (Spain). The aim of the fieldwork was the identification of acoustically significant rocks and rock outcrops in the landscape. It is argued that these rocks represent an interesting longue durée *cultural phenomenon involving the utilisation of natural rocks for sound production. Seven archaeoacoustical sites with these features are described, classified, and an explanation of the acoustic phenomena involved is provided for each of them going beyond the merely lithophonic properties of the rocks. Their possible association with ancient practices is also revised.*

Keywords: lithophones, cup-marks, ethnoarchaeology, archaeoacoustics

Introduction

In the Iberian Peninsula, the cultural significance of peculiar rocks within landscapes, and their potential connections to ancient beliefs, myths and rituals, have only been recently investigated through the lens of surviving ethnographic information. To date, this undertaking has unveiled a substantial number of rocks and geological sites – more than one thousand – that relate to a diverse range of uses and cultural meanings, some of them of a seemingly remarkable antiquity (Almagro-Gorbea and Gari Lacruz 2017; 2021; Almagro-Gorbea 2021; Almagro-Gorbea and Alonso Romero 2022). Among those rocks and geological sites, rocks associated with sounds are particularly interesting, as they throw light on past and present sonic and musical practices and their relationships with the landscapes and soundscapes in which they are inserted.

Various types of sonorous rocks in the landscape have been identified in the Iberian Peninsula. The most well-known are *in situ* lithophones (also known as rock gongs): non-portable rocks or stones situated in the landscape, usually bearing cup-marks that have been created by repeatedly striking on the same spot (see, among many others, Fagg 1997; Bednarik 2010a; Till and Kleinitz 2015). These rocks function as idiophones due to their positioning, shape and mineral composition; the rock, or parts of it, oscillate when struck. This creates a complex sound wave with an overtone array that translates into a metallic sound and that sometimes perfectly aligns with the harmonic series, thus generating pitches with a perceivable fundamental frequency. The Pena do Coto Caldeiro, in the province of Pontevedra, is a good example of these *in-situ* lithophones (Fraguas Fraguas 1983, 225). Other rock formations also emit physical sounds due to natural causes such as wind, expansion and contraction because of heat changes, water evaporation, or the sea's noise, for instance. These sounds can sometimes be regarded as auditory pareidolias, i.e., the perception of a meaningful sound from an actually random or ambiguous auditory pattern. Pareidolias are often considered "magical" in European popular narratives and in historical sources (Almagro-Gorbea and Alonso Romero 2022, 358–359). There are about 30 identified examples of these types of sounding rock sites in the whole Western part of the Iberian Peninsula (Almagro-Gorbea *et al.* 2021; Almagro-Gorbea and Alonso Romero 2022, 352–372). A systematic ethnographic review of culturally significant rocks in the landscapes in some areas on the north face of the Gredos mountain range, specifically in the provinces of Ávila and Salamanca, has allowed us to document a cluster of seven sites of sounding rocks, all of which bear cup-marks resulting from their lithophonic use.[1] The aim of the study undertaken in the pages below is to approach these seven sites by describing their cultural uses, classifying their different typologies, and examining the acoustic phenomena found in them.

Site identification, description and classification

The seven sites are situated west of the Sistema Central mountain range, one of the main mountain ranges of the Iberian Peninsula, particularly on the highlands of the northern flank of the Gredos mountain chain, encompassing an approximate perimeter of 200 km (Fig. 9.1). Of these sites, six are positioned within the administrative boundaries of the province of Avila, while one falls within the province of Salamanca. Notably, they are located at varying distances from the nearest inhabited settlements in which the collective memory of their existence is preserved, ranging from a mere 0.2 km to a maximum distance of 4 km. It is interesting to notice that the site located farthest from its corresponding village, "Canto de la Campana" in Cabezas del Villar, was locally known for its acoustic properties. However, the practice of its percussion with stones and the knowledge of the existence of rock cupules is now lost.

These seven acoustically significant rocks (see Table 9.1) were identified through a diverse array of ethnoarchaeological and ethnological methodologies, including virtual

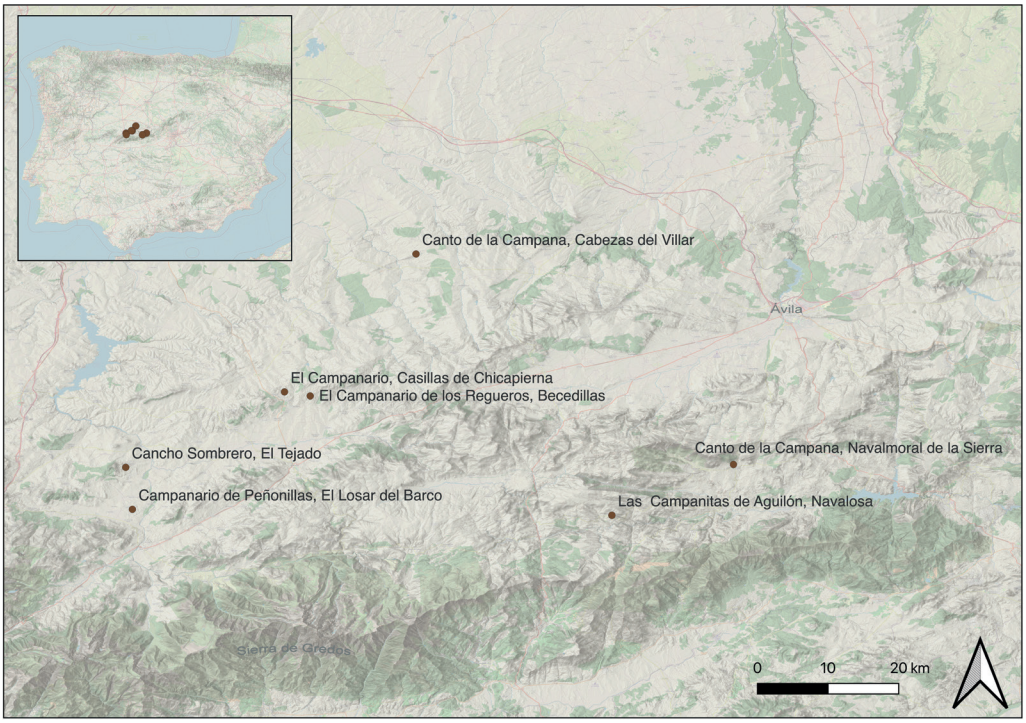


Fig. 9.1: Location of the seven sounding rock sites with cup-marks. Author's own elaboration.

Table 9.1: Site name, location, typology, number of cup-marks identified and present or recent uses.

Site name	*Municipality*	*Province*	*Type*	*Number of cup-marks*	*Ethnographically attested use*
El Campanario de los Regueros	Becedillas	Ávila	3	4	Shepherds' communication and entertainment
El Campanario	Casillas de Chicapierna	Ávila	1	17	Shepherds' communication and entertainment
Las Campanitas de Aguilón	Navalosa	Ávila	1	45	Children's musical practices
Canto de la Campana	Navalmoral de la Sierra	Ávila	1	130	Children's musical practices
Canto de la Campana	Cabezas del Villar	Ávila	2	3	Wishing rock
Cancho Sombrero	El Tejado de Bejar	Salamanca	1	23	Entertainment
Campanario de Peñonillas	El Losar del Barco	Ávila	1	29	Entertainment

and conventional fieldwork, as well as direct interviews. The cultural and historical importance of these sonorous rocks was assessed through the presence of one or more of these attributes: attached myths or stories; a connection to enduring cultural practices; evidence of anthropic intervention; and distinctive toponyms (Almagro-Gorbea 2017). Six of the seven sites examined in this current study are associated with place names featuring references to bells, small bells or bell towers. Furthermore, all these sites exhibit noticeable signs of anthropic intervention in the form of deep cup-marks engraved onto the surfaces of the granitic rocks, caused by repetitive percussion.

Remarkably, several of these sites continued to be used until recent times, with one case even preserving a song associated with its utilisation. Preliminary ethnographic interviews have allowed the identification of three distinct contemporary uses: shepherds' communication (El Campanario de los Regueros and El Campanario from Casillas de Chicapierna), children's musical practices, either on specific ritual calendar days (at Campanario de las Peñonillas) or daily (at Las Campanitas de Aguilón in Navalosa), and wishing rocks, where a stone is tossed to create a sound to make a wish (found in Canto de la Campana in Cabezas del Villar). Nevertheless, additional interviews and fieldwork are required to further explore any potential traditional knowledge that may be preserved within these communities.

Acoustically significant rocks with natural joints forming corridors

These acoustically interesting sites can be categorised into at least three distinct types: natural rock corridors, hollow granitic rocks and rock outcrops. The first category includes five rock sites that are characterised by being in natural joints (*diaclasa*) of large granitic rocks or passages shaped between two large rocks. These passages create open-ended corridors 7 to 10 m long and 0.4 to 0.7 m wide. The walls forming the corridor measure around 5 m in height (Fig. 9.2). These corridors have either straight walls or oblique walls (Fig. 9.2). All sites exhibit a high concentration of cup-marks, which are located predominantly on only one of the walls, primarily around the central region of the corridor. However, there are consistently a few smaller percussion marks on the opposite wall. Within this category of sites, the quantity of cup-marks varies, ranging from 20 to 45 each, except for the Canto de la Campana in Navalmoral de la Sierra, which boasts a remarkable number of at least 130 marks, some of which appear to have not been used for an extended period. Notably, in two of these sites, round quarzitic pebbles suitable for use as percussion tools have been documented (Fig. 9.5). These stones are not found in the immediate area, suggesting that they were transported most likely from nearby riverbeds.

Hollow granitic rocks with acoustic properties

The second category is only illustrated by the Canto de la Campana site in Cabezas del Villar, where a hollow granitic rock is found with an internal height of approximately 1.75 m from the ground and a diameter of around 0.4 m. In this site, the cup-marks are situated in the lower portion of the internal walls, positioned in a manner only

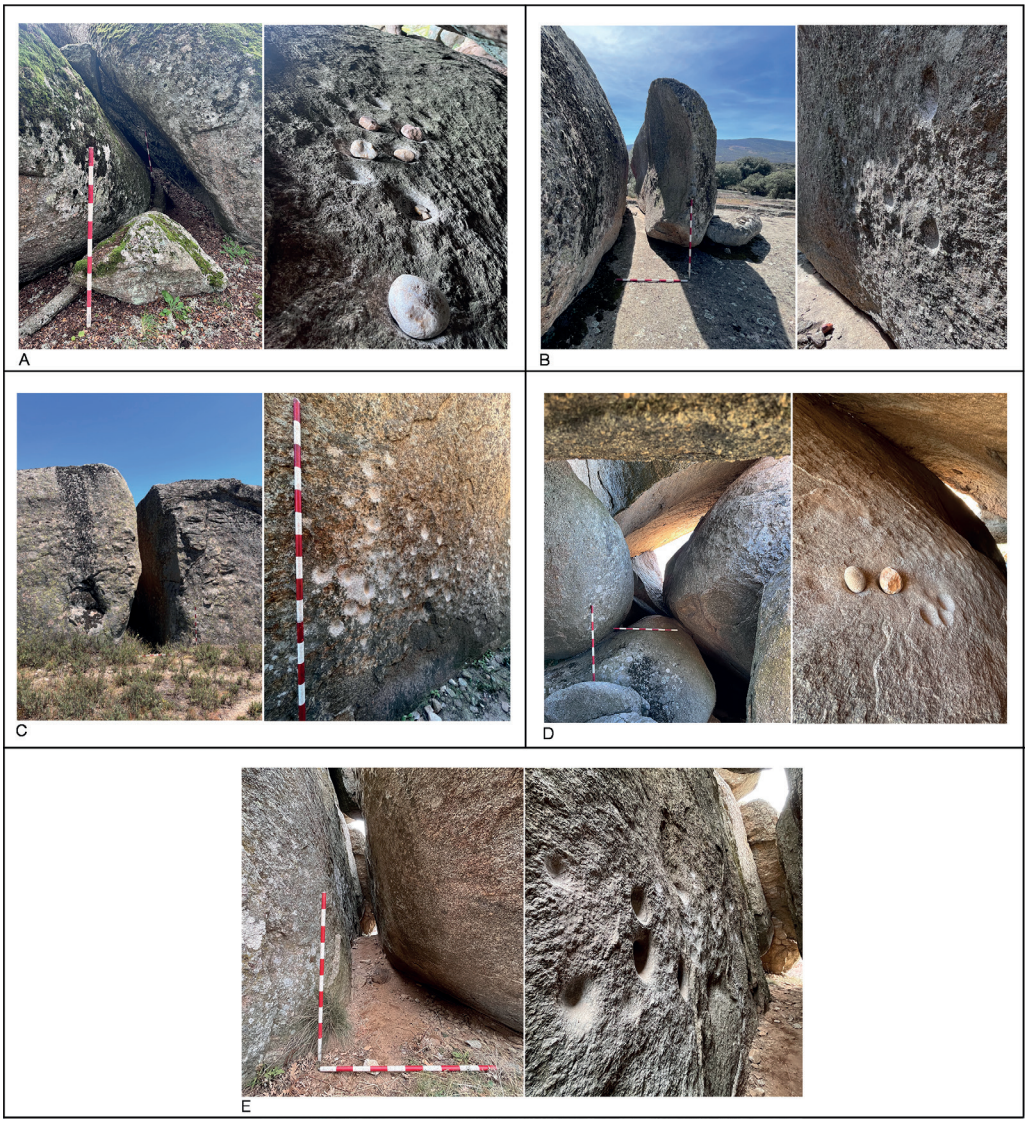


Fig. 9.2: A: El Campanario. B: Campanario de las Peñonillas. C: Canto de la Campana in Navalmoral de la Sierra. D: Cancho Sombrero. E: Las Campanitas de Aguilón. Photographs by authors.

accessible for individuals who may have crawled inside the rock cavity. Even if the special sound of the rock is well-known by the villagers, the presence of rock cupules was unknown to them, as they are only visible from inside the cavity (Fig. 9.3).

Composite rock outcrops with ringing properties

The last site category is represented by "El Campanario de los Regueros", characterised as a series of rock outcrops where several of them possess ringing properties. Although



Fig. 9.3: Canto de la Campana in Cabezas del Villar. Photographs by authors.



Fig. 9.4: El Campanario de los Regueros. Photographs by authors.

there are subtle markings on various rocks' surfaces, in places in which the sound is particularly clear, only four highly distinctive cup-marks are found. They are situated in a challenging-to-reach area at the base of one of the rocks, forming one of the walls of a small passage naturally created by the outcrop. Additionally, quarzitic pebbles are present on the site, likely indicating that they were specifically transported there for playing the rocks.

Commonalities

Despite the three distinct categories, all sites share commonalities, both in terms of the toponyms they are associated with, and the playing techniques employed to

create the cup-shaped marks. Notably, regardless of the site's category, all the cup-marks exhibit consistent dimensions. The length of the cup-marks typically ranges from 8.5 to 13.5 cm, with the most frequently utilised ones showcasing depths between 2.8 and 4 cm, and the less used ones of around 1.5 and 2 cm (Fig. 9.6). A noteworthy exception to this pattern is evident in some of the cup-marks studied at Las Campanitas de Aguilón, the site positioned closer to a village. Here, we have gathered several accounts of a recent, highly active use, primarily by village children who engaged in daily sessions of percussion and singing, and also competing to carve deeper cavities. Consequently, some of the cup-marks in Navalmoral exhibit depths of 10 cm and lengths of 15.5 cm.

Finally, it is crucial to underscore that all these sites require the act of playing "inside" the rock, even if it involves difficult positions for the performers. This phenomenon is especially evident at El Campanario de los Regueros, where the rocks could have conveniently accommodated playing on various surfaces. However, the cup-marks suggest that individuals contorted themselves, effectively playing "inside" the stones. Furthermore, it is worth noting that in the case of the example of Canto de la Campana from Cabezas del Villar, even though today's custom only indicates that stones are thrown in the hollow rock to produce a sound and make a wish, the way of playing the rock may have been different in the past. In our exploration of the site, we were able to observe cup-marks that had to be produced by directly striking the surface from a position "inside" the rock, in a manner analogous to the other sites. These marks were slightly smaller than average (8.5 cm in length and less than 1.5 cm deep), and appeared to have not been recently used, which has interesting implications for the chronological discussion of the sites (see below).

Acoustic study

The group of cup-marked rocks in our study can be considered part of the global phenomenon of *in-situ* lithophones. However, although the anthropic marks seem to coincide with other examples worldwide (Bednarik 2010a), the acoustic characteristics of most of the rock formations studied in the present article indicate a variety of acoustic occurrences.

Results of rocks with natural joints forming corridors

In the first type of sites, characterised by natural joints forming corridors (see above), the sounds generated by striking the walls are perceived as slightly metallic or with a subtle metallic reverberation. The presence of this metallic reverberation varies significantly depending on the striking technique employed. The characteristic sound is more noticeable at the centre of the corridor, corresponding with the clustering of cup-marks and the presence of deeply incised ones. Except for El Campanario, where reaching one of the walls is nearly impossible due to its forward-leaning position, the other four corridors produce similar sounds when played at the midpoint of the walls.

However, as indicated by the distribution of cup-marks, invariably one of the walls was preferred for striking. Interestingly, this preference does not seem to follow a specific geographical orientation pattern. It is also noteworthy to remark that at Las Campanitas de Aguilón site (precisely where the song linked to the percussive practice is preserved), the metallic sound is barely noticeable, even when tested on two contrasting occasions in different weather conditions.

Remarkably, in all five sites of the first category, the rocks do not produce any distinctive sounds when struck outside the corridor. Moreover, similar acoustic effects, akin to the sounds achieved by striking the walls, can be attained by hand clapping or by producing low percussive sounds within the interior of the corridor. It is evident that the walls and the rocks, when struck, do not themselves vibrate to produce a distinctive metallic sound, as is typical in lithophones. Instead, it is the modal resonance of the narrow and towering corridor that sustains specific overtone frequencies. The acoustic analysis of the recorded samples, captured with a Zoom H4n Pro field recorder, has provided initial confirmation of this phenomenon. In the case of rock corridors, acoustic tests were carried out by placing microphones at both exits of the corridor and also at three positions along the corridor: the middle of the first section, the centre, and middle of the second section.

The spectrograms and spectral profiles of direct blows on the corridor walls of the Campanario de las Peñonillas site closely resemble those generated by indirect percussive sounds made by striking two stones or even by hand clapping (see Fig. 9.5, A and B). Following an initial strike that produces a large number of inharmonic overtones, a discernible pattern of overtones emerges, roughly aligning with the harmonic series. As seen in the spectrograms, these frequencies evenly decrease in energy and duration as they move away from the fundamental, indicating that they result from the corridor acoustics rather than the vibration of the rocks. In the example presented in Figure 9.5, both the direct strikes against the rock walls and the indirect percussive sounds created by two rocks colliding at the centre of the corridor resulted in

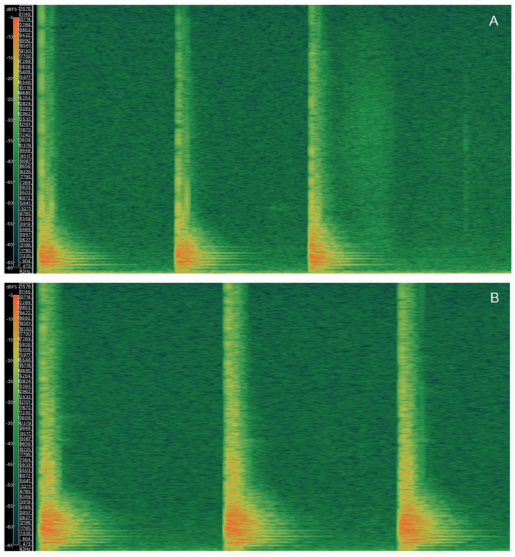


Fig. 9.5: A: Spectrogram of three waves produced by striking at the mid-point of the west wall of the rock corridor of Campanario de las Peñonillas. B: Spectrogram of three waves produced by striking two quarzitic pebbles together, in the centre of the rock corridor of Campanario de las Peñonillas. Authors' elaboration.

comparable soundwaves. The soundwaves correspond mostly to a harmonic series with a fundamental frequency estimated at around 240 Hz, which approximately aligns with the wavelength of the first vibration mode that could be sustained within the width of the corridor (in this case, the distance between the two walls at Campanario de las Peñonillas is around 0.7 m, which can uphold a standing wave with a wavelength of 1.4 m). Similar acoustic patterns were observed in the other rock corridors studied in the area. A comparable acoustic phenomenon is found in Finland, as described by Rainio and Hytönen-Ng at the Finnish Crevice Cave of Pirunkirkko in Koli (2023).

Results in hollow granitic rocks

In the case of the hollow rock of Canto de la Campana, its acoustic examination suggests the concurrent presence of several acoustic phenomena. In this site, the microphones were placed both outside and inside the rock "bell". Both positions recorded different blows to the outer and inner surfaces, executed at the cup-marks or possible cup-marks. The stone is situated in an open-air location with significant reverberation. When struck on the exterior, at a circular cup-mark, either of anthropic or natural origin, it produces a faint ringing sound emanating from the hollow rock. Nonetheless, when heard from the inside of the cavity it is evident that this external strike produces a distinct bell-like sound. This sound is similar to the one generated when striking the inner walls, at the cup-marks within the cavity. The spectrogram of these latter sounds indicates that the rock, when struck, is set to vibrate in modes that create a ringing sound (see Fig. 9.6). Consequently, it seems likely that the Canto de la Campana lithophone functions as an actual ringing rock idiophone, probably due to its compositions and shape. However, it is worth noting that the resonance of the cavity plays a role in shaping the resulting soundwave, which explains the results of the spectrogram.

Results in composite rock outcrops with ringing properties

Finally, the sounds produced in the third category of sites were significantly different. At El Campanario de los Regueros, a strong ringing sound was not only audible when striking the existing cupules, but also when many other areas of the inner and outer surfaces of the rock outcrop were hammered. These sounds were recorded with the microphones placed both inside the rock-crop, in the section facing the cup-marks, and also at two positions outside the rock outcrop. Analysis of recordings

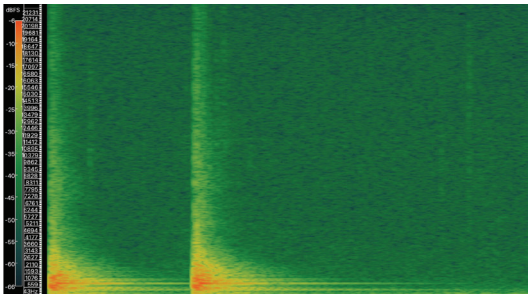


Fig. 9.6: Spectrograms of two waves produced by striking one of the cup-marks inside the hollow rock of Canto de la Campana in Cabezas del Villar. Authors' elaboration.

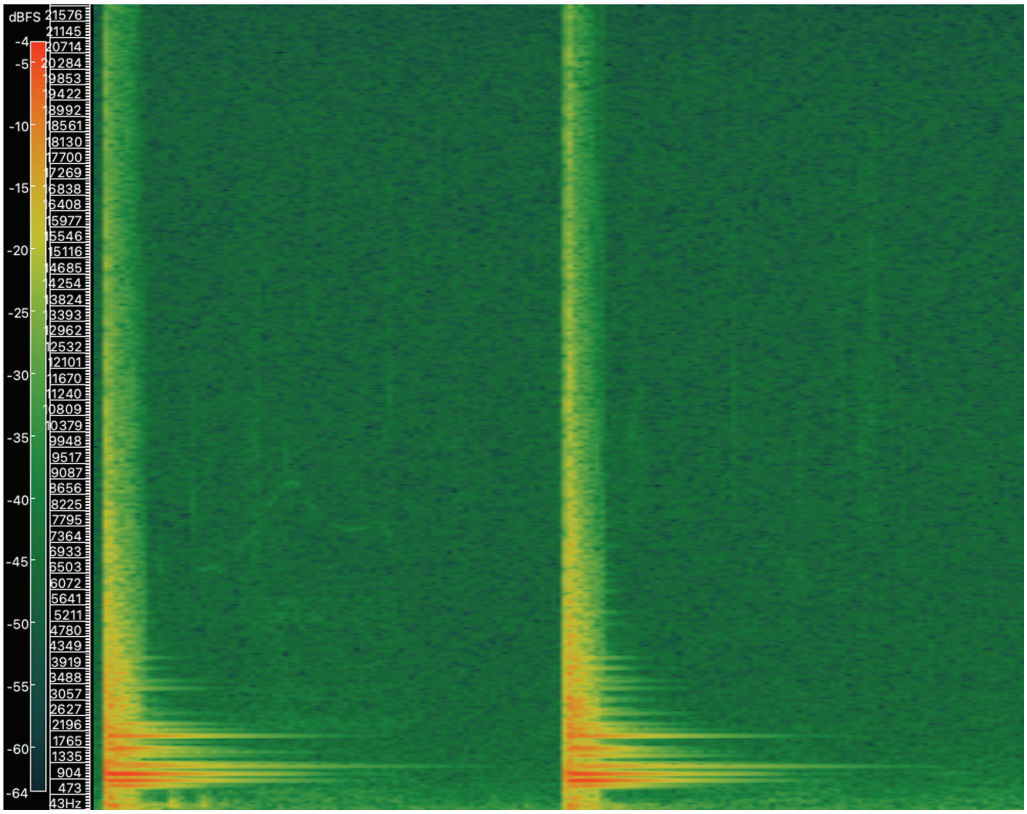


Fig. 9.7: Spectrogram of two waves produced by striking one of the cup-marks at El Campanario de los Regueros. Authors' elaboration.

obtained at this site revealed a spectrogram showing that the soundwave is produced by the rock's own vibration (Fig. 9.7). This is characterised by notably strong harmonic overtones, specifically from the 3rd to the 6th–8th harmonics of a series that originates from a fundamental frequency of around 160 Hz. Consequently, this site can be considered a true lithophone: an idiophone in which the sound is produced by the vibration of the body when struck.

In summary, despite the marks of anthropic action, the toponyms and their geographical proximity indicating a connection to a shared cultural tradition, each of the three different types of sites exhibit a distinctive acoustic nature. It is also important to consider that, to our knowledge, and despite the relatively common occurrence of *in-situ* lithophones with cup-marks in many parts of Europe, Africa, Asia and America (i.e., among many others, Fagg 1956; Lanning 1958; Robinson 1958; Malan 1959; Jellicoe 1965; True and Baumhoff 1981; Álvarez Martínez and Siemens Hernández 1987; Fagg 1997; Purser 2002; Boivin 2004; Lund 2009; Bednarik 2010a; Hultman 2014; Peña Nuñez 2014; Kleinitz 2018; Kleinloog 2019), the acoustic phenomenon of resonant corridors associated to a lithophonic practice that leaves cup-marks on the rock walls

seems to be unique. As far as we know, it has not been confirmed in other areas. There may be only two other potentially similar sites mentioned in the literature, one located in the Jos Plateau in Nigeria (Fagg 1997, 20–21) and a second one in the Vindhyan mountains in India (Wakankar 1975), but there are not testimonies of living traditions that may confirm their sonic use.

Chronological and cultural discussion

The origins of the acoustic use of these sites, as well as the antiquity of the oldest cup-marks, are difficult to assess, especially considering their continuous renewal up until the present time on at least six of the seven sites. However, comparable rock cupules discovered in the Iberian Peninsula have primarily been dated from the Neolithic to the Iron Age, and they have been often interpreted as rock art related to megalithic sites. This connection is also relevant in sites in proximity to our case study (see, for instance, Martín Valls 1983; Barroso Bermejo and González Cordero 1996; López Plaza 2009; Royo Guillén 2009 or González Cordero 2022). This emphasises the need for contemplating the potential ancient origins of the cluster under study.

Firstly, it is important to recall that even if the memory of the ringing properties of the site of Canto de la Campana from Cabezas del Villar was locally preserved, the presence of cup-marks in the inside was unknown. There was also no recollection of any practice that would imply crawling inside the rock or striking it with stones. This indicates that it is likely that this practice predates the 20th century. Furthermore, residents of the villages close to these seven sites, well-versed in their own cultural traditions and who knew the acoustical interest of their respective sites, displayed no awareness of the fact that similar sites existed in neighbouring villages. Consequently, it seems that only a past shared cultural or ideological framework may explain why the playing techniques and player positioning "inside" the rocks appear to be consistent across all these sites, despite the differences in their shapes and acoustic properties. For instance, as previously remarked, it is essential to play within the rock joints to produce metallic sounds in Type 1 sites, while the Types 2 and 3 do not necessitate the uncomfortable positioning required to produce the existing cup-marks. Similarly, the presence of resemblances in rock cupule production and location, such as the placement of the most numerous or deeper carvings on only one wall of the corridor, even when the sound is similar on both sides, raises substantial chronological questions.

It is interesting to note that some of these sites are in proximity to culturally and ritually significant rocks in the landscape, as identified in previous studies (Caballero Arribas and Mariné Isidro 2021a), and for which folk ritual practices and legends are documented. For instance, there are two sliding rocks near the Canto de la Campana site in Navalmoral de la Sierra, namely Esbarona del Cenicero and Lancha de la Casilla de la Zorra. Sliding rocks are found all over this territory, and although in most recent times were used as children's playgrounds, some accounts still link them with

fertility rites (Caballero Arribas and Mariné Isidro 2021a). Another example is the Campanario de las Peñonillas site, which is in the proximity of two other culturally significant rock formations, known by the locals as Silla de la Reina ("Queen´s Chair") and La Cama ("The Bed"), which have documented evidence of their use during fertility and passage rites (Caballero Arribas and Mariné Isidro 2021a). Connecting these sounding rock sites to these and other sacred rocks identified in the territory, it would be possible to suggest that these musical or sonic practices likely precede medieval times. Written sources from the 5th to the 8th centuries CE mention that ritual behaviours involving the veneration of rocks and stones persisted for centuries following the Christianisation of Western Europe. In Iberia, the Councils of Toledo IV (633), XII (681) and XVI (693) repeatedly condemn the *veneratores lapidum* (stone worshippers), among others, which indicate the prevalence of cults related to natural features in the landscape.[2]

Many of the ritual practices in the landscape forbade by the Visigothic Councils do not seem to correspond to Pagan Roman rites but are most likely remnants of indigenous pre-Roman practices. It is then interesting to point out that the Cancho Sombrero site is positioned within the vicinity of the important Cerro del Berrueco Iron Age settlement. Indeed, this cluster of seven sites is located at the centre of the Vetton territory, an important Second Iron Age Celtic cultural group that is also known for the creation of large granitic sculptures (*verracos*, see Alvarez-Sanchís 1994) and granitic altars (i.e., at the *oppidum* of Ulaca). Interestingly, the still-standing Iron Age granitic *verracos* seem to have maintained, in some villages, certain public and ritual significance (Caballero Arribas and Mariné Isidro 2021b; Almagro-Gorbea 2022). Also the Cancho Sombrero site is located at the centre of a Final Bronze Age settlement that features numerous surface finds of Bronze Age pottery. The juxtaposition of these archaeological contexts suggests a deep-rooted history, as it would be unlikely that these special acoustic conditions would have gone unnoticed to past populations frequenting the area.

If indeed these sonic practices and the acoustic awareness of these sites are rooted in antiquity or even in prehistory, they possess the potential to shed light on past sonic and ritual behaviours. For instance, they may suggest the existence of specific ontological frameworks that attributed live or supernatural significance to rocks within these landscapes, and that used sounds or music in order to relate with these non-human beings. It is possible that these rocks were conceptualised as animate entities possessing agency or as dwellings of non-human beings (*numina loci*) that engaged in communication with humans through distinctive auditory phenomena. This is certainly attested in ethnographic accounts in other areas of the Iberian Peninsula (Almagro-Gorbea and Alonso Romero 2022). Producing sounds by striking the rock may have been a ritual way for humans to engage with these supernatural beings, both sonically and physically. Furthermore, the existence of a past shared ontological framework in which rocks possessed agency, were considered animated beings, or were believed to be the dwellings of non-human entities with

supernatural powers may also explain the enduring ethnographic tradition of making wishes by tossing a stone at the Canto de la Campana in Cabezas del Villar. In fact, within the same studied area, there is a still well-known custom of throwing stones to the top of specific large rocks in order to make a wish (Caballero Arribas and Mariné Isidro 2021a), maybe a faint reflection of a long-lasting conception in which landscape features and their supernatural inhabitants are entities with the capacity of intervening in human life. However, further interdisciplinary research and exploration will be essential to better understand their possible archaeological, historical and cultural significance.

Conclusion

This ethnoarchaeological study has delved into the granitic landscapes of the northern flank of the Gredos mountain range, Spain, and has unveiled an acoustically significant phenomenon located both in the south of Avila and in neighbouring areas of the province of Salamanca: the utilisation of natural rocks in the landscape for sound production, resulting in numerous cup-marks on the rock surfaces. The seven sites under analysis in this article share commonalities reflecting a cohesive cultural cluster, evident in the associated toponyms and the presence of similar cup-marks. This preliminary study marks the first attempt to classify and unravel their cultural, historical and acoustic dimensions. We have first categorised the seven sites into three distinct types: natural rock corridors, hollow granitic rocks and rock outcrops. Even if all sites initially seemed to have the same acoustic properties, as a discernable metallic sound is produced in all of them when the rock surface is struck, our study has uncovered at least two different acoustic phenomena. At the natural corridor sites, the metallic sounds result from an acoustic modal resonance that reinforces specific frequencies after a first percussive sound. At the open-air rock outcrop, the metallic sounds are produced by the vibration of the rock itself, aligning with a common phenomenon worldwide, the use of ringing rocks as lithophones. Finally, at the hollow rock site, both phenomena seem to be happening simultaneously.

The origins of these acoustic practices pose a significant challenge to archaeology due to the continuous renewal of cupule marks across time. Nevertheless, several compelling clues suggest significant antiquity. Only a shared past cultural framework could explain the consistent techniques and player positioning observed across sites, despite variations in their acoustic properties and different recent uses. Moreover, the enduring ethnographic tradition of making wishes by tossing stones at specific rocks might trace its origins back to a time in which the population shared an ontological framework in which rocks and other natural features were considered living entities with agency, or the dwelling sites of non-human entities with supernatural powers.

Finally, this research shows the importance of ethnographical fieldwork to better understand past and present cultural landscapes and soundscapes. To our

knowledge, the current case study may constitute the first ethnographically confirmed idiophonic practice of striking the walls in natural resonant corridors, thus creating cup-marks on its rock surfaces. We believe that these examples could even allow an inquiry into whether there is a possible acoustic explanation for the existence of prehistoric rock cupules in similar natural settings (such as rock corridors or hollow rocks) or perhaps within prehistoric architectural structures, such as megalithic corridors, for which ringing properties of the rocks have not been considered worth of examination.

Notes

1 While this article was being published, we identified and studied an eighth site in the same area, which falls under the Type 1 category.

2 For instance, in Tol. XII, Chapter XII, about the Worshippers of Idols: *"Pracepta haec Domini non in ultione sed in terrore delinquentium adponentes non mortis per hane sententiam promulgamus, sed cultores idolorum, veneratores lapidum, accensores facularum et excolentes [sacra] fontium vel arborum admonemus, ut agnoscant quod ipsi se spontaneae morti subiciunt qui diabolo sacrificari videntur"* ("Remembering these precepts of the Lord, not for the punishment of criminals, but for terror, by this our decree we do not impose the death penalty, but we warn the worshipers of idols, those who worship stones, those who light torches, and they worship the fountains and the trees, who recognize how those who make sacrifices to the devil are spontaneously condemned to death"). The translation is ours from the Spanish translation in Vives *et al.* 1963, 21.

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Chapter 10

The rock art soundscapes of the Karakol valley (Republic of Altai, Russia): An archaeoacoustic study of a unique landscape

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Abstract

This article explores the presence of shamanism in the Karakol valley, analysing its historical timeline from prehistoric to modern times. Scholarly opinions vary, suggesting origins from the Neolithic to the modern era, with clearer depictions emerging in the 18th and 19th centuries. Acoustic tests conducted in four areas associated with shamanic practices revealed inconclusive results due to their location in an open-air environment. However, accounts of intense auditory experiences during shamanic rituals suggest that, even if acoustics may be used in some occasions, there are other alternative means of emotional control. It is argued that the lack of significant acoustic effects in the tested sites does not rule out the possibility of shamanic rituals. The discussion also delves into the representation of shamans in rock art and the interpretation of results from acoustic tests, considering factors like reverberation and sound clarity. This study highlights the complex interplay between shamanism, sensory experiences and ritualistic practices in ancient societies.

Keywords: archaeoacoustics, Altai, Siberia, shamans, reverberation, sound clarity

Introduction

In August 2019 the Artsoundscapes project carried out a fieldwork campaign in Russian Altai. Acoustic tests were conducted in four zones: the Lower Chuya valley, Urkosh, Karakol and the middle sector of the Katun river close to the rural locality of Kuyus (Fig. 10.1). The results obtained in the two first zones indicated that the acoustic conditions of the rock art sites were appropriate for storytelling and singing, intangible cultural practices well attested in the area by the ethnographic sources.

More importantly for the chronology of the rock art, the excavations undertaken at some of these sites point to the possible existence of these practices in earlier periods, given the presence of campfires around which singing and storytelling took place in recent times. Evidence of sacrifices performed close to decorated walls indicate that these locations had a special meaning for those who spent some time around them (Díaz-Andreu *et al.* 2023a; 2023b). Like these two already published areas, the third area where acoustic tests were performed during our fieldwork, the Karakol valley, is placed along the Chuysky (Chuiskii) Tract – a road that crosses from north to south/southeast of today's Republic of Altai and was most likely used already in prehistory (Fig. 10.1). Yet, despite this similarity, there were key differences with the previously analysed areas.

The Karakol valley contrasts with the two previous areas analysed because of its unique character (Plets 2013, 247–263). In Karakol, the number of prehistoric sites is smaller, and none of them shows a high concentration of motifs. Moreover, many rocks in Karakol display fine engravings dated to the Turkic[1] and the historic periods. Especially among the latter, there are many representations of shamans, a term that comes from the Evenk of northern Siberia but has been used to designate a form of religious sensibility and practice found around the world, although not a single, unified religion (Vitebsky 2001, 10–11). One of the key features of this type of religion is trance, shamans's ability "to leave the body and travel to other parts of the cosmos, particularly to an upper world in the sky and a lower world underground" (Vitebsky



Fig. 10.1: Map of Russia and countries to its south with the Altai Republic marked. The four areas where acoustic tests were undertaken in August 2019 are shown in the inset to the bottom right. 1: Lower Chuya area; 2: Urkosh area; 3: Karakol valley; 4: Kuyus. The line transversally crossing the Republic of Altai represents the Chuysky Track. Author's own elaboration.

2001, 10). The high number of shamans' motifs in the Karakol valley is significant and marks the singular nature of the region, which is still considered sacred by today's local populations (Plets *et al.* 2011, 377). This article will explore whether the distinctive character of the Karakol area is reflected in the different acoustics of its rock art landscapes. A review of the evidence of shamanism, especially in relation to rock art in Siberia throughout the different historic periods is undertaken, paying particular attention to the Karakol valley. This is followed by a brief description of the rock art sites where archaeoacoustic tests were performed and an explanation of the results obtained. All this will be the basis for discussing the nature of shamanistic rock art soundscapes of the study area.

Shamanism and rock art in Siberia

Did the rock art of Altai have a shamanic character? This question will first be answered by looking at the evidence in the prehistoric and historic periods, not only in rock art but also in other types of sites. We will then look at the possible confirmation found in Siberia to narrow the angle and focus on Altai.

Shamanism in the prehistory of Altai?

History of research

Scholars have discussed evidence of shamanism in rock art since the end of the 19th century. Znamenski mentions that in 1892, Russian ethnographer Grigory N. Potanin (1835–1920) presented a "Report on shamanic drums and the sign of the cross on them" at a session of the Russian Imperial Geographical Society. In it, he linked the cross motifs found in the rock art of a site he called Kaibazhi with the same sign painted in Siberian frame drums (also called tambourines in the literature) (in Znamenski 2003, 97–98). Also, in the first third of the 20th century the painter Grigory I. Choros-Gurkin (1870–1937) recorded some images of shamanic tambourines in the Karakol valley, in the hill of Bichikty-Bom (see below). For his part, many decades later Soviet archaeologist Alexei P. Okladinikov (1949 in Hoppál 2007, 44) insisted in the connection between rock art and shamanism. He suggested a date for the appearance of shamanism in the Bronze Age and identified some figures as shamans (see, for example, Figs 10.2a and 10.2b). Moreover, Hungarian ethnographer Vilmos Diószegi, who visited with Okladinov some panels next to the Bolshaya Khada community, found the representation of a drum on a large cliff with many rock art motifs, a drum that his colleague considered to be from the Bronze Age (Diószegi 1968, 192–195) (Fig. 10.2c). Later additions to the number of representations of shamans and shamans' drums, together with the earliest findings already mentioned, can be found in later publications (see, for example, Devlet 2001; Rozwadowski 2001; Devlet and Devlet 2002; Rozwadowski and Kosko 2002) (Fig. 10.2).

The abundance of recent publications that mention shamanism in the context of Siberian rock art can be connected to the high-profile debates taking place from

the mid-1980s. These started in South Africa (Lewis-Williams 1986; 1987) and then extended to other parts of the world such as the European Palaeolithic (Lewis-Williams and Dowson 1988) and Neolithic rock art (Lewis-Williams and Dowson 1993). There were voices, however, against the consideration of shamanism as a global prehistoric religion (Bahn and Vertut 1997; de Beaune 1998; Lorblanchet *et al.* 2006; Bahn 2010, 67–135) and nuancing its presence, something that we can see in scholars working in Central Asia such as Henri-Paul Francfort (Francfort *et al.* 2001; see also below). However, most scholars working on Siberian rock art remained oblivious to the debates and continued with the long-established tradition of relating rock art and shamanism. The only sign of some influence of the complaints expressed by the small group of authors against shamanism can be seen in the use of the term "proto-shamans", a term that appeared in the literature in the year 2000 in relation to the motifs dated to the prehistoric period (for example Devlet and Devlet 2000, 371; Rozwadowski 2017; 2019; 2021). Nowadays, three decades after the proposal of shamanism as an all-embracing theory, scholarly debate has moved on. Since the 2010s, rock art researchers' attention has turned to animism and ontology (Janik 2010; Willerslev 2013; Díaz-Andreu *et al.* 2023a) and, although shamanism is still mentioned, there is a higher awareness of the very high diversity of ritual practices that can take place beneath this umbrella term.

Shamanic evidence in rock art?

What elements did scholars use to identify shamanism in the rock art motifs in Siberia? In 2001, regarding the oldest motifs, Russian rock art specialist Ekaterina Devlet commented on shamanic flights (Fig. 10.2e), drums and drumsticks (Fig. 10.2f), bows as an object that could have had the same function as a drum (Devlet 2001, 49), and particular head-gear "often decorated with horns or antlers, and with bird feathers or other ornithomorphic features" (Devlet 2001, 50) (Fig. 10.2g). Regarding the key presence of drums, there seems to be some disagreement, for Andrzej Rozwadowski has noted that, at least in Southern Siberia and Central Asia, it is challenging to find unequivocal representations of drums in rock art that could be older than the 1st millennium BCE (Rozwadowski 2009, 316). He mentions that some researchers only date the appearance of shamanism to that millennium (Bokovenko 2006) and this leads him to date Figure 10.2g not in the Bronze Age but in the Iron Age Scythian period. Rozwadowski is not the only one reluctant to talk about shamanism in the Bronze Age. American specialist in the rock art of Mongolian Altai, Esther Jacobson-Tepfer, has also criticised this early date, and a similar opinion has been expressed by French specialist, Henri-Paul Francfort. According to him it is only from the second half of the 1st millennium BCE there are more abundant representation of characters with drums and other paraphernalia with similarities to the shamans of the historical period (Francfort 2006, 173).

Focusing on the Altaian area, no representations of shamanic drums have been found in the prehistoric rock art motifs. However, there are other elements usually

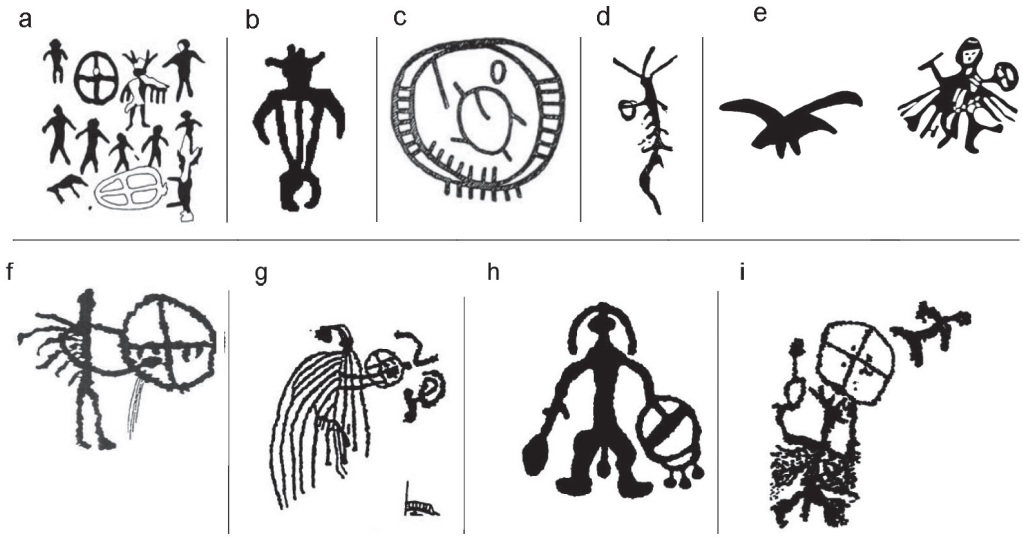


Fig. 10.2: Motifs likely represent shamans and/or frame drums. a: Scene with a motif possibly representing a shaman recorded by A.P. Okladinov in 1949. Mokhsogollokh-Haja, middle Lena. Source: (Devlet and Devlet 2005: figure 237, Hoppál 2007: figure 13); b: Shaman carved near a tambourine on the rocks above the Bolshekadinsky rapids on the Oka River, above Bratsk (Irkutsk Oblast) (Source: Okladnikov 1964, 74); c: Shaman's drum from Krasnoiarsk first published by Diószegi (1960, 108–109) (Source: Diószegi 1968, fig. p. 196; Hoppál 2007, fig. 27); d: Lake Maloye, Middle Yenisei River (Source: Devlet 2001, fig. 7.2); e: Representation of the shamanic flight at the Niukzha rock art site in the Olekma River basin (Amur Oblast) (Source: Devlet 2001, fig. 7.4); f: Oglakhty, Middle Yenisei river (Khakasia) (Source: Devlet 2001, fig. 3.5.1; Devlet and Devlet 2005, fig. 241.1); g: Oglakhty (Khakasia) (Source: Devlet 2001, fig. 3.5.2; Devlet and Devlet 2005, fig. 242.1); h: Motif found in a cleff of the rock in the Minusinsk Basin. The site is near Ilinskaya Village, Krasnoyarsk County (Source: Rozwadowski 2009, fig. 1); i: Middle Yenisei (Khakasia) (Source: Devlet and Devlet 2005: fig. 241.3). Author's own elaboration.

associated with shamans that Devlet sees as evidence of shamanism before the Iron Age of Altai. As she puts it, talking about motifs such as Figure 10.3a:

> frontal images of male and female figures wearing long, fringed coats with bands hanging down from the hands, arms, and sometimes from the sides, chest and hem... Most of these figures are shown with raised hands, suggesting that they are "praying", perhaps appealing to celestial realms or supernatural powers; others are shown with extended hands, as if they are flying... Female images are usually shown with more complicated clothing, including a more prominent skirt-like element. Fringes may be depicted on both sides of the torso, as well as at the sides, breast and hem of the clothing. The evident differences between the male and female representations in the rock art may be connected with the co-existence of male and female shamans and persons involved in shamanic activity. (Devlet 2001, 45)

Delvet also offers alternative explanations for some of these figures, as illustrated in the case of the motif in Figure 10.3b, that she does not interpret as a shaman but

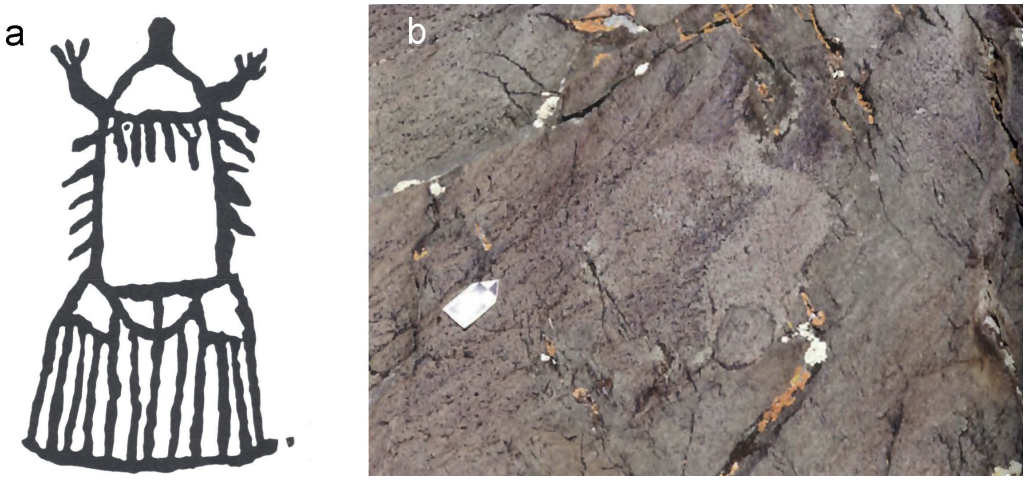


Fig. 10.3: a: Female frontal motif with bands hanging down from the sides and chest. Kalbak Tash I (Source: Kubarev and Jacobson 1996, fig. 194); b: Spirit Figure with moth wings and horns. Tsagaan Salaa III, Bayan Olgiy aimag, Mongolia (Photo: Gary Tepfer. Source: Jacobson-Tepfer 2015, fig. 3.18). Author's own elaboration.

a "spirit Figure with moth wings and horns" from the Early Bronze Age (Jacobson-Tepfer 2015, 102).

It could be said that, at least in a great deal, the difference in opinion of these different authors seems to be related to geography: the more to the south, the more reluctant scholars are to see shamanism in the prehistoric period, at least before the Iron Age. Yet, as we will see, in the case of Altai, there are some scholars who still insist on talking about shamanism in the Bronze Age (see below).

Evidence of shamanism beyond rock art

What about other evidence that can tell us about early shamanism in Altai? Two sites are relevant in this respect: the Tourist-2 archaeological site and the prehistoric burial area excavated in the village of Karakol. The first of them, the Early to Middle Bronze Age cemetery at the Tourist-2 site, is located north of the Karakol valley in Novosibirsk. In it, a series of theriomorphic and ornithomorphic figures with parallels to the so-called Karakol culture (see below) were found. They were interpreted as a reflection of the cult of the ancestors and early forms of shamanism (Basova *et al.* 2019) (Fig. 10.4).

A key site for those who are in favour of the existence of shamanism from the Neolithic in the Altai area is the burial found in the village of Karakol. This archaeological site has become the representative site of the Karakol culture, considered by some to be a regional variation of the hunting-dependent Okunev culture of the Minusinsk basin, located about 450 km to the northeast, and traditionally dated to the Early Bronze Age or earlier (Jacobson-Tepfer 2015, 40, 82). Yet, despite certain similarities between both (Kubarev 1988), there are also many differences

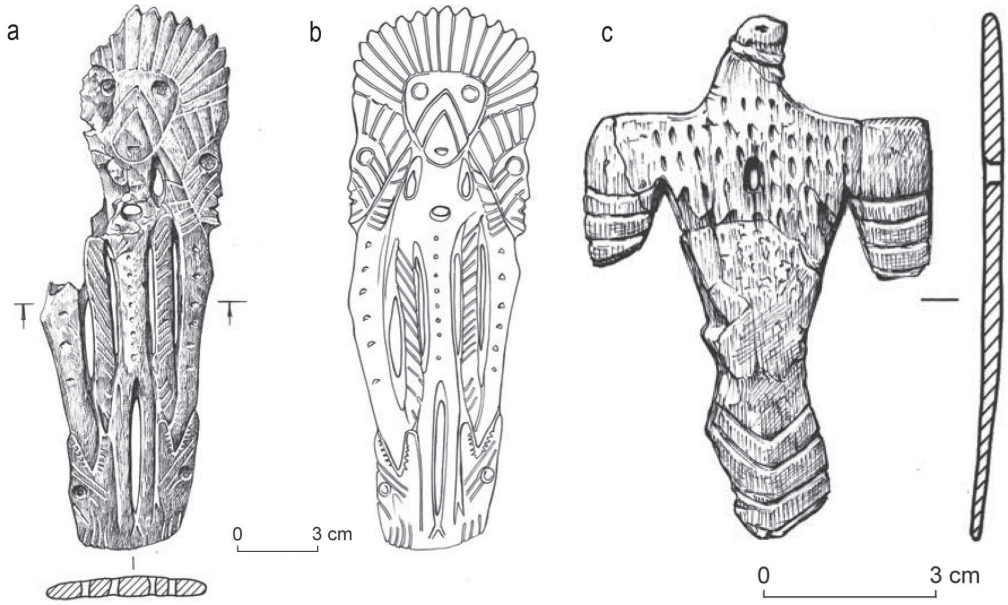


Fig. 10.4: Figurines found in the Early to Middle Bronze Age cemetery at the Tourist-2 site. a and b: Belt buckles with anthropomorphic representations; c: Image of a bird. Source: based on Basova et al. 2019, figs 2 and 6. Author's own elaboration.

regarding ritual, and, according to Jacobson-Tepfer, there is a lack of diagnostic material culture (Jacobson-Tepfer 2015, 81n).

The Karakol burial was excavated in 1985–1986 by Vladimir Kubarev (1946–2011) (Kubarev 1988). The site was found while landscaping a plot of land in the village to make a schoolyard next to a community building (Jacobson-Tepfer 2015, 82) (Fig. 10.5). Five burials were identified; some, unfortunately, had already been disturbed by the bulldozers. They were small, rectangular cists delimited by stone slabs. Interestingly, many of them seemed to be reused, a practice characteristic of the northeastern Okunev and eastern Isakovo[2] burials (Jacobson-Tepfer 2015, 82), and in general in other parts of Asia (Miklashevich 2003a, 30). Kubarev dated the burials to the middle of the second half of the 2nd millennium (Kubarev 1988). In contrast, other scholars have proposed an earlier date, the first half of the 2nd millennium (Jacobson-Tepfer 2015, 81n; Molodin 2006, 281).

The inner walls of the rectangular cists were covered with engraved, pecked and painted motifs. For the latter, red, white and black colours were used and the motifs seemingly formed scenes involving anthropomorphic creatures and animals, including moose, ibexes, birds and dogs. Moose and caprids seemingly belonged to an earlier phase. The stone slabs where these figures had been executed were later turned clockwise and reused for the Karakol burials (Jacobson-Tepfer 2015, 89). The figures of a later period include some composite motifs part human and part animal with similarities with other figures found in a vast territory that includes Southern



Fig. 10.5: a: View of the village. Karakol. Altai Republic. The arrow indicates the site of archaeological excavations (Kubarev 2009, fig. 2); b: Burial 2 of Kurgan 2 (Kubarev 2009, fig. 30); c: Reproduction of the painted motifs found on the south wall of burial 2 in the kurgan 2, south wall, Karakol. Two frontal figures with large, feathered heads and long, tail-like hands are accompanied by frontal figures with vertical horns and clawlike hands (Kubarev 2009, fig. 32); d: Documentation made of the motifs in c. Drawing: L.-M. Kara, after Kubarev 1988 (Jacobson-Tepfer 2015, fig. 3.3). Author's own elaboration.

Khakassia, where the burial site of Tas-Khazaa has been excavated (Savinov 2019) and the area of the Tuba river in Krasnoyarsk, where the site of Shalabolin is found (Jacobson-Tepfer 2015, 37). The most important of these figures, in Jacobon-Tepfer's view (2015, 90), were front-facing, and displayed haloes formed with horns or feathers (Fig. 10.6). Other figures were running and were also adorned with either a feathered headgear or a peculiar looped structure emerging from their heads (Fig. 10.5c and 10.5d). Jacobson-Tepfer sees parallels between the feathered heads of the Karakol burials and those from Shalabolin in the Krasnoyarsk Krai (2015). Writing about the motifs the excavator wondered:

> Who are the main characters depicted on the Karakol plates? Are they shamans? Good or evil ghosts? And may be even Gods? Everything is posible. (Kubarev 2009, 81)

Historic period

Regarding the Turkic period, there does not seem to be much in terms of evidence of representations of tambourines in the area of Altai. Erkinova and Kubarev believe that the engravings that have been dated to that period are, in fact, of the historic

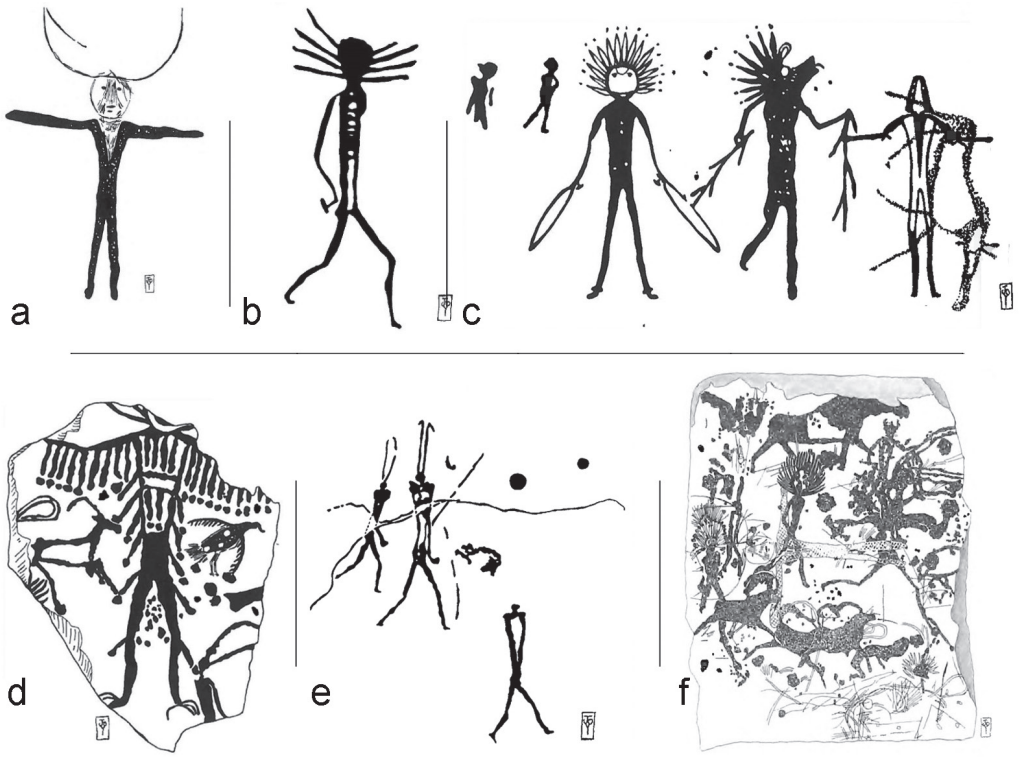


Fig. 10.6: Engraved and painted motifs in the upper layer of a slab forming the west wall in burial 2 of kurgan 2, west wall. Karakol. Drawing: L.-M. Kara, after Kubarev 1988 (Jacobson-Tepfer 2015, fig. 3.2); Running anthropomorph with peculiar headdress made on a cover slab of kurgan 2. The motif was pecked, engraved and scrapped. Drawing: L.-M. Kara, after Kubarev 1988 (Jacobson-Tepfer 2015, fig. 3.4); c: Painted and pecked motifs with feathered headdresses. The one at the centre has a bear-like head. Burial 5, on a slab from the south wall. Drawing: L.-M. Kara, after Kubarev 1988 (Jacobson-Tepfer 2015, fig. 3.5); d: Motif of bird-man pecked and scraped on a slab from burial 2, kurgan 1 (Jacobson-Tepfer locates this burial 2 in kurgan 1 (Jacobson-Tepfer 2015, 86) and kurgan 2 (Jacobson-Tepfer 2015, 85) (Jacobson-Tepfer 2015, fig. 3.6); e: Three pecked and engraved motifs, two of them with tall headdresses and all executed with pecking and engraving techniques. Slab 6, burial 5 (Jacobson-Tepfer 2015, 87, fig. 3.8); f. Superpositions in slab 3 of burial 2, Kurgan 2 (Jacobson-Tepfer 2015, 87, fig. 3.7). Author's own elaboration.

period (Erkinova and Kubarev 2004, 91). Indeed, there is plenty of evidence of shamanism in the Modern period: the same items mentioned for the prehistoric period – drums, drumsticks, particular head-gears and cloth decorations – are found in the much finer rock engravings dated in the last few centuries, probably with a chronology from the 18th century onwards, Interestingly, a series of representations found in other types of objects such as tobacco containers also show the places where shamans performed. These were mainly in enclosed spaces but occasionally also in the open-air (Fig. 10.7).

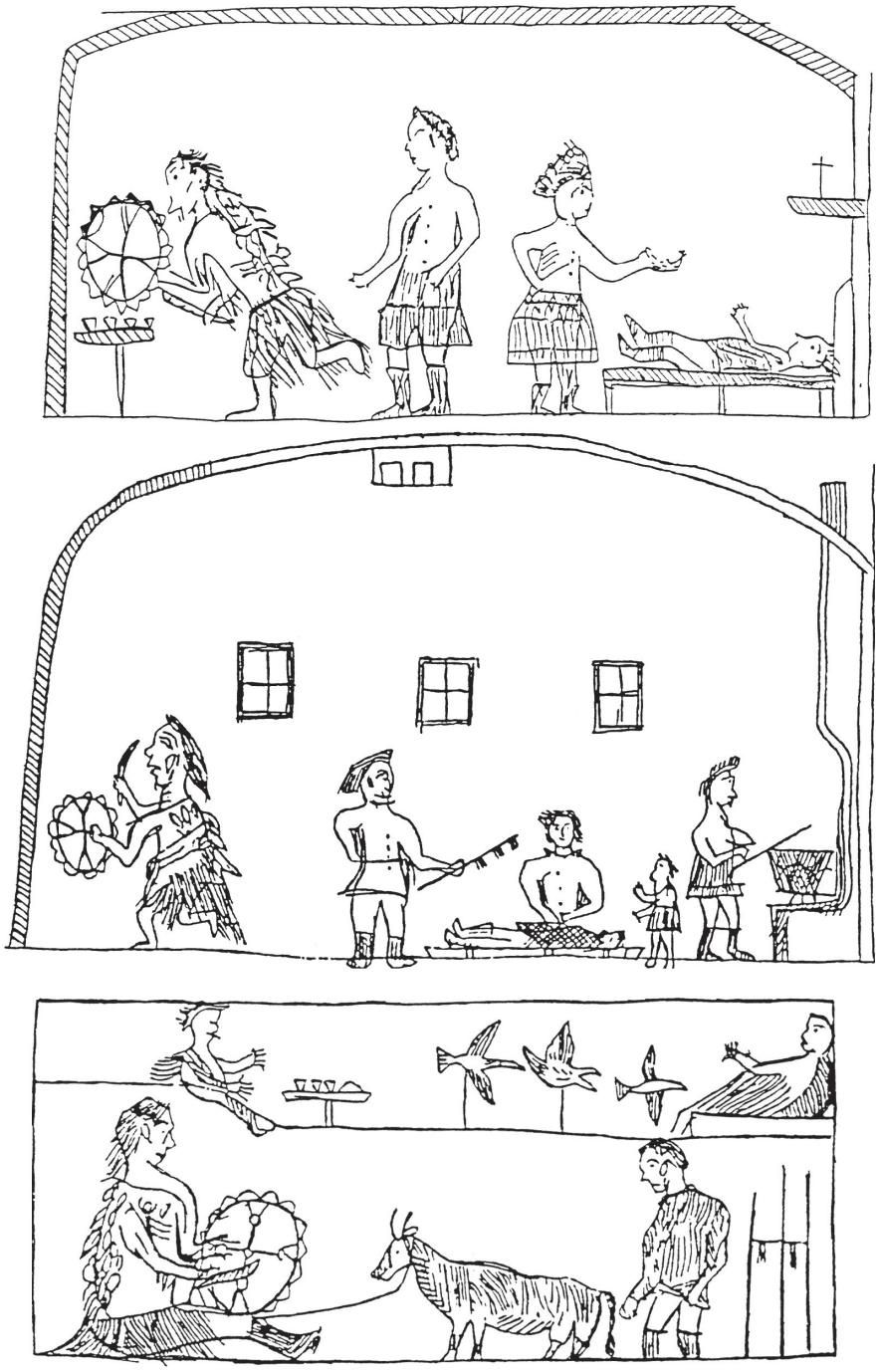


Fig. 10.7: Decoration of Yakut tobacco containers made from birch bark showing shamanic séances (Devlet 2001, fig. 3.9).

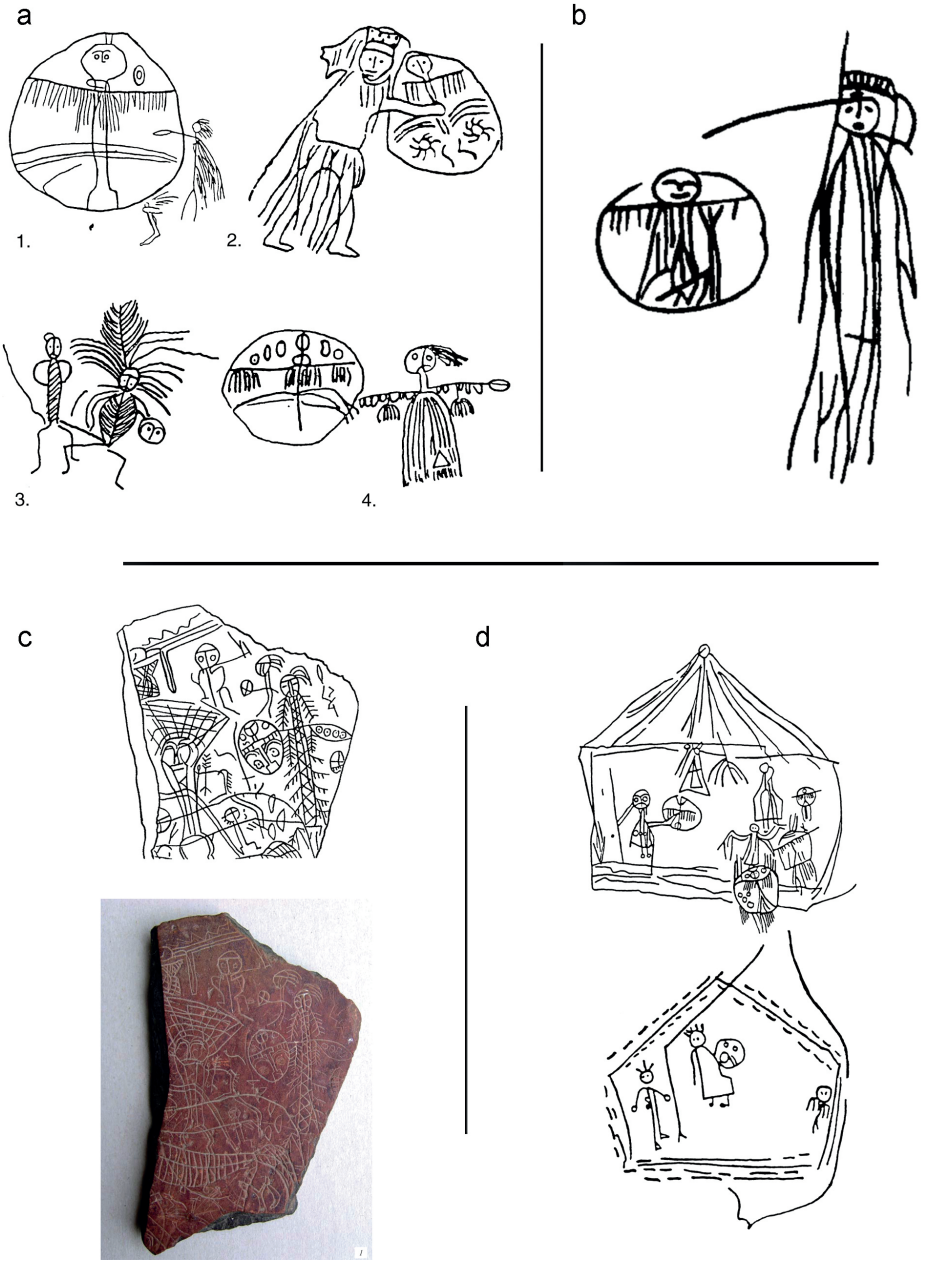


Fig. 10.8: Historic motifs of shamans from the Altai region. a: 1. Karakol; 2. Altai; 3–4. Shalkoby. (Devlet 2001, fig. 3.2); b: Late modern engraving from Karakol published by Kubarev with no data of provenance; c: bottom: engraving on a piece of sandstone tile now in the school museum, Karakol (Devlet and Devlet 2002, fig. 6.4); top: Documentation of the tile (Kubarev 2009, fig. 157). c: Karakol. (Kubarev 2009, fig. 157); d: shamanizing in a yurt. Rock art panels from the historical period, Shalkoby, Altai (Devlet 2001, fig. 3.10). Author's own elaboration.

In the last few years, rock art specialists have started asking local shamans about the meaning of rock art. Thus, Jean Clottes recently described how a modern Tuvan shaman identified cross rock paintings with the cross represented in his drum, which symbolised the cardinal points (Clottes 2016, 80), seemingly confirming what Potanin had said more than a century earlier (see above).

In contrast with the earliest rock art, all authors agree on the connection between historic engraved drum motifs and shamanism (Fig. 10.8). On a piece of sandstone tile in display in the school museum of the village of Karakol there is even a representation of a scene of shamanising in a yurt (Fig. 10.8d).

Sites tested in the Karakol valley

As mentioned in the introduction, in August 2019 the Artsoundscapes project undertook research on the acoustics of rock art landscapes in Russian Altai, including in the valley of Karakol. The archaeoacoustic studies of rock art sites have followed a great variety of methodologies over time, evolving from simple observational methods (Glory 1964; Reznikoff 1987), to quantitative approaches based on principles and techniques from the field of acoustic engineering (Dauvois and Boutillon 1990; Fazenda *et al.* 2017). The method used for the Artsoundscapes project is built on the analysis of a full set of Impulse Responses (also referred to as IRs) gathered at each site (Díaz-Andreu *et al.* 2023a; 2023b). The methodology employed to register and analyse the IRs follows the recommendations outlined in the ISO 3382-1 (2009). However, certain adaptations in the measurement protocol are needed in each case to account for the particularities of rock art sites such as those with which we worked in Altai because of their location in open natural sites. For a more detailed discussion on the applicability of the standard in rock art sites, see Alvarez-Morales *et al.* (2023).

The archaeoacoustic campaign in Karakol included several sites of the lower section of the Karakol valley (Russian Каракол) river valley, before the junction with the river Ursul (Russian Урсул) next to the rural locality of Kurota (Russian Курота) (selo) in the Ongudai District. In this area, we identified four rock art sites (Fig. 10.9) where we performed 15 acoustic measurements, although a series of technical constraints meant that only nine can be considered valid (Table 10.1).

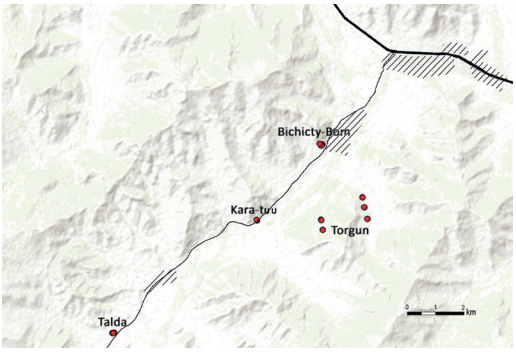


Fig. 10.9: Map of the lower section of the Karakol valley with the rock art sites of Kara-Tuu, Torgun, Bichicty Bom and Talda. Red dots indicate test points. The slashed lines indicate modern settlements. The lines indicate roads, the thicker one being the Chuysky (Chuiskii) Tract. Karakol is the village at the crossroads. Author's own elaboration.

The methodology followed involved a Multiple Input-Multiple Output (MIMO) approach, involving the use of a custom-built dodecahedral sound

Table 10.1: Number of acoustic measurements per site.

Date	*Site name*	*Number of acoustic measurements*	*Valid acoustic measurements*
19/8/2019	Kara-Tuu	2	0
19–20/8/2019	Torgun	5	4
21/8/2019	Bichicty-Bom	5	2
21/8/2019	Talda	3	3

source (a MIMO loudspeaker with a configurable directivity (www.adrianofarina.it/MIMO/). A 3rd-order Ambisonics microphone (Zylia ZM-1) was also employed. The IRs are obtained by post-processing the audio recordings with the MIMO Matlab script (the latest version of the MIMO script is available at github.com/xorgol/MIMO_Matlab). The acoustic data gathered has been archived to be used to generate auralisations, so that the acoustics of the tested sites can be experienced even by those unable to visit it (Benítez-Aragón *et al.* 2024).

Kara-Tuu

This site is located between the rural locality of Bichikty-Boom (Бичикту-Боом) and Boochi (БооЧи) in the Ongudai District. The rock art panel is next to the routeway through the Karakol valley. It has a high quantity of carvings dated to the Neolithic, Bronze Age and Scythian periods (Fig. 10.10). Interestingly all, or at least the great majority, of animal motifs, are looking towards the northeast, i.e. towards today's village of Karakol, where the burial was excavated. This site is, as yet, unpublished.

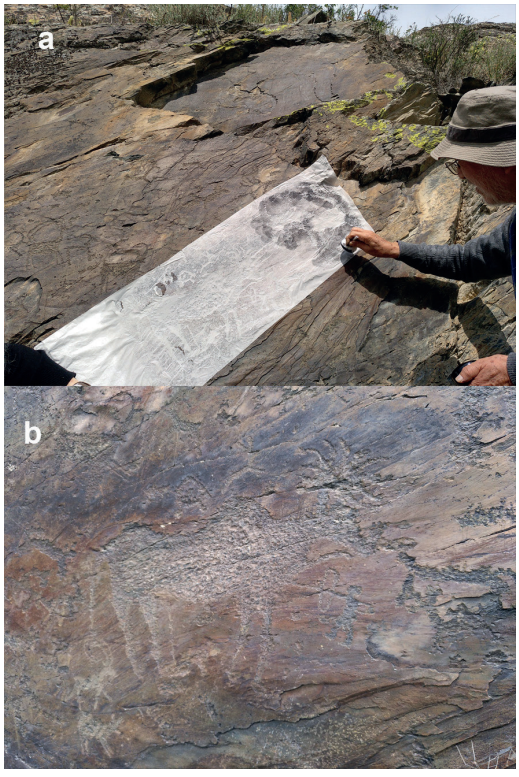


Fig. 10.10: Kara-Tuu panel. a: Japanese rock art avocational archaeologist documenting the panel; b: details of the Kara-Tuu panel. Photographs: M. Díaz-Andreu.

Torgun

At about 2 km to the south of the village of Bichikty-Boom, on the right bank of the Karakol river, there is a series of carved rocks on a hill locally called Torgun. The site has been divided into two main areas: Torgun I on the northeast slope, opening into a wide valley known as the Ustyu-Ayra tract, and Torgun II on the northwest side of the mountain. The site was discovered in the 1980s by Prof Anatoly I. Martynov's students, who were sent to search for rock

art sites while working in the area. A more systematic investigation was undertaken a few years later by one of the discoverers, Elena Miklashevich, who also, together with Leonid Bove, searched for further petroglyphs between Torgun and Karakol no other petroglyphs without success (Miklashevich and Bove 2010, 233).

In Torgun I, 10 decorated rocks were published in 2003, although the existence of more was mentioned. Of the published ones, only two in the extreme ends of the area are clearly visible (Miklashevich, pers. comm. 18/08/2019). In the case of Torgun I-1 the darker colour of the rock marked it in the landscape.

Torgun I, site 1

Torgun I was published in 2003 by Elena Miklashevich (2003b). Rock art site Torgun I-1 was dated to the Turkic period (Fig. 10.11). It was poorly preserved. She explained that

> The images are made with the thinnest carved lines, with a careful study of details ... Judging by the surviving fragments, hunting scenes were depicted here - deer, rams and other ungulates racing in a gallop ... One of the animals (a horse?) is shown pierced by an arrow. There are also figures of archers, indistinct and fragmentary images, and disorderly carved lines. (Miklashevich 2003b, 84)

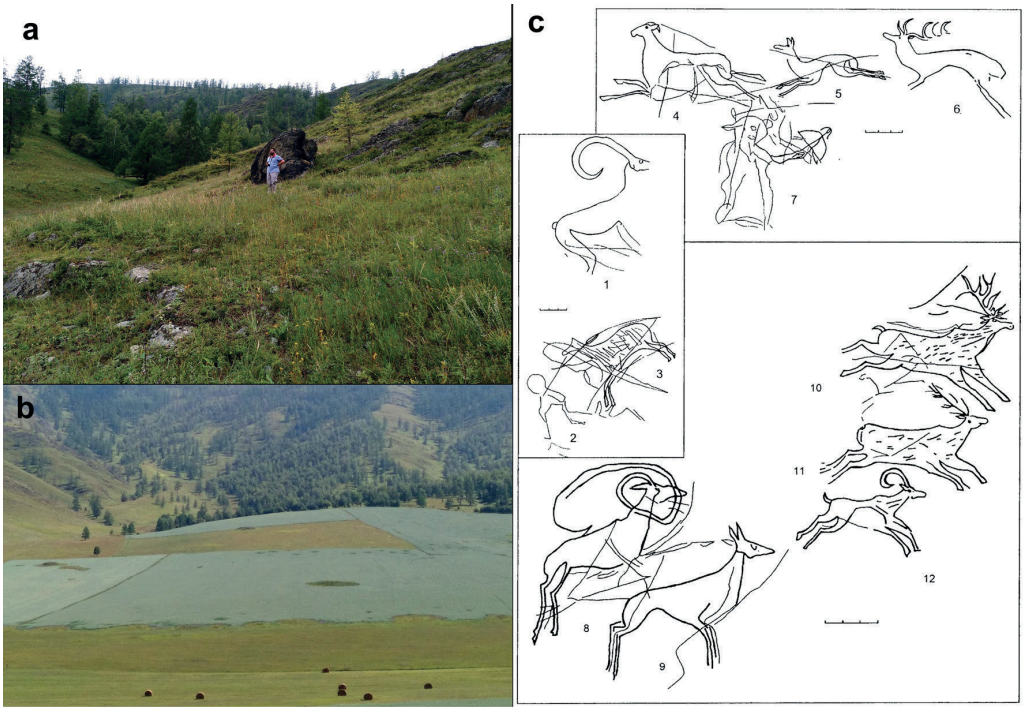


Fig. 10.11: Torgun I-1. a: View of Torgun I-1. b: View from Torgun towards the Ustyu-Ayra valley. Photographs: M. Díaz-Andreu. c: Motifs documented in Torgun I-1 (After Miklashevich 2003b, fig. 6).



Fig. 10.12: Torgun I-8. 1: Panel with multi-temporal images at the Torgun-I site. In the lower left part detail of the engraved sun-headed motif; 2: remains of engraved and polished drawings of the Karakol culture (sun-headed figure and elk), found on the panel between the engraved images of the Scythian period I (Miklashevich and Bove 2010, fig. 1).

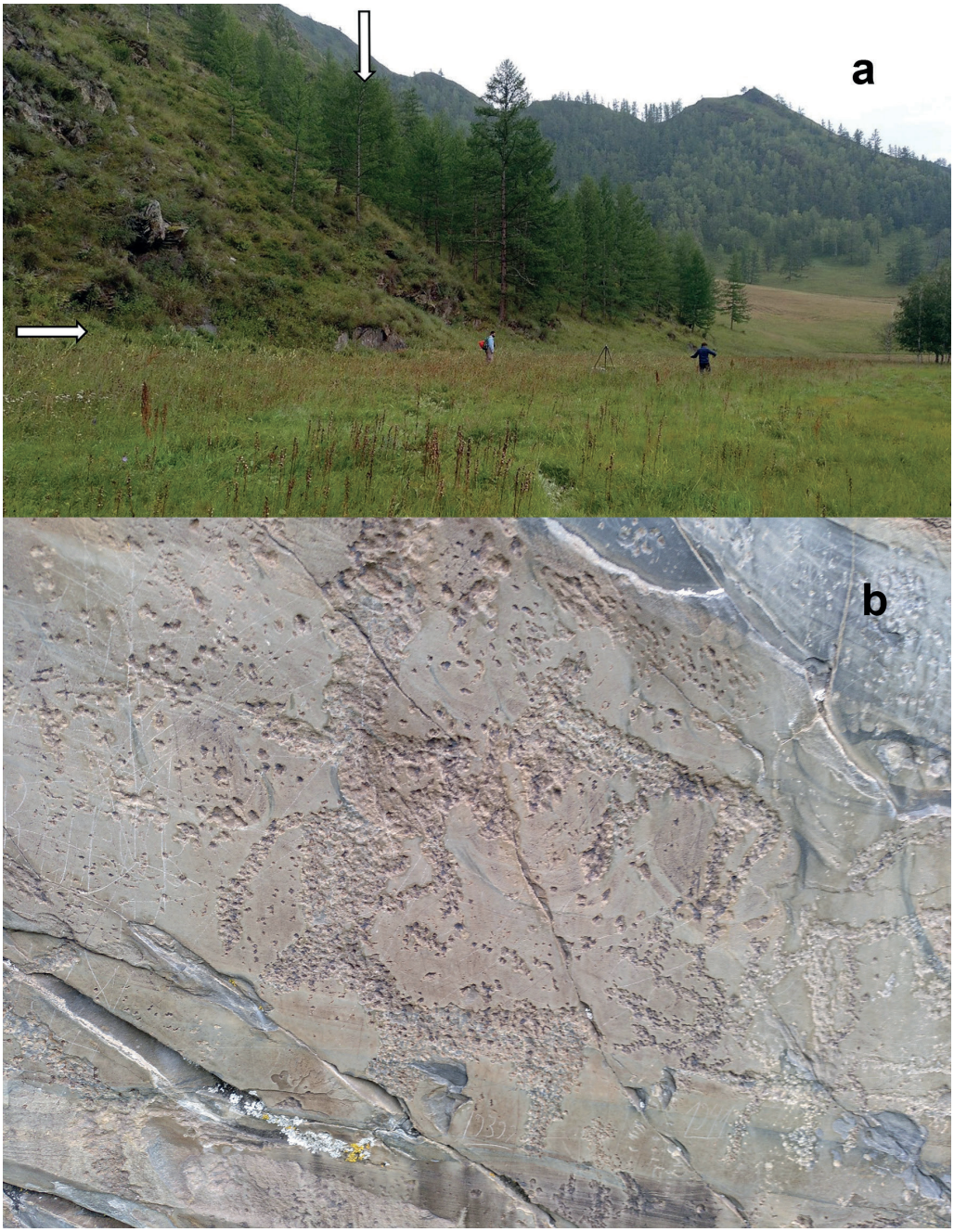


Fig. 10.13: Torgun II-3. a: General view of site; b: panel. Photographs: M. Díaz-Andreu.

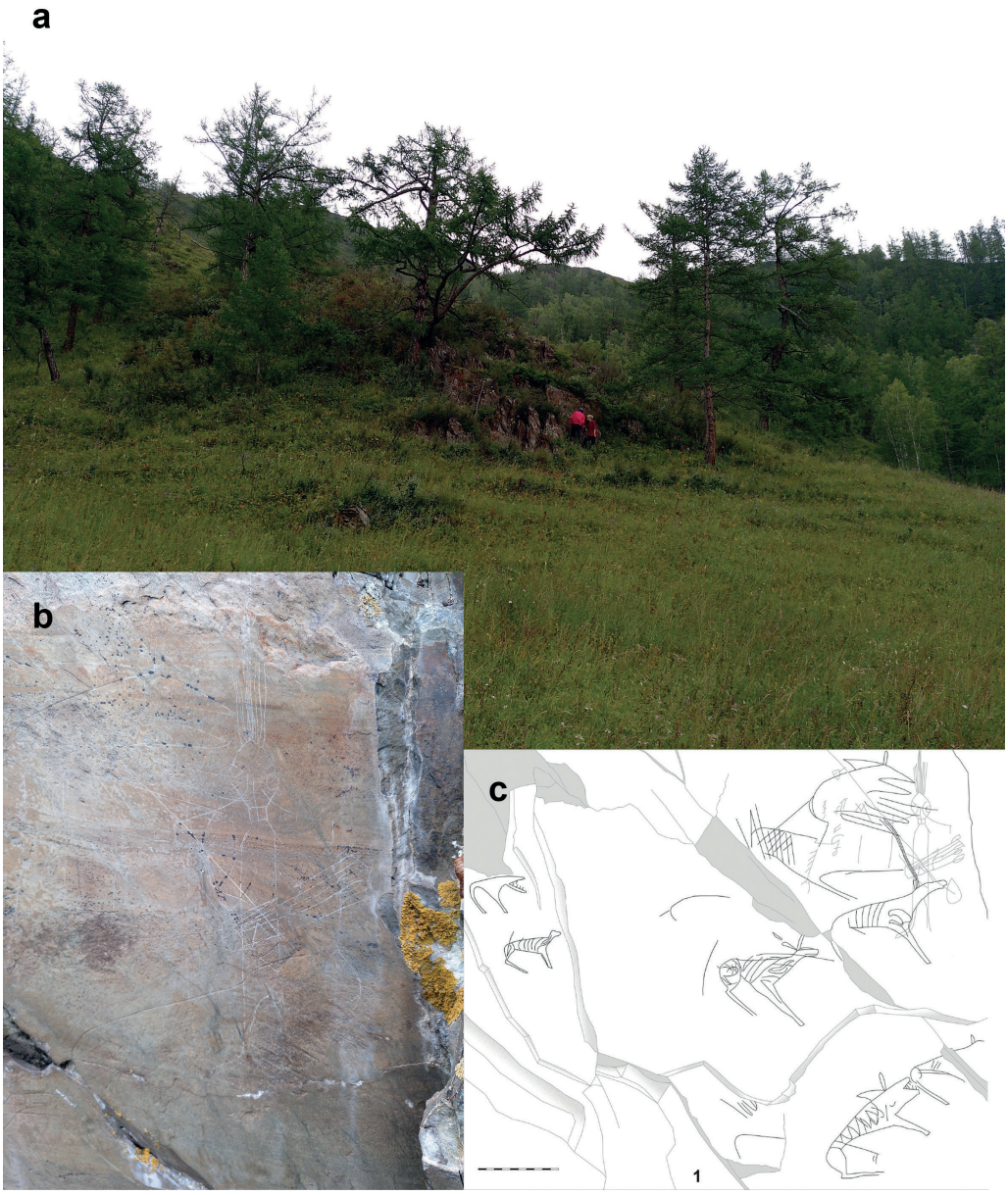


Fig. 10.14: Torgun II-4. a: General view of the site; b: motif, perhaps of a shaman. Photographs: M. Díaz-Andreu; c: motifs of Scythian style (Miklashevich and Bove 2010, fig. 2.1).

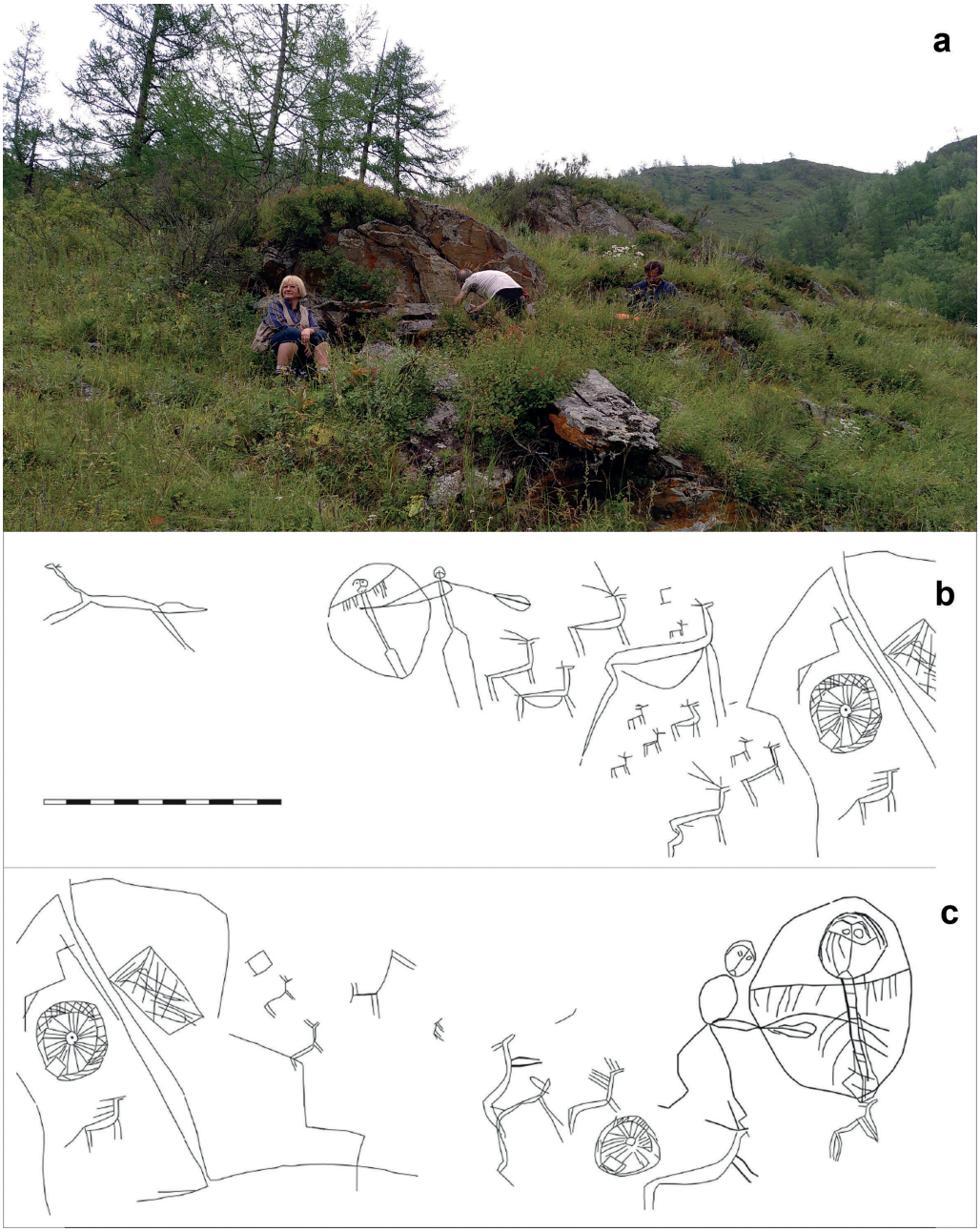


Fig. 10.15: Torgun II-5. a: General view of the site; b and c: Motifs representing shamans and other motifs. b represents the left side of the panel, and c the right side (Based on Miklashevich and Bove 2010, figs 2-2a and 2-2b).

And she added:

> Obviously, this stone was considered sacred and revered by the local population until recently. In front of it there is a very comfortable horizontal platform, well trampled down. The slope below the stone is quite gentle and is also very convenient for performing rituals. (Miklashevich 2003b, 84–85).

Torgun I, site 8

First recorded by Miklashevich and Bove in 2003 as rock number 8, a proper description, together with a new recording, was published in 2010. They identified engravings and carvings of the Bronze Age Karakol culture, including an engraved sun-headed figure and an elk using the technique of engraving and polishing ("scraped"). There are also deers and goats of the Scythian period (Miklashevich and Bove 2010, 229–231) (Fig. 10.12).

Torgun II, site 3

Elena Miklashevich dates the earliest rock art in this area II in the Late Bronze Age, although the published recordings have a chronology of the Scythian, Turkic and contemporary periods. Because of the freshness of the engravings of the motifs of shamans with tambourines, she considers them recent. The decorated rocks in Torgun II have not been identified with numbers and therefore we are providing our own numbering. Technical constraints will make us focus on sites 3 to 5.

Visited on 18 and 21 August, site 3 was located in an outcrop at the foot of the hill. It consisted of a panel with Bronze Age pecked carvings of goats, other quadrupeds and a few anthropomorphs (Fig. 10.13).

Torgun II, site 4

Located in the hill slope, site 4 had a series of carvings of Scythian style with predators and ungulates recorded by Miklashevich and Bove (2010, fig. 2.1) together with a figure of what seems to be an anthropomorph, perhaps a shaman (Fig. 10.14).

Torgun II, site 5

Located in an area nearby site 4, this site has a historic engraving of a shaman (Miklashevich and Bove 2010) (Fig. 10.15).

Bichikty-Bom

The hill of Bichikty-Bom (also spelled as Bichiktu-Bom and Bitchiktu Boom in the literature) is located next to the village of the same name on the left bank of the Karakol River, a tributary of the Ursul. The site's name, translated as "rock with scribbles", indicates that its existence was well known to the local population. In the many rocky outcrops of slate rock of this mountain, there is an abundance of flat panels that may reach large dimensions (3–4 m). Many panels have been inscribed with engravings, as many as 800 (Erkinova and Kubarev 2004, 88). Their study has a long history starting in the early 20th century, when artist Grigory I. Choros-Gurkin recorded some of them, a task that he continued during the Altai ethnographic

expedition of the Society for the Study of Siberia and its Productive Forces [Общества изучения Сибири и е производительных сил] in 1930 (Seregin and Matrenin 2015, 96). Some of these recordings were later published by Erkinova and Kubarev in 2004. Other scholars continued mentioning them from the 1950s, but a more thorough study was only conducted in the 1980s by Anatoliĭ I. Martynov, and this resulted in a series of articles by him and others (Martynov 1985, 88; 1993; 1995; Martynov *et al.* 2006). In the lower parts of the hill the motifs are small, from 5 to 15–20 cm, and most of them depict deers. There are also several hunting scenes. The medieval engravings depict battle, domestic, erotic and cult-religious scenes. The dating ranges from the Bronze Age to the Scythian time for the oldest, but most of the motifs are later, from Turkic to later medieval and contemporary (Erkinova and Kubarev 2004, 88). Regarding the depictions of drums or tambourines, as mentioned above, Erkinova and Kubarev are unsure on whether they may go back to the Turkish period or should be dated in a recent period, before the time when Choros-Gurkin copied them (Erkinova and Kubarev 2004, 91).

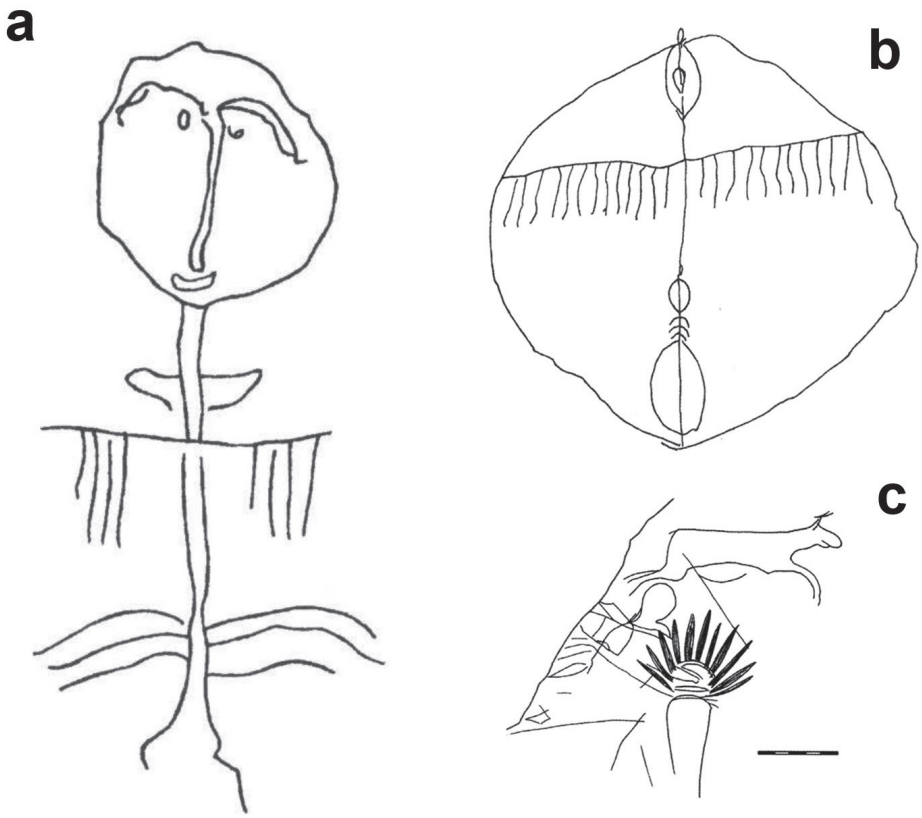


Fig. 10.16: Engraved motifs recorded in Bichikty-Bom: a: the image of the drum spirit proper in the form of an anthropomorphic figure (Erkinova and Kubarev 2004, fig. 4.2). b: drum (Erkinova and Kubarev 2004, fig. 1.2); c: anthropomorphic motifs (after Miklashevich and Bove 2009, fig. 1.3). Not to scale.



Fig. 10.17: Talda Hill. Left: View of Talda Hill from afar; Right: Engraved motif of a drum. Photographs: M. Díaz-Andreu.

Talda

This small hill located south of the rural locality of Boochi (Russian: Боочи) in the Ongudaysky District has many panels with fine-line rock art engravings and carved figures. The great majority of them are dated to the historic period. There is no publication on this site.

Results of the acoustic tests

Several tests involving different source and receiver positions were conducted on the sites to account for their spatial features (Table 10.1). To accomplish a fair comparison



Fig. 10.18: Acoustic measurements undertaken in the Torgun area I, site 5. Photo: © Artsoundscapes project.

between tests here, we present a similar disposition between sound receiver (listener) and sound emitter (sound emitter) regarding spatial configuration, in which the first is in the area where the rock art is, while the latter is placed at 10 m in front of the receiver location. Figure 10.18 shows an example of this arrangement in the field.

This hypothesis was tested in the four locations, and therefore, a selection of the captured IRs is discussed in this work. Table 10.2 details which are the IRs selected. For the analysis of the IRs, EASERA 1.2 and ARTA 1.9.4 software tools have been utilised. In our discussion about the results we will highlight reverberation, echoes and sound (speech and music) clarity. Regarding the first, given the open field characteristics of the studied rock art areas in Karakol, it is not meaningful to discuss reverberation (Mo and Wang 2012; Rindel 2023). Actually, the early decay curves derived from the measured IRs do not exhibit sufficient linearity for an accurate estimation of the reverberation parameters ($r^2 < 0.96$). These results follow the line of those found in the Lower Chuya and the Urkosh valley rock art areas (Díaz-Andreu *et al.* 2023a; 2023b).

As it could not be otherwise, the absence of reverberation and late reflections result in very high values of the speech definition and musical clarity parameters (D_m close to 1 and C_{80m} well above 20 dB), which is within what it would be expected in an open-air environment. Besides, in our acoustic analysis, the centre time is used to assess sound clarity, since this energy parameter does not initially distinguish between late and early reflections. The results included in Table 10.2 not only highlight the expected sound clarity perceived in the sites ($T_{Sm} < 5$ ms), but also lead us to dismiss the presence of echoes. The echo criterion introduced by Dietsch and Kraak (1986) additionally assesses whether a listener might detect a disturbing echo considering both speech and music, but in this respect the acoustic data gathered in Karakol provides negative results. Finally, the values of the sound strength parameter (G_m approximately 0 dB relative to the free field at the same distance) lead us to dismiss the idea of any reflections from the landscape being sufficiently potent to increase the perceived sound level (loudness) in the sites.

It is essential to mention that the suffix "m" in Table 10.2 refers to the spectral average value or mid-frequency value of the results obtained for each parameter, calculated as the average between the values obtained at the 500 Hz and 1000 Hz frequency bands. In this case, the mid-frequency value is considered sufficiently representative when evaluating the acoustic characteristics of the sites, as no significant variation in the spectral behaviour of

Table 10.2: Acoustic parameters obtained in the Karakol area. Mid values are averaged at 500 Hz and 1 kHz frequency bands as defined in the ISO 3382-1 (2009). The parameters obtained in Kara-Tuu and Torgun I-1 had technical problems and are not taken into consideration in the analysis.

Test point	T_{Sm}	G_m
	[s]	*[dB]*
Talda T1	4,16	0.25
Talda T2	3,71	0.30
Talda T3	3,06	0.10
Kara-Too T1	6,31	–
Bichiktu-Bom T3	2,42	0.10
Bichiktu-Bom T4	2,63	0.15
Torgun I-1 T1	26,19	–
Torgun I-5 T1	2,77	0.15
Torgun II-2_3 T1	4,46	0.25
Torgun II-4_5 T1	3,05	0.10

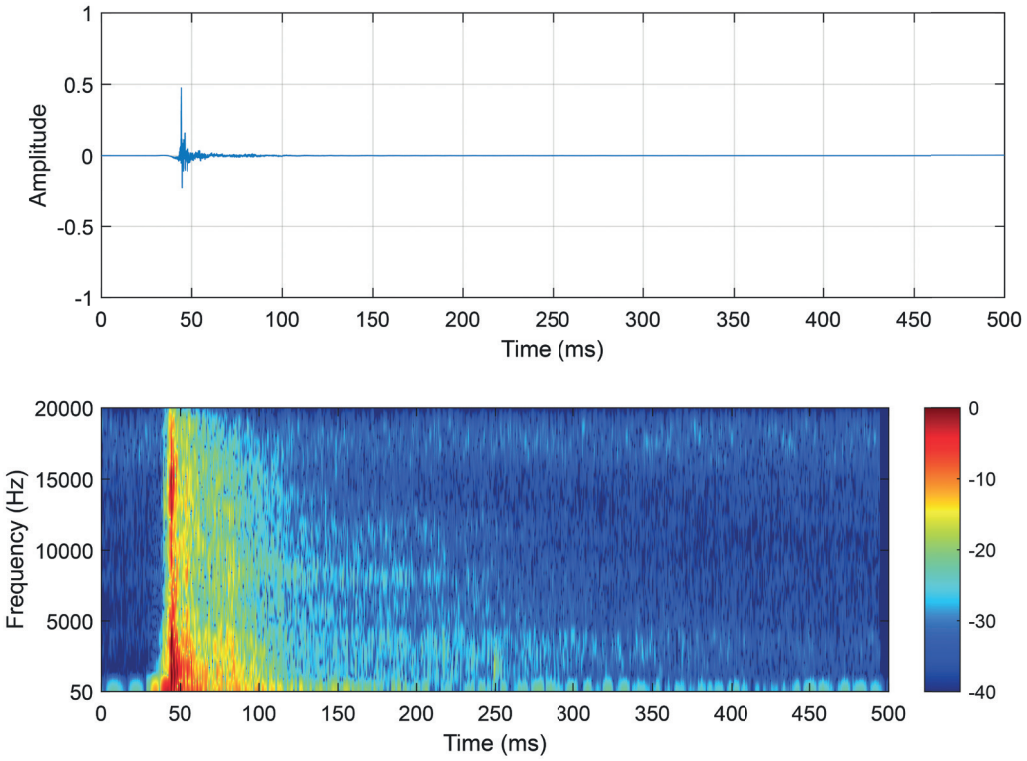


Fig. 10.19: Waveform and spectrogram of the impulse response measured in the acoustic test in site 5 in Torgun I. Authors' elaboration.

the parameters is observed. For example, the spectrogram in Figure 10.19 demonstrates the lack of enhancements or any notable variations in specific frequencies.

Discussion

The area of Karakol is considered to be sacred by today's Altaians. Indeed, in contrast to the other two areas where we performed acoustic tests and have already been published, the Lower Chuya (Díaz-Andreu *et al.* 2023a) and the Urkosh areas (Díaz-Andreu *et al.* 2023b), where no motifs representing shamans have been identified, the rock art of Karakol has a high number of them. These are finely engraved, and most scholars date them to the modern period, as mentioned in the sites' description. Archaeologists, however, disagree on how far back shamanism goes as a religious practice. As explained in our discussion on shamanism above, Devlet argues in favour of the Neolithic, whereas others such as Rozwadowski, Jacobson-Tepfer and Francfort move this date forward to the 1st millennium BCE during the Scythian Iron Age. The Neolithic burial site discovered in Karakol village, with its very peculiar figures decorating the cists, can have alternative interpretations but indeed seem

to indicate that this area may already have been special at that time. The Tourist-2 site, a later cemetery dated in the Early to Middle Bronze Age found in Novosibirsk, shows that beliefs in magical creatures may have existed, given the theriomorphic and ornithomorphic figures found in it, perhaps reflecting an early form of shamanism. Yet, as mentioned above, most of the rock art motifs representing shamans seem to be chronologically placed in the last few centuries. Given their numbers, our initial question at the start of this article was whether there were distinct acoustics in the rock art sites of the Karakol valley. However, the result of our acoustic tests indicate that this was not the case. Reverberation was not significant, there were no echoes, and the clarity of music and speech were normal in an open-air environment. Let's analyse now whether we should have expected a different set of results.

Tempo and reverberation

Key acoustical aspects of shamanism practices generally involve acoustic stimulation, often of a repetitive sound (Oohashi *et al.* 2002; Aparicio-Terrés *et al.* forthcoming). The rhythm created by the recurrence of short, quick sounds may be produced with drums, rattles, clapping with clappers or with the hands, or stamping feet while dancing. As our neuroacoustical research in the ERC Artsoundscapes project has found, rhythmic sounds at particular tempos produce entrainment that may lead to altered states of consciousness (Aparicio-Terrés *et al.* in prep). Is entrainment enhanced by reverberation? There is no research on this, but it would not be surprising if it were. In practice, however, it is not at all essential for shamanic seances. As the ethnographic literature shows, these may occur indoors (as in Alaska, see Salius Guma 2014) and outdoors (for example, in the Kalahari desert, see Marshall 1969). As seen in Figures 10.7 and 10.8d, both settings were present in Altai in recent history, the period to which it is most likely that the engravings are dated. The fact that outdoor rituals were organised seems to indicate that reverberation was not a key factor leading to altered states of consciousness, the central practice in shamanism. Reverberation may be helpful to enhance sound, and to boost a sense of community within the group as we have argued elsewhere (Santos da Rosa *et al.* 2023), but is not essential to induce an altered state of consciousness or trance, and as examples around the world show, it is not essential for shamanic seances.

A different issue is whether the place where the fine engravings have been located ratifies that shamanic seances occurred precisely there. So far, there is nothing that can confirm or disprove this. There are no ethnographic accounts of the possible ceremonies that may have taken place in places such as Bichikty-Bom or, indeed, any of the other places. The only comment in the literature comes from the area of Torgun I, site 1, where, as explained earlier in the article, the trampling of the front area adjacent to the panel and its general location close to a flat surface terrain made Elena Miklashevich argue that the local population had venerated the stone until recently (Miklashevich 2003b, 84–85; see above).

Yet, her comments were very general, for she did not mention any particular type of religion or ritual practice.

Echoes

Echoe is an acoustic effect that the literature has often linked with shamanism in many parts of the world (for example, Arsenault and Zawadzka 2014; Boyd and Busby 2022). Yet, in our acoustic tests in the area of Karakol no evidence of them was found. A detailed reading of the publications on the connection between echoes and shamanism, however, makes clear that their presence is usually related to beliefs in spirits living within the rocks and, as Levin and Süzükei (2006) mention for Tuva, with the world (the rocks, trees, and so on) being alive, but not to their importance to induce trance. Thus, echoes are considered a particular acoustic cue, but their presence is not essential for shamanistic practices involving an altered state of consciousness. They are not necessarily associated with the shaman figure, although they belong to the shamanic worldview.

Speech and music clarity

Regarding speech and music clarity, the results found in Karakol are similar to those in the lower Chuya and the Urkosh area, where we discussed the benefits of these acoustic parameters for the intangible practices of singing and storytelling, which, the ethnographic sources indicate, were key for the relationship between people and spirits in Siberia (Díaz-Andreu *et al.* 2023a; 2023b). These practices were most likely taking place in Karakol throughout the different periods in which rock art was produced, also in the modern period when the shaman motifs were most probably produced.

Regarding speech, there are some indications that, at least in contemporary ritual uses of rock engravings and petroglyphs that may or not be connected with old traditions, it may be a relevant aspect. In a brief article by Isabel Célestin-Lhopiteau published in 2009, she recounts her experience with a Buryat shaman. During Célestin-Lhopiteau's research on shamanism and medicine, a shaman brought her to a 2 × 1 m wall with petroglyphs near Lake Baikal showing anthropomorphic figures and animals. The shaman touched all the animals and humans or spirits and explained that:

> For us, shamans, this rock painting is like an icon for other religions. Here we have a hunting scene, in particular that of the reindeer, here is the adult reindeer with her baby, here are the dogs or wolves; we can only think that they are wolves, as we think that these are men, but it is possible that they are gods. There it is certain that we see the shaman carrying out a rite near a fire. There is a small altar. There above are the spirits (...) Our aim is to preserve all that, we have already made an impression of this rock engraving against vandalism or theft (Célestin-Lhopiteau 2009, 28).

After this explanation he performed a ritual, touching the engravings and performing diverse gestures towards the floor, the sky, his heart, and speaking to the spirit of the steppe. Apparently, once out of trance, the shaman explained that this ritual

had allowed him to contact his ancestors, those who made the engravings, and also with the animals, the spirits and the elements. He also stated that he would make rituals with rock art carvings when someone in the village had a problem. This ritual reconnected through trance and by touching and talking to the engravings linking him with the shamans of the past (Célestin-Lhopiteau 2009, 29).

The association between music and shamanism is well documented (Pentikäinen 1998, 12; Walker 2003). In shamanism, music is a medium to communicate with other sentient beings, and as a way for the shaman to access the spirit world (Walker 2003, 42). In Khakassia, Caroline Pegg describes a shamanic ritual celebrated in her honour, with drumming and singing, which took place in a sacred archaeological site that the shaman considered important in terms of her ancestry. In the site, there were two anthropomorphic standing stones that were thought to be remains of ancient European populations (Pegg 2006, 29). The multisensory experience seems to have been very strong for the scholar, and she describes increasingly feeling an intense aural effect (Pegg 2006, 32). Yet, there is no indication of any awareness from her part of the author experiencing any especial acoustic effects related to the landscape.

As a result of our discussion, we could argue that even if the type of landscapes in which representations of shamans have been found are not special in terms of their acoustics, this does not mean that sound and music were not important for the local shamans represented in the engravings. As the ethnographic sources tell us, there are other factors that create the atmosphere in which shamans undertake the more important practice of shamanism, and these include repetitive sounds produced by music and dancing, as well as ingestion of psychotropic drugs, isolation, intense pain, or sensory deprivation (an absence of light, sound and physical stimulation) (Clottes and Lewis-Williams 1998, 14).

Conclusions

The diversity of acoustic phenomena in rock art sites around the world is large: there are places where the presence of echoes seems to favour the choice of shelters to be decorated in reverberant landscapes (Díaz-Andreu and García Benito 2012; Díaz-Andreu *et al.* 2019); in others, augmented audibility indicates a strong possibility of being behind their selection (Mattioli and Díaz-Andreu 2017); other rock art places used as aggregation sites have fine qualities for the transmission of word and music, something that would have facilitated communication and the enhancement of a feeling of community (Santos da Rosa *et al.* 2023). Yet, in contrast with these rock art landscapes that illustrate a direct connection between acoustics and rock art, there are others where such a relationship is less clear. Among the latter, we find the rock art landscapes of Altai, where we have argued elsewhere that, although they are not particularly special from an acoustic point of view, the acoustic conditions of the area may have been beneficial for specific intangible practices such as singing and storytelling (Díaz-Andreu *et al.* 2023a; 2023b). This is

indeed the case of the rock art sites discussed in this work, located in the Karakol valley, despite the area being unique because of the presence in it of many motifs representing shamans.

The discussion in this article has revolved around the existence of shamanism in the Karakol valley, starting with an examination of its chronology, if it can be considered prehistoric, and if so, from when, or only historic. As explained, scholars' proposals range from the Neolithic, to the more possible Iron Age for a sort of proto-shamanism, to the Turkic and, especially, modern period. Despite this ample chronology, the clearest representations of shamans are most likely dated to the modern period, probably in the 18th and 19th centuries. A description of the four areas acoustically tested has also emphasised the representations of shamans in them. The results of the acoustic tests have been discussed in terms of the values obtained for reverberation, echoes and sound (speech and music) clarity. The lack of any acoustic values that we can ponder remarkable has partly been related to the open-air environment of the rock boulders where the rock art was produced. Yet, this does not mean we can rule out the performance in their vicinity of shamanic rituals. In the literature, there are several accounts of people being guests or participants in them who report a strong experience and, in the case of researcher Caroline Pegg, an increasingly intense aural effect (see above).

Can motifs with any sort of links to shamanism be considered an indication of séances being held at the rock art sites where they have been carved or engraved? We cannot answer this question solely based on the rock art motifs, and nothing in the ethnohistoric sources hints at this. Nevertheless, even if this were the case, the absence of special acoustic effects found in our case study might be attributed to the small space in which ritual practices were performed and the small number of people participating in these séances. Cambridge ethnomusicologist Carole Pegg describes a ritual organised for her in Khaakassia, also located in the Sayan-Altai Mountain region of central southern Siberia, in 2002. The ritual took place at the entrance of a sacred valley marked by two prehistoric standing stones and involved much drumming and multi-sensory experience including not only sound but also sights, tastes and smells. She explains that, "as a result, a change in personhood occurred for all involved" (Pegg 2006, 27).[3] In this and in other occasions we would contend that the ritual specialist, the shamans and shamanesses, find it easier to control participants' feelings and emotions through other means than acoustics. In more complex societies, however, acoustics are, to a large extent, needed to produce emotion (López-Mochales *et al.* 2022). It is then, with the appearance of complex, state societies, that acoustic effects, such as high reverberation, appear as a key element in closed religious spaces – usually purposedly built buildings – all over the world, with specific religions fostering particular soundscapes (Zhang *et al.* 2024). Before this, we argue, acoustics may be a factor chosen by societies to enhance community and religious feelings, but it should not necessarily be expected at every rock art site – or any other type of site – linked to ritualistic practices.

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Notes

1 The Turkic period is dated to the 6th–8th centuries CE (Jacobson-Tepfer 2008, 208).
2 The Isakovo culture is found in Mongolia and dated to the Neolithic, c. 4000 BCE.
3 Jean Clottes states that "The traditional shamans of southern Siberia consider some rock art sites as 'places of power' and on occasion hold ceremonies there (as I have personally witnessed)" (Clottes 2011, 142).

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Chapter 11

Sound imagery in medieval Serbian frescoes

Zorana Đorđević

Abstract

Fresco paintings decorated the interiors of medieval Orthodox churches, enhancing the auditory experience of religious services that primarily focused on both spoken and chanted voices. While the analysis of church fresco painting in medieval Serbia has indirectly touched upon the aspect of sound, prior studies on Byzantine churches have suggested a particular correlation between church acoustics and images associated with chanting. This article aims to illuminate sound imagery in medieval Serbian fresco paintings (mid-12th to mid-15th centuries), laying the groundwork for future archaeoacoustic analysis. It identifies four key elements that qualify a fresco painting as sound imagery: 1) musical instruments, 2) musical gestures, 3) inscribed voices *on scrolls and books, and 4) the celestial sounds resonating from depictions of Heavenly Liturgy. Ultimately, the article discusses the integration of sound imagery into the comprehensive archaeoacoustic study of medieval Serbian churches.*

Keywords: sound imagery, fresco paintings, religious soundscape, archaeoacoustics, medieval Serbia

Introduction

The multisensory approach to studying medieval Orthodox art has gained increasing attention from scholars in the past decade. This perspective is grounded in the recognition that our experience of sacred spaces involves our entire body extending beyond the purely visual aspect (Webb 2018). Scholars have extensively explored the corporeality of Byzantine sacred art and architecture, highlighting the significance and interplay of all senses in the encounter with sacred spaces and religious rituals (Pentcheva 2011; Harvey and Mullett 2017; Bogdanović 2018). In addition to the

external or physical senses, scholars have argued the existence of inner senses within Christian thought, operating through mental processes such as imagination and discourse (Caseau 2014). Imagination is a multifaceted cognitive process encompassing the generation of novel mental images and creative ideas, whereas discourse is a mental activity centered on the use of language within the mind to structure thoughts and interpret concepts. As we delve further into this article, we will explore how the hypothesis of inner senses becomes particularly relevant when examining the relationship between sound and fresco paintings in Orthodox art.

The Byzantine Empire (395–1453 CE), also known as Byzantium or the Eastern Roman Empire with a capital in Constantinople (today Istanbul, Turkey), played an essential role in shaping Christian Orthodoxy and, consequently, Orthodox art and architecture. Influenced by Byzantine culture, sacred art and architecture continuously evolved in medieval Serbia from the mid-12th century, when the Nemanjić dynasty ascended to the throne, until the mid-15th century, when Serbia fell definitely under Ottoman rule. During this period, monasteries were established across the country, following the Byzantine monastery model, with churches as the most representative buildings of the monastic complex (Korać and Šuput 2010). Typically, the interiors of these churches were entirely fresco-painted, from the floor to the dome's apex, depicting scenes and narratives from the Bible. The liturgy and the church interior, with its space divisions and painted images, were designed to harmonise, providing a multisensory experience and the feeling of God's presence (Caseau 2014). However, so far the analysis of church fresco painting in medieval Serbia has primarily focused on the visual aspect, indirectly addressing other sensory dimensions.

The aim of this paper is to, for the first time, identify key elements in medieval Serbian fresco paintings that qualify them as sound imagery, laying the groundwork for future archaeoacoustic analysis. Initially, we explore how previous research endeavours have sought to unravel the mystique of sound in medieval Orthodox churches, drawing insights from analysis of church acoustics and also Byzantine art history studies of fresco paintings. Subsequently, our focus shifts to examples found in medieval Serbian churches, analysing the representations of sound in fresco paintings. In this context, we identified four visually suggestive elements in fresco paintings: 1) musical instruments, 2) chanters making musical gestures, 3) the *voices* inscribed on scrolls and books, and 4) the celestial sounds resonating from depictions of Heavenly Liturgy. Ultimately, we conclude by laying a foundation for further archaeoacoustic examination, discussing the absence of certain musical instruments played in medieval monastic soundscapes but missing from fresco paintings, the elicitation of emotions through notions of sound, and the correlation of sound imagery with church acoustics. This paper is of particular interest to archaeologists interested in the aural dimension of past human experiences, as it establishes the groundwork for archaeoacoustic research of the medieval auditory surroundings within sacral spaces, incorporating elements of sound imagery. It underscores the need for a multidisciplinary approach to archaeological exploration, emphasising the sensorial interplay, primarily that of sight and hearing, in experiencing sacrality through medieval art and architecture.

The explorations of sound in medieval Orthodox churches

Regarding sound, past research on medieval Orthodox churches has followed two approaches: the acoustic examination of the church interior and the analysis of notions of sound in medieval church art, encompassing fresco paintings, reliefs and sculpture. To elucidate the rationale for integrating these two approaches in the archaeoacoustic analysis of Serbian fresco paintings, this section highlights the research directions hinted at in earlier studies.

The examination of church acoustics

The archaeoacoustic study of churches is a field whose development accelerated in the 1990s, examining the relationship between the sonic environment in the church interior and religious performance (Girón *et al.* 2017). An overview of the most recent research in this field in relation to Byzantine churches highlights two projects – *Icons of Sound*, led by Bissera Pentcheva (art history, Standford University) (Pentcheva 2017; 2018) and *Sounds of Byzantium* led by Sharon Gerstel (art history and archaeology, UCLA) and Chris Kyriakakis (acoustics, USC Viterbi School of Engineering, California).

The project *Icons of Sound* included the thorough archaeoacoustic research of the Hagia Sophia (Holy Wisdom) in Constantinople. This has been one of the most significant churches in the Orthodox Christian world, commissioned by Byzantine Emperor Justinian I in the 6th century. The main architectural feature of the church is the central dome that covers the 31 m square nave. The significant height of the dome (56.6 m), the enormous overall volume of the church (exceeding 250,000 m^3), as well as the materials composing the space, result in a long reverberation time (T30 at 500 Hz reaches almost 12 seconds). Thus, sound is constantly present in the church and acts as an immersive medium that reaches all present, helping the integration of multisensory experience of the Orthodox liturgy (Woszczyk 2018). Besides the acoustic analysis of the church, this study resulted in the live auralisation – an accurate recreation of the church's highly reverberant acoustic environment in a different location, enabling the chanters to perform and the audience to enjoy as if they are aurally present in the church itself. The Byzantine chant live performances of Cappella Romana, a choir specialising in early music, in a virtual Hagia Sophia took place in three performance halls: the Bing Concert Hall and the Center for Computer Research in Music and Acoustics at the Standford University, and the San Francisco Ritz-Carlton Ballroom (Abel and Werner 2018). Although the project *Icons of Sound* led us to a better understanding of the acoustic environment of Hagia Sophia, it also left us with an important question. As Pentcheva herself wondered: was this acoustic environment intentionally designed or was it accidental as a by-product of the architectural tradition of domed churches and large marble surfaces? (Pentcheva 2011)

The second major project related to Byzantine churches was *Sounds of Byzantium*, which undertook archaeoacoustic studies of eight Byzantine churches in Thessaloniki

(Greece, 5th to 14th century) that had largely retained their original form and decoration. This project is of particular interest to this article because it included the documentation and analysis of the wall paintings inspired by choral performance and hymns. Based on the acoustic testing in front of the representation of hymns in fresco paintings, it was concluded that sound reception might have been related to the placement of this particular sound imagery (Antonopoulos *et al.* 2017). It was further pointed out that Byzantine notions that humans and angels shared the same space of the church are not only metaphorical, but a precise perception of the movement of sound in the church space, enclosed by concave forms of domes, vaults and apses, that reflect the sound in a particular manner: "sound [is] rising from the floor to the dome and cascading downwards, creating the impression that voices emanated from both heaven and earth, mingling in the centre of the nave harmoniously and seamlessly" (Gerstel 2015, 139).

In addition to the two projects mentioned above, it is crucial to highlight the conclusions drawn from previous archaeoacoustic studies on medieval Serbian churches. The initial exploration of sound was motivated by the discovery of acoustic vessels embedded in massive walls of medieval churches at the beginning of the 20th century (Nenadović 2003; Đorđević *et al.* 2017). Typically positioned high above the ground, these vessels were found in pendentives (spherical triangles supporting the dome) or in the walls beneath attached arches. Over the past three decades, the aural aspect of Serbian medieval churches has been investigated through acoustic measurements and an analysis of the relationship of acoustic properties and Byzantine chanting art practiced in medieval Serbia, including the acoustic measurement of acoustic vessels (Mijić and Šumarac-Pavlović 2004; Đorđević *et al.* 2019a). A 2016 study examined and compared several Serbian churches built in the 14th and 15th centuries, leading to the identification of two primary acoustic requirements for religious services: maintaining speech intelligibility and inducing a spiritual experience through the sonic environment (Đorđević and Novković 2019; Đorđević *et al.* forthcoming). Two distinctive architectural features of medieval churches, suspected to significantly influence acoustics and the liturgical experience, are the central dome and the iconostasis – a barrier dividing the naos where the faithful attend the liturgy and the sanctuary that is reserved for the clergy. An examination of these crucial architectural elements through an acoustic model revealed that the dome had a positive impact on speech intelligibility. In contrast, the height of the iconostasis did not significantly influence reverberation time. As anticipated, however, the presence of the iconostasis led to a decrease in the intelligibility of speech from the sanctuary compared to the portion of the service occurring in the naos (Đorđević *et al.* 2019b).

The notions of sound in medieval fresco paintings

A complementary approach to studying the connections between church acoustics and religious performance is the examination of fresco paintings. In Byzantium, as well as in medieval Serbia, the interior walls of churches were usually covered in

fresco paintings from the floor to the apex of the dome. Thus, in parallel to research in archaeoacoustics, and with the exception of the project *Sounds of Byzantium* that combined both approaches, the focus of scholars, mostly Byzantinists, has been placed on the sound imagery and "the sensorial activation of the images" (Peers 2021). The sound *imprinted* in fresco paintings is addressed in the studies examining the depictions of musical instruments (Pejović 1984; Büchler 1989; Ilnitchi Currie 2010; Botonakis *et al.* 2022), portrayals of chanters making musical gestures (Moran 1983; 1986), and text inscriptions on the scrolls, fresco paintings background, or in the central dome. In this sense, important questions were raised: do images resound? Can we hear an image? (Boynton and Reilly 2015, 15). How imagery evoked a "sense of sound" engaged in worship? How was the painted text used to arouse emotions within sacred space? (Gerstel 2019, 93, 102).

In Byzantine churches, painted texts were incorporated into various fresco scenes, with one notable example being the depiction of *Officiating Bishops*. This scene can be found in the lower register of the apse and on the side walls of the sanctuary. The bishops are portrayed holding open scrolls, with both ends grasped in their hands, revealing a portion of the inscribed silent prayer from the liturgy. Two prominent authors of the Divine Liturgy, Saint Basil the Great (330–379 CE) and Saint John Chrysostom (347–407 CE), are frequently represented in these frescoes holding scrolls. Saint Basil's scroll typically features the text of the prayer of Cherubicon, recited during the concecration of the Holy Gifts around the Holy Table in the altar. On Saint Chrysostom's scroll, the prayer of the Prothesis is usually inscribed. This prayer belongs to the first part of the Divine Liturgy when the Holy Gifts are prepared (Babić and Walter 1976).

The emergence of depictions showing bishops holding open scrolls aligns with the liturgical practices of the time, particularly from the 12th century onwards (Gerstel 1994). During specific moments in the liturgy, these scrolls were unrolled and recited by the principal celebrant. By reading the inscribed scrolls, the celebrant entered a spiritual state appropriate for their subsequent role in the eucharistic sacrifice (Gerstel 1999). This suggests that, as the celebrant reads the prayer, they activate the image, integrating the saintly bishops into a "mystical liturgy that transcends the physical boundaries of the walls on which they are painted" (Gerstel 1994). Given the Byzantine rethoric that painted figures could convey speech, the scrolls held by saintly bishops served as a medium through which the bishops participated in the liturgical celebration (Gerstel 1999).

Furthermore, direct speech passages can be found written directly onto the background of frescoes, representing the voices of Christ and angels. These *written voices* are accompanied by gestures of speech, emphasising the power of the written words. Art historian, Nancy Ševčenko refers to these inscriptions on the background of frescoes as *fruitful* because they *bring* the represented *event into being* (Ševčenko 2015). Additionally, inscriptions around a central dome regularly contain the notion of sound. The depiction of devotional images and texts is intended to evoke emotions like joy, sorrow and fear (Gerstel 2019). For instance, the text around the dome of a

12th-century Trikomo church has a direct intention to elicit fear in the faithful, concluding with: "Mortals, tremble (with fear) before the Judge (Judgement)". Combined with the image of all-seeing Christ in the dome above the text, this allows us to assume Christ's terrifying voice (Binning 2018).

Building upon the aforementioned studies that recognised the depictions of sound in Byzantine fresco paintings and their correlation to church acoustics, we have identified four key elements that characterise a fresco painting as a sound imagery. The subsequent section analyses these key elements – musical instruments, musical gestures, inscribed voices and celestial sounds – within the context of medieval Serbian fresco paintings.

Key elements of sound imagery in medieval Serbian frescoes

Musical instruments

Images of a musical instrument often trigger mental associations with sounds. If we are unfamiliar with the instrument, our mental representation of the instrument's timbre may be imprecise, but the connection to the idea of producing sound remains intact. The importance of musical instruments in Serbian medieval frescoes was recognised by Roksanda Pejović in 1984 when she published an inventory of the fresco-painted musical instruments in Serbian monasteries. Her discussion revolved around the accuracy of representations of medieval musical instruments and their playing, examining how these depictions evolved over time. Pejović's findings, essential for understanding the auditory dimension evoked by medieval fresco paintings, address two key questions: first, which iconographic themes incorporate musical instruments and why, and second, which musical instruments were depicted in medieval Serbian frescoes?

Pejović's investigation revealed that musical instruments were featured in specific iconographic themes, including the *Mocking of Christ*, *Last Judgement*, *John of Damascus Stichera*, *Christ on the way to Calvary*, *Descendants of Cain*, *Psalm 150* and *Nativity of Christ*. Table 11.1 combines data collected by Pejović spanning from the 13th to the mid-15th century, detailing the number of instruments depicted per scene and church (Pejović 1984). Among the 21 churches examined, only two date back to the 13th century. This can be attributed to the emergence of a new fresco painting style during the reign of Serbian king Stefan Uroš II Milutin Nemanjić (1307–1321) in the 14th century. King Milutin's strong ties with the Orthodox Church and Byzantium reflected in the art and architecture of Serbia, as he sponsored the construction of over 40 churches. The narrative fresco painting style (1300–1370) that flourished during his reign was particularly focused on intricately depicting biblical scenes, including the representation of musical instruments (Todić 1998).

The map below (Fig. 11.1) illustrates the locations of churches where frescoes depict musical instruments, covering the regions of present-day Serbia, Kosovo, and North Macedonia. The decision to include a musical instrument in fresco painting was influenced by references in both the Bible and the ecclesiastical literature. While

Table 11.1: Total number of represented musical instruments in medieval Serbian churches. The data presented in this table is compiled from tables published by Pejović (1984) and is limited to the period until the mid-15th century.

No.	*Church*	*Year of building*	*Scene*						
			Mocking of Christ	*Last Judgement*	*John of Damascus Stichera*	*Christ on the way to Calvary*	*Descendants of Cain*	*Psalm 150*	*Nativity of Christ*
1	Gradac Monastery	End of 13th c.							1
2	Arilje Monastery	1296							1
3	Hilandar Monastery, Main Church	1303	4						
4	Bogorodica Ljeviška Church	1307–1309		2	6				
5	Studenica Monastery, Church of the King	1313–1314							1
6	Staro Negoričane Church	1317–1318	5						1
7	Gračanica Monastery	1321		2					
8	Dečani Monastery	1335–1350	5	2		2	3		
9	Poloshko Monastery	1340	4		4				1
10	Lesnovo Monastery	1349	6 + 4					2	
11	St Sofia church, Ohrid	1350	6		3				

(Continued)

Table 11.1: Total number of represented musical instruments in medieval Serbian churches. The data presented in this table is compiled from tables published by Pejović (1984) and is limited to the period until the mid-15th century. (Continued)

No.	Church	Year of building	Scene						
			Mocking of Christ	Last Judgement	John of Damascus Stichera	Christ on the way to Calvary	Descendants of Cain	Psalm 150	Nativity of Christ
12	Kučevište Monastery	1350						6	
13	Matejče Monastery	1355	1						
14	Marko's Monastery	1370	2						
15	St. Andrea Monastery	1389	3						
16	Saints Constantine and Helen Church, Ohrid	1390–1400	2						
17	Veluće Monastery	1370–1380		2					
18	Holy Mother Bolnička church, Ohrid	1390–1400		1					
19	Koporin Monastery	1402–1410	3						
20	St. Elijah church, Dolgaec	1456–1457							1
21	Leskoec church	1456–1457							1



Fig. 11.1: Map of medieval Serbian churches featuring representations of musical instruments in fresco paintings. The numerical annotations on the churches in the map correspond to the numbers in Table 11.1: 1 – Gradac, 2 - Arilje, 3 – Hilandar (Mount Athos, Greece), 4 – Bogorodica Ljeviška, 5 – Studenica, 6 – Staro Negoričane, 7 – Gračanica, 8 – Dečani, 9 – Poloshko, 10 – Lesnovo, 11 – St. Sophia, 12 – Kučevište, 13 – Matejče, 14 – Marko's Monastery, 15 – St. Andrea, 16 – Saints Constantine and Helena, 17 – Veluće, 18 – Holy Mother bolnička, 19 – Koporin, 20 – St. Elijah, Dolgoec, 21 – Leskoec. Author's own elaboration.

the Bible itself does not specifically mention musical instruments in the context of the Nativity of Christ, other texts provide such references. Pejović pointed out an example found in the Athenian edition of the Festal Menaion, a liturgical book for the celebration of feasts and saints in the Byzantine rite's fixed annual cycle. In this text, an anonymous author wrote: "Stopping the playing of the shepherds' flutes, the angelic army cried out" (Pejović 1984, 18). Statements like this, or similar ones from various ecclesiastical texts, served as justification and inspiration for depicting musical instruments in scenes such as the *Nativity of Christ* in several medieval Serbian churches.

Table 11.2, based on Pejović's documentation (Pejović 1984), provides an overview of the diverse musical instruments depicted in medieval Serbian fresco paintings. The instruments encompass various categories, including percussion instruments – idiophones (castanets and cymbals) and membranophones (talambas, drum, tambourine), chordophones or string instruments (psalterion, lute, strings, harp), and aerophones or wind instruments (olifant, horn, short horn, tuba, *busina*, flute, *šamalaj*). Some instruments, such as castanets and cymbals, were consistently painted in pairs. Notably, Table 11.2 reveals that different musical instruments were often depicted within the same scene. Thus, in the *Nativity of Christ* scene, a shepherd is portrayed holding either a flute or a *šalamaj*, which both belong to aerophones.

What is particularly striking from Tables 11.1 and 11.2 is that musical instruments were most frequently depicted in the scene *Mocking of Christ*, appearing in 11 out of the total 21 churches. In the well-preserved fresco paintings of Dečani monastery, founded by the Serbian king Stefan Uroš III Dečanski in the first half of the 14th century, three scenes featuring musical instruments stand out: *Mocking of Christ, Christ on the Way to Calvary* and *Descendants of Cain*. Musical instruments emerged as an iconographic element in the *Mocking of Christ* during the 14th century, serving as the latest and final component. This addition complemented the gestural mocking of commonly represented dancers, with the sonic mocking of musicians (Ilnitchi Currie 2010). The *Mocking of Christ* (Fig. 11.2) is depicted on two sides of the pillar in the northern choir of Dečani church, thus deviding the scene participants in two groups. On one side, Christ, mocking soldiers and a musician playing cymbals are found (Fig. 11.2, left). On the other side, two kneeling soliders, a half-naked dancer and a group of musicians playing a horn (a long transversal wind instrument), two talambas (a pair of kettle drums), a double-headed drum, and strings (a rebec-like bowed lute) are located. The double-headed drum is depicted being played with slightly curved sticks, featuring a pair of snares, while the rebec-like bowed lute is notably missing from the earlier depictions in Byzantine art (Ilnitchi Currie 2010).

In the background of Figure 11.3, depicting a scene of *Christ on the Way to Calvary*, an individual hidden on the left side of the painting blows a slightly arched long horn. On the right, another man blows an instrument resembling a horn but featuring a long straight pipe with a bell-like ending. This instrument, recognised as *busina,* is renowned for producing a bright and ringing sound (Pejović 1984). It is also represented in pair in the scene of the *Descendants of Cain* within the same church (Fig. 11.4).

Table 11.2: Musical instruments represented per fresco-painted scenes in medieval Serbian churches. Based on Pejović (1984).

No.	*Scene*	*Church (year of building)*	*Represented musical instruments*															
			Idiophones		*Membranophones*			*Chordophones*				*Aerophones*						
			Castanets	*Cymbals*	*Talambas*	*Drum*	*Tambourine*	*Psalterion*	*Lute*	*Strings*	*Harp*	*Olifant*	*Horn*	*Short horn*	*Tuba*	*Busina*	*Flute*	*Šalamaj*
1	Mocking of Christ	Hilandar Monastery, main church (1303)										3						1
		Staro Negoričane Church (1317–1318)		1		1							2				1	
		Dečani Monastery (1335–1350)			2	1				1			1					
		Lesnovo Monastery scene I (1349)	2	1		1										2		
		Lesnovo Monastery scene II (1349)				1		1						1		1		
		St. Sofia church, Ohrid (1350)				1		1	2						2			
		Poloshko Monastery (1340)		1		1										2		
		Matejče Monastery (1355)													1			
		Marko's Monastery (1370)														2		
		St. Andreaš Monastery (1389)		1		1										1		
		Ohrid, Konstantin I Jelena (1390–1400)														2		
		Koporin Monastery (1402–1410)		1											2			
2	Last Judgement	Bogorodica Ljeviška Church (1307–1309)											2					
		Gračanica Monastry (1321)											2					
		Dečani Monastery (1335–1350)													2			

(Continued)

Table 11.2: Musical instruments represented per fresco-painted scenes in medieval Serbian churches. Based on Pejović (1984). (Continued)

No.	Scene	Church (year of building)	Represented musical instruments														
			Idiophones		Membranophones			Chordophones				Aerophones					
			Castanets	Cymbals	Talambas	Drum	Tambourine	Psalterion	Lute	Strings	Harp	Olifant	Horn	Short horn	Tuba	Busina	Flute	Šalamaj
		Veluće Monastery (1370–1380)														2		
		Bogorodica bolnička Church, Ohrid (1390–1400)													1			
3	John of Damascus Stichera	Bogorodica Ljeviška Church (1307–1309)		1		1		1	2		1							
		Poloshko Monastery (1340)		1		1										2		
		Ohrid Sv Sofija (1350)						1	1		1							
4	Christ on the way to Calvary	Dečani (1335–1350)											1		1			
5	Descendants of Cain	Dečani (1335–1350)				1										2		
6	Psalm 150	Lesnovo 1349				1		1										
		Kučevište (1350)				1		1	2						2			
7	Nativity of Christ	Gradac (end of 13th c.)															1	
		Arilje (1296)																1
		Kraljeva crkva, Studenica (1313–1314)															1	
		Staro Negoričino (1317–1318)															1	
		Pološko (1340)															1	
		Sv Ilija, Dolgaec (1456–1457)															1	
		Vaznesenje, Leskoec (1456–1457)																1



Fig. 11.2: Mocking of Christ, Dečani Monastery (1335–1350). Photo: courtesy of BLAGO Fund.

Of particular interest is Pejović's note regarding medieval fresco artists and their depiction of sound. The author highlighted that when illustrating a biblical theme sourced from the Bible or ecclesiastical literature, artists often interpreted the text uncritically. While their aim was to portray musical instruments mentioned in ecclesiastical books, little consideration was given to how these instruments were actually held and played. Furthermore, there was no attention paid to whether they were used in group performances (Pejović 1984, 78). Pejović's observation that the representation of musical instruments in medieval Serbian frescoes lacked any musical reference allows us to suggest that these depictions were intended to evoke specific emotions. Illustrative examples of evoking emotions through the depictions of musical instruments are evident, particularly in the *Mocking of Christ* scene, where musical instruments elicit sensations reminiscent



Fig. 11.3: Christ on the Way to Calvary, Dečani Monastery (1335–1350). Photo: courtesy of BLAGO Fund.



Fig. 11.4: Descendants of Cain, Dečani Monastery (1335–1350). Photo: courtesy of BLAGO Fund.

of a noisy street with loud music. Similarly, in the *Christ on the Way to Calvary* scene, musical instruments might be associated with the atmosphere of a significant and noteworthy event.

In the medieval period, there was a belief that the robust sounds of drums or trumpets could expel evil forces. However, a strict distinction between musical instruments associated with God and those linked to the devil did not exist. Trumpets were frequently referenced in the context of announcing Judgement Day, as exemplified in Matthew's passage: "and he will send his angels with a loud trumpet call, and they will gather his elect from the four winds, from one end of the heavens to the other" (Matthew 24:31). Additionally, the Book of Revelation states: "I saw the seven angels who stand before God, and seven trumpets were given to them" (Revelation 8:2). Consequently, angels were often depicted in fresco paintings blowing trumpets toward the sea and the earth, announcing the Judgement Day and awakening the dead (Fig. 11.5). Thus, instruments in the hands of angels symbolise the power of divine voice and the praise of God (Pejović 1984, 78).

The aforementioned musical instruments (see Table 11.2) were not utilised in medieval Serbian churches. However, historical records indicate the presence of large percussion instruments – bells and semantra – in the monastic soundscape of medieval Serbia from the mid-12th to mid-15th centuries (Miljković 2018; Rodriguez Suarez 2018; 2021). These instruments were exclusively positioned and played outdoors. In contrast, while the semantron (a wooden board struck with mallets) has



Fig. 11.5: Last Judgement, detail, Dečani Monastery. Photo: courtesy of BLAGO Fund.

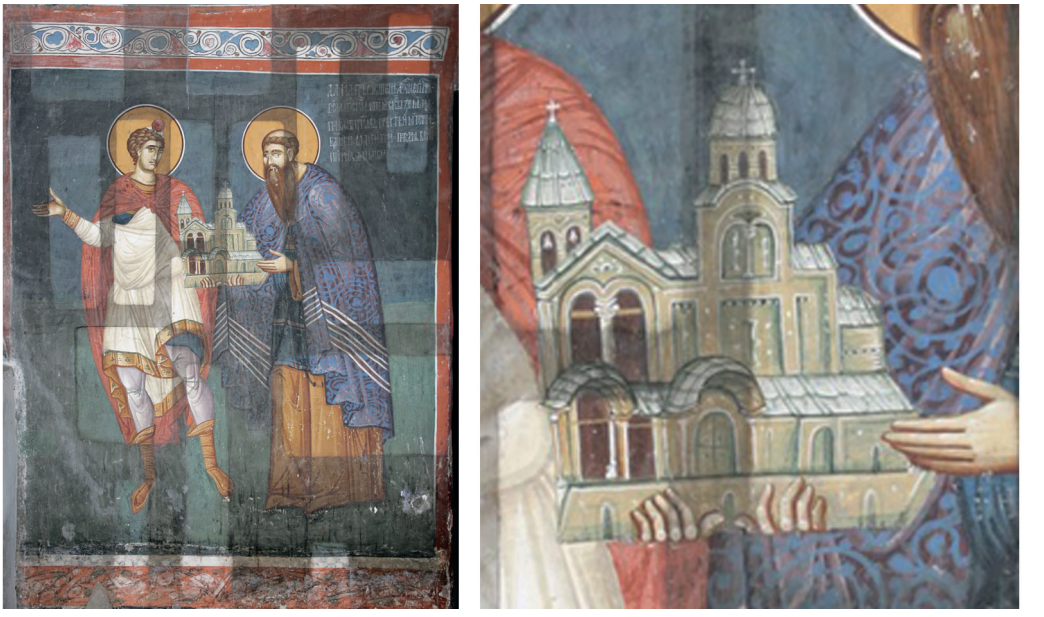


Fig. 11.6: Donor's Composition, Patriarchal Church of the Virgin Hodegetria in Peć. Photo: courtesy of BLAGO Fund.

not been observed in any Serbian medieval frescoes, there is at least one indisputable representation of bells (Bura 2005; Rodriguez Suarez 2021). This depiction is found in the Church of the Virgin Hodegetria in the Patriarchate of Peć, founded by Archbishop Danilo II in the 1320s and painted in the 1330s. In the Donor's Composition, painted on the west wall of the nave, Archbishop Danilo II, accompanied by Prophet Daniel, is depicted offering a model of the church to the Virgin. The church model held by the donor and the prophet features a belfry with two arched openings, each containing a bell inside (Fig. 11.6).

Musical gestures – cheironomia

Byzantine specialist, Neil Moran thoroughly examined representations of singers in Byzantine and Slavic fresco paintings, emphasising the significance of *cheironomia* – musical gestures of chanters. *Cheironomia* is a science of directing a choir through hand movements indicating musical intervals, melodic figures and expressions. It was an integral aspect of Byzantine choral music, thus also depicted in medieval fresco paintings (Moran 1983; 1986).

Neumatic notation, used for Byzantine chants, implies that each neume signs one or a group of successive musical pitches. Moran identified three neumes represented in medieval fresco paintings, depicting specific cheironomic gestures. Two of these hand gestures were discerned in a music manuscript from the Koutloumousi Monastery on Mount Athos, featuring three Late Byzantine composers with added inscriptions of the neuma names they gestured. Both signs were formed with the right hand. The *oxeia* sign represents a musical interval of ascending second and it is formed with two pointing fingers. The *ison* signifies a drone note that accompanies the melody and it is depicted as the thumb and index finger held together, with the other fingers extended. Moran also identified the third cheironomic sign, but could not relate it to any neume. This sign is formed with the left hand, pointing straight out the little finger while the other fingers are curled beside the thumb (Moran 1986).

Chanters are also observed in medieval Serbian fresco paintings, specifically, in seven scenes: *Source of Wisdom, Psalm 148-150, Akathistos Cycle, Christmast Hymn, Saint Nicolas Cycle* and related scenes, *Church Assembly,* and *Feast of the Cross* (Moran 1983). An example of depicting musical gestures is found in the scene *Dormition of St Arsenius* in the Patriarchal Church of the Virgin Hodegetria in Peć (now in Kosovo) portraying two chanters: the left chanter gestures *oxeia*, and the right one *ison* sign (Fig. 11.7). Furthermore, since the early Palaeologan age (1261–1360) the chanters are fresco painted in the final scenes of Akathistos – an early Byzantine liturgical hymn that praises the Holy Mother of God. In the church dedicated to Saint Demetrius in Marko's Monastery, the last scene of the Akathistos Cycle depicts the icon of the Virgin Hodegetria praised by the church dignitaries on the right side and by the chanters on the left side of the composition (Fig. 11.8). According to the vestments, the first chanter next to the icon is identified as a protopsaltis – choirmaster, clearly gesturing *oxeia* with both hands. Figures next to him are identified as a chanter (psaltai) and a domestikos – leader of the left or right choir, both gesturing *oxeia* with their right hands

(Tomić Đurić 2019). The same scene in Dečani Monastery (Fig. 11.9) depicts a chanter gesturing *oxeia* with his right hand and the third cheironomic sign with his left hand by extending the little finger outward while the other fingers are curled beside the thumb (Moran 1986).



Fig. 11.7: Dormition of St Arsenius, detail, Patriarchal Church of the Virgin Hodegetria in Peć. Photo: courtesy of BLAGO Fund.

The inscribed voices

Two types of inscriptions have been identified in medieval Serbian fresco paintings: historical and iconographic inscriptions. The historical inscriptions include votive and tombstone texts, as well as those naming a founder or craftsman. In contrast to historical inscriptions, the content of the iconographic inscriptions is closely related to the fresco painting in which it is incorporated, reinforcing the meaning of the depicted scene. Thus, the iconographic



Fig. 11.8: The Acathistos Hymn of the Virgin (XII kontakion), Marko's Monastery. Photo: courtesy of Marka Tomić-Đurić, Author of the photograph: Đorđe Đoković.

inscriptions are a sort of sound transmitter offering a peek into the audio dimension of a fresco painting. They are verbal components of the paintings because they represent what the depicted saints were saying. As the image signified the presence of the depicted saints in the church, the inscribed text might equally stand for their voices. The convention was that if the inscription was on the scroll, then the one holding the scroll was saying the written words. If the inscription is a part of the painting, then one of the persons depicted in the scene is saying the text. Hence, the inscribed text offered a voice to the represented figures. These texts were always taken from various sources, including Old and New Testament, apocryphal writings, works of church's fathers and hymnographers, or often liturgical books. Although the iconographic themes followed a series of norms, there was a significant freedom in the choice of details. Therefore, the epigraphic repertoire was diverse. Often, only one part of the text was written, but it does not mean that the saint was saying the incomplete text, rather, a part represents the entirety. Thus, the acrostic of a hymn, often found on the scrolls of hymnographers, replaces the entire hymn (Barišić 1967).



Fig. 11.9: The Acathistos Hymn of the Virgin: The twentieth strophe (XI kontakion). Dečani Monastery. Photo: courtesy of BLAGO Fund.

From the last decades of the 11th century, holy bishops were depicted holding a scroll with an inscribed text taken from the prayers of the Eucharist. On a limited sample of Byzantine churches, Babić and Walter (1976) identified 30 different texts that occurred on such scrolls in the apse decoration. They showed that the choice of texts was random, although some texts occurred more often than others. However, there are examples in which the represented figures of saints share the text of the same prayer. In the church of Sopoćani monastery, founded by the Serbian King Stefan Uroš I Nemanjić in mid-13th century, the scene *Officiating Bishops* represents the procession of the ecumenical bishops together with the first three Serbian archbishops that emphasises the autocephalus status of the Serbian Orthodox Church (Fig. 11.10). The first Serbian archbishop was Saint Sava, also known as Rastko Nemanjić, the youngest son of the dynasty founder Stefan Nemanja. Saint Sava was responsible for achieving the autonomy in the governance of the Serbian Orthodox Church in 1219. When *Officiating Bishops* were fresco-painted in Sopoćani, the autocephalous status of Serbian Orthodox Church was endangered due to the disputes within Byzantium over the acceptance of the church union with Rome (Todić 2002). Therefore, the representation of Serbian first archbishops among the ecumenical patriarchs of Constantinople seemed to indicate the same ideological standing of the Serbian and Byzantine church, as well as the independence of the Serbian church. Another way of communicating this idea was through the inscription of a prayer. Each represented figure is holding a scroll with the inscription of one prayer – the entire Trisagion, an ancient hymn of the Eastern church, often included in one of the scrolls in Byzantine apse decoration (Babić and Walter 1976). However, the depiction of a single prayer that continues from one scroll to another, in the case of Sopoćani, was also used to communicate an idea of spiritual unity. Activating this image through the celebrant's reading of the same hymn from the scroll he is holding himself (Gerstel 1999), the represented saintly bishops are invited and enabled to simultaneously take part in the liturgical celebration, united with the sounds of the prayer.

The activation of the image through the reading of the text inscribed on it, can also be seen in some of the representations of Christ. In the altar apse of the chuch



Fig. 11.10: Officiating Bishops. Sopoćani Monastery. Photo: courtesy of BLAGO Fund.

of Saint Marko's Monastery, which is founded by Serbian King Vukašin and his son Marko in the mid-14th century in today's North Macedonia, Christ is represented as the Great Archpriest with the open book on the Holy Table in front of him (Fig. 11.11). The book contains the text of the initial anaphora blessing, a thanksgiving prayer said in the most solemn part of the Divine Liturgy when the Holy Gifts – bread and wine – are consecrated as the body and blood of Christ. In front of this fresco painting, the celebrant is saying the anaphora blessing that could be read on the book Christ is holding (Tomić-Đurić 2015). In this way, the celebrant activates the image, offering a voice to Christ.

Looking further for the representation of the voice of Christ, there are two examples in Lesnovo Monastry, founded by Jovan Oliver, a nobleman at the court of the Serbian King Stefan Dušan Nemanjić, in the mid-14th century in today's North Macedonia. On the eastern pair of pillars in the naos, in front of the altar, there are two representations – Christ holding a book and the Virgin Mary grasping a scroll. In the first case, Christ is represented with an open book on the western side of one pillar facing the naos. In the book there is the inscribed text from the Gospel of John (8:2), refering to Christ as "the light of the world" (Đorđević and Marković 2001). This inscription – its position and meaning – is deeply related to the religious practice. Namely, during the Divine Service, still nowadays, the laity stands turned towards the altar, the most holy space of the church that is oriented to the East as that is where the light comes from. Consequently, turned towards the light, the faithful sees the image of Christ with the inscription confirming that he is the light himself. On the other pillar, also on the side facing the naos where the faithful stand during the liturgy, the standing figure of the Virgin Mary is painted. She is pointing with her right hand the scroll she holds with a customary text of her conversation with Christ. Her words are painted in black, whereas Christ's words are red. In this dialogue, the Virgin expresses her request to Christ for the salvation of the human race (Đorđević and Marković 2001).

All the aforementioned examples of inscribed sounds demonstrate that the inscriptions on scrolls and books give voices to the depicted figures, enabling them to convey various ideas. In the case of the *Officiating Bishops* in Sopoćani, the inscribed prayer suggests the idea of unity between Serbian and Byzantine churches. At Lesnovo Monastery, the inscription in the depiction of Christ with an open book serves as a reminder to the laity that Christ is the light of the world, whereas the text on the scroll held by Virgin Mary represents her dynamic dialogue with Christ and underscores the importance of her advocacy for humanity.

The celestial sounds

Byzantine theological doctrine emphasises the concelebration of Heavenly and Earthly liturgy, in which angels chant with humans. It is believed that the liturgical events deliver angels into the physical world and lead to their mystical assimilation with the faithful present in the church. This idea has been visually embodied in the wall

paintings of the scenes of the *Officiating Bishops* and the *Heavenly Liturgy*, usually in the lower register of the sanctuary. As art historian, Amy Gillette pointed out, the images of angels who are singing chants attributed to them in the Bible were active forces "which opened the door of heaven and enticed human beings into spiritually joining their liturgy". They reified the celestial liturgy as it was performed in the church (Gillette 2018, 30).

An example of representing the concelebration of the Heavenly and Earthly liturgies is located in Marko's Monastery. In the lowest zone of the sanctuary apse the *Great Entrance* scene is depicted (Fig. 11.1). The Great Entrance is the central part of the Divine Liturgy, during which the Eucharistic gifts (bread and wine) are carried from the Table of Preparation in the Prothesis chamber through the nave to the Holy Table in the *bema* where the gifts will be consecrated.[1] It is the only segment of the rite that is performed outside the sanctuary, thus enabling the laity to have a direct contact with the Eucharistic gifts. The depiction of the *Great Entrance* in Marko's Monastery combines the elements of two themes – *Heavenly Liturgy* and *Officiating Bishops* – thus representing the simultaneity and unity of the Heavenly and Earthly Liturgy and placing the important theological and liturgical issues before the eyes of the celebrants. Christ is represented as the Great Archpriest with the open *leitourgikon* (the collection of hymns chanted in the Divine Liturgy) on the Holy Table in front of him. From his right side, he is approached by the prominent bishops (Saint Basil the Great, Saint John Chrysostom, etc.), while from his left side, he is approached by a procession of angels. The image of *Christ the Great Archpriest* is visible through the open Royal Doors during the Cherubic Hymn, placing a strong impression on the congregation and intensifying the religious feelings. The text written in the *leitourgicon* is reconstructed as: "The Grace of our Lord Jesus Christ and the Love of God the Father and the Communion of the Holy Spirit be with you all". This is an initial anaphora blessing – a thanksgiving prayer said in the most solemn part of the Divine Liturgy when the Holy Gifts are consecrated. The anaphora blessing takes place when the Royal doors close after the Great Entrance, thus making the celebrant and the image of *Christ the Great Archpriest* visually inaccessible to the faithful. The anaphora blessing is followed by the laity's response in the form of short exclamations. The only connection between the celebrant and the laity is through the laity's vocal participation in the liturgy, while the visual connection with the image of Christ lasts shortly, only while the Royal Doors are open (Tomić-Đurić 2015).

In the sense of the auditory interactions during the religious service in medieval Serbian churches, revisiting the archaeoacoustic studies conducted by Đorđević and Novković proves captivating. These studies revealed that the aural connection between the laity in the naos and the celebrant in the sanctuary can be described as unclear, or even unintelligible. This is attributed to the celebrant's execution of the primary portion of the rite behind the iconostasis – a physical barrier that separates the naos from the sanctuary. Consequently, the iconostasis established aural distance between the laity standing in the naos and the celebrant performing the service in



Fig. 11.11: Great Entrance. Marko's Monastery. Photo: courtesy of Marka Tomić-Đurić.

the sanctuary, diminishing the intelligibility of the celebrant's speech in comparison to the portion of the service he performs in the naos (Đorđević and Novković 2019; Đorđević *et al.* 2019).

Since the latter half of the 14th century, the theme of the *Heavenly Liturgy* has been independently depicted, detached from the *Officiating Bishops* and situated in the church's central dome – a symbolic representation of heaven. The *Heavenly Liturgy* is portrayed as a solemn procession of angels, without any specific reference to a particular moment in the Holy Liturgy. Frequently, this depiction incorporates the inscription of a hymn, such as Epinikios or Trisagion, evoking the sensation that, in the words of art historian Tatjana Starodubcev, the procession resonates with the echo of an angelic song celebrating the Lord (Starodubcev 2002). An illustrative instance of the *Heavenly Liturgy* can be observed in the dome of the Dečani monastic church (Fig. 11.12), illustrating a procession of 21 angels partaking in the Divine Liturgy around the centrally depicted Christ Pantokrator. Above this *Heavenly Liturgy* scene, the Trisagion (thrice-holy hymn), integral to Isaiah's vision (Isaiah 6:3), is inscribed: "Holy, holy, holy, Lord God of Sabaoth; heaven and earth are full of Thy glory." The presence of this hymn suggests that the angels, positioned alongside the inscription, are singing this hymn during the Heavenly Liturgy. Under the dome and the *Heavenly Liturgy* scene, humans chant the same hymn during the Earthly Liturgy as the angels above. This arrangement suggests the intertwining of angelic and human voices, embodying the doctrine that posits the simultaneity of the Heavenly and Earthly liturgies. As noted by Gillette, depictions of angels' songs serve as active forces of engagement, acting as a gateway to heaven and inspiring the faithful to spiritually participate in the Heavenly Liturgy (Gillette 2018). This observation holds true for all the cases with inscriptions examined above, as the inscribed text actively involves the faithful in the service, functioning as a link that bridges the realms of earth and heaven, facilitating the joint celebration of the Divine Liturgy.

Both of the aforementioned examples of fresco-painted notions of celestial sounds – the *Great Entrance* in Marko's Monastery and *Heavenly Liturgy* in Dečani



Fig. 11.12: Heavenly Liturgy. Dečani monastic church, central dome. Photo: courtesy of BLAGO Fund.

Monastery – provide an insight into how frescoes, religious service and church acoustics work together to contribute to the mystery of heavenly sounds. The obscure aural conection between the laity in naos and celebrant in the altar adds to the mystery, especially when the celebrant reads the anaphora blessing inscribed in the book held by Christ, thus offering the voice to Christ. On the other hand, the procession of angels depicted high above the laity in the central dome, surrounding the all-seeing Christ, interacts with the acoustic effects of the dome, creating an experience uncommon in everyday life.

Discussion: Integrating sound imagery into archaeoacoustic research

The fresco-painted scenes that included musical instruments in medieval Serbian churches represent an excellent approach to study the relationship of sound and image in medieval art. The review undertaken for this article has identified the presence of musical instruments in 21 medieval Serbian churches, most of them painted in the narrative style that has been characterised by an accurate representation of detail (1300–1370). From the numerous fresco-painted scenes, percussion, string and wind instruments were included in seven of them. However, the Orthodox Church has never allowed playing musical instruments inside a church. Therefore, it is even more interesting to note the musical instruments that are missing, like bells and

semantra – wooden boards struck with mallets, despite their documented presence in the monastic soundscape of medieval Serbia from the mid-12th to mid-15th centuries (Miljković 2018; Rodriguez Suarez 2018; 2021). This absence may be due to the fact that bells and semantra were exclusively located and played outdoors. As mentioned earlier, the only representation of bells in medieval Serbian frescoes is found in the Church of the Virgin Hodegetria in the Patriarchate of Peć, specifically within the Donor's Composition painted in the 1330s. However, the lack of additional portrayals of bells in medieval Serbian frescoes raises the question: what could be the reason for this absence? This becomes even more intriguing considering that the oldest image of bells in a wall painting was discovered not far from Serbia, in the Saint Nicholas church in the Niata village in the southeast of the Peloponnesos, Greece, dating back to the second half of the 13th century (Miljković 2018). One could argue that the representations of bells and semantra, common in neighbouring countries such as Greece at the time, might not have endured in Serbian churches up to the present day. The later Ottoman rule that started in the mid-15th century and lasted until the late 19th century forbade the tolling of bells, and during this period a significant number of fresco paintings was neglected and even intentionally destroyed.

The question may also be posed of whether the painter's idea was to evoke a feeling of sound. If we think about the scene *Mocking of Christ,* although without referencing the real-life group playing, musical instruments were most often depicted in it. Was the painter's idea to evoke a feeling of the noisy street events in contrast to spiritual calmness? Similar questions about the emotions that the fresco paintings arouse in the faithful could be posed regarding the inscribed texts on fresco paintings: was the artist's intention to represent the particular prayer at a place in which the church acoustics provoked a sense of intimacy when one stood in front of the inscription and prays quietly or aloud? Gerstel noted that the written texts were often modified to emphasise a particular part and work together with the image, providing an aural and oral component (Gerstel 2019). This idea, together with the idea of Christian inner senses that operate mentally through imagination and discourse (Caseau 2014), encourages us to raise some further questions, although answering them goes far beyond the scope of this article. Can we mentally hear the written words? Do the religious rites put us in the state of mind in which this occurs spontaneously? Or do we need to give voices to the depicted figures by reading aloud or chanting the represented text, and thus activate the aural dimension of the image?

Besides emphasising certain parts of the religious service, the inscribed texts might evoke a feeling of solemn speech especially if reinforced by church acoustics, regardless of the literacy of the viewer. Both *Officiating Bishops* and *Heavenly Liturgy* are fresco painted on concave surfaces, such as the sanctuary apse or the dome drum. The central dome is a main feature of the churches built in Byzantine tradition, symbolicly implying the Universe, the depiction of heavens above the earth (Korać and Šuput 2010). Relocating the scene of *Heavenly Liturgy* to the central dome in the 14th century, besides having a theological significance, might have had an

acoustical reason as well. Since the goal was to enhance the feeling of simultaneously participating in both Heavenly and Earthly liturgies, the acoustic mirroring effect of the Late Byzantine domes, which redirects sound reflecting it downward, contributes to this immersive effect. Chanted words rose to the dome, to the heaven and to Christ Pantokrator, and reflect downwards by the dome's geometry, creating the effect that angelic and human voices mingle in the centre of the temple (Gerstel 2019). But, as Pentcheva (2011) wondered, was this acoustic environment intentionally designed or accidental as a by-product of the architectural tradition of domed churches and large marble surfaces? This question will never be fully answered for medieval Serbian churches due to the lack of written evidence. However, even if we assume that the church acoustics was an architectural by-product, it is certain that the fresco painters accounted for already established church acoustics. Therefore, it is reasonable to presume that the painters could work in accordance with the sound environment when positioning and designing fresco-paintings striving to enhance the religious experience. In this line of thought, Gerstel suggested that some fresco paintings might have been positioned in relation to the acoustic properties of that particular spot in the church (Antonopoulos *et al.* 2017; Gerstel 2019). This hypothesis, including in particular the acoustics under the central dome and in the apses, should be further tested, examining the relation of church acoustics and the sound imagery in Serbian medieval churches.

Conclusion

In recent decades, archaeoacoustic research on medieval Serbian churches has primarily focused on acoustic measurements and the correlation between the church's acoustic properties and religious practices, particularly the Byzantine chanting tradition. This article argues that the archaeoacoustic exploration of Serbian medieval churches should also encompass sound imagery. Therefore, it is especially relevant to archaeologists focusing on sound, as well as medieval art and architecture. In this article, for the first time, four key elements are identified that qualify a fresco painting as sound imagery: 1) musical instruments, 2) musical gestures, 3) inscribed *voices* on scrolls and books, and 4) the celestial sounds resonating from depictions of Heavenly Liturgy. As shown, these visually suggestive elements are present in various iconographic themes. Given the liturgical role of fresco paintings in medieval Serbian churches, where saints and heavenly beings were intended to evoke their presence in religious services, it is pertinent to investigate whether the interplay of church acoustics and sound imagery facilitated their auditory companionship for the congregation during religious ceremonies. This article establishes the foundation for a future, comprehensive archaeoacoustic investigation of medieval Serbian churches that includes sound imagery. The proposed multidisciplinary approach to archaeological exploration, incorporating insights from acoustics, the history of art and architecture, medieval musicology, and religious studies, emphasises the

fundamental role of the senses – primarily sight and hearing – in the experience of sacrality within medieval art and architecture. Such an examination would allow us to derive conclusions about the deliberate incorporation of sound imagery and its interaction with church acoustics.

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Note

1 The Prothesis is the preparation room located next to the altar. The Eucharistic gifts are carried from the Prothesis through the side doors of the iconostasis to the nave where the faithful stand, and then through the Royal Door (central door in the iconostasis) to *bema.*

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Chapter 12

Acoustic space then and now: Listening to history

Tess Knighton

Abstract

This brief chapter considers how and in what ways spatial and acoustic recovery using Digital Humanities (DH) tools of virtual reality and auralisation can elucidate historical relationships between sound and space in order to analyse the significance and sensory impact of sonic experience of the past. It also proposes that theoretical approaches and methodologies drawn from modern sound studies can, in combination with digitally inflected research, lead to a reassessment of the historical earwitness's role in listening to history. Since the late 1960s, study of the soundscape has been based to a large extent on ethnographic analysis and acoustic measurement, methods that, with the aid of DH tools, can be applied increasingly to the interrogation of the relationship between sound and space in the past. Historical ethnography, in which the written evidence of primary sources is interrogated through the filter of research into its social, political and religious context, can be used to inform digital recovery of acoustic space and auralisation and, in the process, open up new perspectives on existing historical paradigms.

Keywords: soundscape, earwitness, sound studies, acoustic community, soundscape competence, historical ethnography, archival resonance, acoustic space, acoustic recovery, auralisation, digitally inflected research

Introduction

This chapter looks at how the dynamic relationship between sound and space can be analysed in the context of the historical past. Particularly challenging for the historian

is how to analyse the performance aspect of the production and reception of sound: how sound communicated meaning and its role in creating emotional or affective impact as part of organised ritual. Recent developments in Digital Humanities (DH) tools have facilitated new ways of measuring and evaluating the acoustics of historical spaces, even – perhaps especially – those that no longer survive, and, through the use of auralisation techniques, that allow sounds, and particularly musics, to be heard within or through the recovered historical acoustic. In this way, the reach and diffusion of sound, its directionality, whether it can be heard with clarity (that is, to use Murray Schafer's 1977 term, "hi-fi") or muffled, and the extent to which a sound signal is contaminated and the message it is intended to convey distorted or made inaudible (lo-fi). In other words, this technology allows the historian to draw nearer to sonic communication and impact – intended or otherwise – through experiencing sound as heard in its original acoustic environment. Modern interpretation of past sonic experience remains, of course, highly problematic, but techniques of acoustic recovery have the potential to open up new ways to approach that issue.

Historical sound studies

One of the pioneers of modern sound studies, R. Murray Schafer, in his now classic study of the sonic environment, explored the notion of hi-fi sonic experience, in which the balance between meaningful sound and background noise was tipped in favour of being able to distinguish communicative or information-bearing sounds. At the other extreme, in the lo-fi experience, possible auditory significance is drowned out by acoustic interference and contamination, and subsequent loss of sonic perspective (Schafer 1994, 43). Although Schafer was primarily concerned with modern sound studies based on the era of recorded sound, in his *Tuning of the World* (1977), he recognised that "for the foundation of historical perspectives we will have to turn to earwitness accounts from literature and mythology, as well as to anthropological and historical records" (Schafer 1994, 8). Schafer's prescient reference to "earwitness" evidence resonates with historical ethnography, and the interrogation of written testimony to the past (see Knighton forthcoming). Recent developments in digital technology have the potential to transform the recording and acoustic measurement techniques formulated by Schafer as a methodological basis for modern sound studies into a theoretically based approach to historical sound studies. In this context LIDAR (Laser Imaging Detection and Ranging) scanning, together with advanced tools of acoustic measurement that are able to detect distance, audibility, reverberation, absorption, balance, decay and dispersal of sound, builds on the pre-digital methods of acoustic measurement pioneered in the general field of contemporary sound studies. See, for example, the case studies of village soundscapes undertaken by the World Soundscape Project in the 1970s (Schafer 1977).

The question here is how far can new digital techniques make it possible to bring together the resonance of historical acoustic spaces – many of which no longer exist

or do so in a limited or adulterated form – and the auditory experience of those who participated in a sonic event and the meaning it held for them. Archaeological-based studies of the prehistoric and ancient sonic environments, such as the ERC *Artsoundscapes* research project, dedicated to the study of archaeoacoustics in rock art landscapes (García Atiénzar *et al.* 2022; Santos da Rosa *et al.* 2023), have led the way and are finding resonance in recent historical projects, some of which will be briefly discussed in this essay. Drawing on the latest technologies and findings, the research project *Soundspace* questions how civic ritual in the form of processions moved in sound and space in the chronological period c. 1400 to c. 1700 and in the context of four Mediterranean cities – Barcelona, Valencia, Tarragona and Palma de Mallorca – in order to analyse their significance for participants as sensory and affective experience. In this project, the complex and multi-faceted relationship between sound and space will be explored to engage with the sensory and emotional elements implicated in performance that are key to understanding the impact of civic and religious processions that formed such an important part of the historical urban soundscape.

Processional practice will be interrogated from different but interrelated perspectives through the use of a variety of DH tools: Virtual Reality and auralisation to recover the acoustic properties and impact of the spaces through which processions moved; digital cartography to analyse the density and reach of processional experience in the four cities, with visualisation of results; and discourse analysis using data-mining tools in an innovatory approach to historical ethnography and interrogation of the written evidence of the earwitness. This essay will focus on the first of these three strands related to acoustic and spatial recovery, with an assessment of recent research that has developed DH techniques and established models for the realisation of the *Soundspace* project. However, this project differs from and goes beyond the paradigms of previous studies in that it involves the recovery of sound-in-motion and the combination of the various different acoustic contexts as the procession moved through the city.

The case study to be developed through Virtual Reality 3-D recovery of spatial context and auralisation of acoustic environment is based on in-depth analysis of a particular type of procession: the litany processions held on the three days before Ascension Day, as celebrated in Valencia in the first half of the 16th century. Litany processions involved establishing a ritual and sonic connection between major urban spaces over the three days. They involved a substantial part of the city's inhabitants: contemporary accounts describe the participation and attendance of thousands of people in events that often lasted three to four hours, or more. Each procession started at the cathedral while radiating out on consecutive days to the city's three major monasteries – Dominican, Franciscan and Carmelite – before returning to the cathedral. Stations along the three routes resulted in ceremonial and sonic nodal points and the creation of further spatial-acoustic environments. As a result, at some point in the first half of May (Ascension Day was a moveable feast dependent on

Easter) almost the whole city was involved in an annual rogative ritual that dominated spatial and temporal aspects of the urban soundscape. The reconstruction of these events through Virtual Reality (VR) and auralisation techniques presupposes the analysis of urban processional practice as intersensory experience, and raises issues regarding the visual, olfatic and haptic, as well as sonic, aspects of the event as well as the body choreography of its ritual.

The extent to which intersensorial experience has been studied and realised through DH tools to date is explored here through analysis of recent studies involving attempts to recover the resonance of past acoustic spaces approached from the perspectives of materiality, sensoriality and experiential discourses contemporary to the period and geographical location in question. First, it is necessary to address methodological issues relating to the sensorial recovery process. In all its aspects, this process has to be deeply rooted in archival research and a systematic unlocking of archival silence with the aim of being able to interrogate the earwitness.[1] Martin Walraven has suggested that the hidden resonances of silent documentation can be heard via the archive through its potential to evoke sounds within acoustic communities (cf. Truax 2001, 66; 2017, 258–259), seen as "social groupings identified with certain spaces and models of causality that stem from the negotiation of social relationships and rituals developed over time" (Walraven 2013). Bissera Pentcheva, speaking of aural architecture, in which analysis of visual characteristics of a space are analysed together with its sonic properties, likewise develops the notion of reverberance as a metaphor "to denote the whispers of the past that can be detected in the present" (Pentcheva 2021, 4).

The historian of the senses Mark Smith stresses the need to take "seriously the full social and cultural context of [sensory] experiences", and to attempt to understand "the way that people thought about the senses, the cognitive processing of the sense perceptions" (Smith 2007, 4). A way forward for the historian is proposed by Emily Cockayne who, in her analysis of noise and stench in early modern England, suggests that members of society reacted to experiences "as beings-in-the-environment, not as detached observers" (Cockayne 2021, 16). Cockayne extracts and analyses the traces of those reactions from close reading of contemporaneous texts through the filter of their historical context. There is an interesting parallel here with the archaeologist's use of trace evidence to recover a sensorial archaeology, that, in Yannis Hamilakis's words should advocate "the celebration of the concrete and the empirical, and of multi-sensorial modes of being and understanding in and attending to the world" (Hamilakis 2013, 9). He considers that the sensorial field is embedded in matter, leaving 'plenty of material evidential traces' (Hamilakis 2013, 5). Close reading of written texts is, in some ways, similar to close reading of material trace evidence in, for example, rock art.

Also necessary is the need to elucidate how sound might have worked as a form of communication in the context of historical sound studies. As Alexander Cowan and Jill Steward have suggested in the light of Alain Corbin's study of the communicative

nature of bells in a 19th-century French village (Corbin 1994), "sound plays a crucial role in the perceptual and cognitive processes that determine the way that geographical and social spaces are mapped out and negotiated by individuals" (Cowan and Steward 2007, 13). The procession, as a form of negotiated social interaction that, through its kinetic nature, bodily mapped the significant spaces of the city, provides a useful vehicle for exploration of the perceptual and cognitive response to sound heard in space. Furthermore, the social, political and cultural processes that came together to create the performative act that was the procession fed into the expectations of the urban community, while the perceptual processes resulting from the sensory experience and emotional discourses of and around the performance helped shape the identity and collective memory of the acoustic community. In the words of Vincent Meelberg, "sound-as-perceived is related in another way to history, namely via its ability to trigger memories [...] sound has the capacity to evoke strong memories, sensations and emotional associations" (Meelberg 2017, 335). Bringing together methodologies from sound studies, sensory history and acoustemology, with their corresponding empirical, epistemological and hermeneutic approaches, should help in understanding how sound communicated in a social and performative context, and the possible meaning(s) it may have had for the acoustic communities that participated. Moreover, the nature of sound travelling through space meant that acoustic communities were essentially fluid and overlapping, depending on the spaces in which members moved in their daily lives through the urban complex, whether spaces associated with official capacity and daily work patterns, domestic environment and devotional, ceremonial and ludic activities.

All these approaches – material evidential traces, sensorial presence in the past and resonances (and reverberations) of the past – are useful in addressing the question – central to the *Soundspace* project – as to how we might, in the present, connect with the historical earwitness and their experience and understanding of a procession that, hundreds of years ago, moved through space and articulated social meaning through sound. Tim Carter, in querying the feasibility of an "historical acoustemology", pinpointed the stumbling-block for urban musicologists as being the difficulty of knowing "how those who inhabited a soundscape interacted with it by way of hearing or listening" (Carter 2018, 32). It is this specific aspect that the *Soundspace* project seeks to address through research focused on the processes involved in mounting and experiencing a procession in the past: those processes that were involved in bringing the urban community together in a shared expression of identity and belief, and those by which that collective experience, filtered through sound and space, was communicated.

This interdisciplinary conceptual and methodological framework for interrogating the earwitness of the past can be made more present through recent developments in digital technology. Just as material-based traces can be considered to be imprinted with sensory and perceptual information, the digital imprint of the characteristics of acoustic space, recovered through the process of acoustic measurement and

auralisation,[2] can enhance – that is, make more dynamic and present – what can only be suggested by earwitness accounts. For example, sound and space can, through digital tools, be convolved through the materiality of buildings and the role of material objects in the sounding spaces of the city. Some urban centres retain street topographies that are relatively little changed; others have been completely or partially destroyed. Technological advances in 3-D modelling and acoustic recovery, together with research into the materiality of ephemeral architecture, street furniture and decorations can help to understand how processions interacted with and modified spatial acoustics and transformed the daily experience of sound in urban spaces, interior and exterior. The location and height of buildings (open squares, narrow streets – paved and unpaved – bell-towers), as well as building materials used (marble, brick, stone, plaster or wood) with their resulting textures (plain, decorated, smooth, rough), and the presence (or absence) of absorbent materials (robes, hangings, tapestries, carpets of flowers and plants) would have affected the acoustic impact of processions as part of urban ritual. All these elements have to be thoroughly researched through archival evidence, including the visual aids of old maps, drawings, photographs and iconographical material. This research is currently being undertaken for the recovery of the Valencian litany processions in the first half of the 16th century.

Pascale Rihouet has discussed the centrality of material objects and decorative elements to the procession as visual and sensory markers of identity in the case of Perugia (Rihouet 2019). In the materialisation of processions, those objects and decorations also had a sonic impact, notably in houses lining processional routes or fringeing squares that were ceremoniously – and acoustically – transformed by hangings of rich cloth, carpets and tapestries. Rushes, aromatic plants and flowers carpeted the streets and dampened the sound of footfall and horses' hooves while simultaneously releasing olfactory delights (or at least disguising the less pleasant odours that marked daily life). As Hamilakis has proposed, sensory history should not focus on individual senses but "on the field of sensoriality and on the affective and mnemonic flows it engenders" (Hamilakis 2013, 14).

The identification and interrogation of contemporary sensory and emotional discourses relating to sound and space is thus greatly enhanced by digital recovery of performative spaces and analysis of their acoustic properties and reach. It is also key to enabling the historian to go beyond descriptive analysis of the symbolic significance of processions. The *Soundspace* project proposes to analyse "the moving sonosphere of processions as social practice" (Knighton 2021, 33), in the sense that habituated practices in urban ritual can be considered skilled behaviours. In terms of acoustic sound, such skilled behavious would include Barry Truax's concept of "soundscape competence", that is, the ability of the acoustic community to identify different sounds in space and time, and what they might – or might not – communicate, leading its members to respond to or act upon that sonic information (Truax 2001, 57).

Practice, as skilled behaviour, sees "people move about in the social environment [...] supremely practiced at the subtleties of movement, posture, gesture, and expression that connect them with others as well as communicate to themselves who they are" (Scheer 2012, 202–203). I have recently suggested that we might think of the procession and sonic environment through and in which the inhabitants of the city circulate and are connected, as an (im)material object for the purposes of analysis and comparison (Knighton 2021, 39). However, sound itself could also be considered in this way despite its entropic nature in that it will immediately and inevitably begin to diminish (Fisher 2014). For example, the emblematic sound of the trumpet,[3] characteristic of all celebratory and festive processions, goes beyond its materiality as a musical instrument to a sound that is both meaningful and informative, with shared identifiable properties: loud, rousing, reminiscent of outdoors activities such as battles or the hunt, or the heralding of the presence of authority and its messages through town cries.[4] In effect, the sounds of a procession form an (im)material object that can be quantified and categorised through frequency and density of experience.

Use of DH tools in spatial restitution and acoustic recovery

Technological developments in spatial restitution and acoustic recovery – one of the three main research strands of the *Soundspace* project – are making it increasingly possible to materialise sound in acoustic space, thus revolutionising how we might "hear" the past and ourselves become earwitnesses to it. Even though the sounds of times before the advent of recording are, in effect, lost forever to modern ears, it is now possible to restore something of the resonance of the past. In the attempt to do so, it is viable to draw closer to that symbiotic process of production and reception of sound in ritual practice. It cannot be claimed that digital tools such as virtual or augmented reality can reconstruct how sound was experienced in the past, nor its impact on listeners of the time. As Deborah Howard has pointed out with regard to her project related to Renaissance Venetian churches: "Although personal devotional experience cannot be quantified, scientific examination of the boundary conditions can help us to understand the impact that acoustics may have had on those in attendance at the ceremonies" (Howard 2021, 135; similar ideas are found in Pentcheva 2021, 2; and Wall 2014a, 1). Yet, it has become clear that a virtual recovery or digital evocation of an historic procession can be a useful intellectual exercise for two main reasons. First, it can bring to the fore the *presence* of sound in historic ritual, which in historical studies has so often been lost or overshadowed through a more or less exclusive emphasis on the visual elements that are more often and more fully described in contemporaneous accounts and more readily interpreted as symbols of political and religious authority. Second, the use of DH tools such as VR and digital cartography in the process of mapping the historical past has already shown that they give rise to unexpected lines of inquiry

that open up new perspectives that inform or modify theoretical approaches in innovative ways.

The question of "presence" clearly goes beyond that of "absence", that is, the absence, until recently, of sound in historical writing, to an intellectual approach that consciously strives to uncover and interpret the traces of the presence of sound in daily life and social identity and communication of the past. Presence, rather than representation, lies at the heart of Yannis Hamilakis's study of archaeology of the senses which, in his words, "does not attempt to represent the past, or the present for that matter, but to evoke their sensorial qualities, their life processes, to conjure up the interweaving of materials, bodies, things, and substances in motion, to reignite their affective power" (Hamilakis 2013, 12–13). He uses the written "conjuring up of images, sounds, smells, bodies of things, and bodies of persons, places, movements, and situations" as "a conduit through which to engage in sensorial and sensuous understanding and reflection" (Hamilakis 2013, 13).

In terms of materiality, Lisa Snyder has concluded that virtual environments based on rigorous academic standards, can afford "insights into the material culture of past civilisations in ways never before possible" (Snyder 2012, 395). A digital spatial model and acoustic recovery, undertaken with awareness of its limitations as regards representation and of the boundary conditions in play, and based on a highly detailed and contextualised analysis of acoustic space, has the potential to lead to a deeper level of intellectual engagement. This has been shown by Nicholas Terpstra, whose Digitally-Encoded Census Information and Mapping Archive DECIMA project (Terpstra 2016) demonstrates how digital mapping and visualisation can be used "to describe spatial, kinetic and sensory dimensions" of urban society in earlier periods (Terpstra 2016, 1). With digitally inflected scholarship, he has argued, it should prove possible to interrogate existing paradigms from different perspectives, and to open up new – quite possibly unexpected or unanticipated – questions to reveal "patterns and juxtapositions" that will take historical research in innovative directions (Rose 2016, 29; Terpstra 2016, 1). DECIMA is based on digital cartography, using an historic map of 16th-century Florence, and an unusually detailed census of the city carried out in the same period that has enabled a wide range of pioneering studies, notably that by Niall Atkinson on "Seeing Sound: Mapping the Florentine Soundscape" (Atkinson 2016), or making it possible, for example, to visualise how fear of contagion of the plague spread through the city of Florence.[5]

The *Soundspace* project aims to demonstrate how the use of DH tools aids the concept of processing the procession. Archival research can unlock the social and cultural processes required for the mounting and production of the procession, while close reading and analytical processing of texts and discourses relating to the procession can be used to filter some of the cognitive and perceptual processes involved in its reception and significance. The processing of large amounts of evidence – documentary, textual, material, spatial and visual – through different digital tools, from analytical and semantic databases through digital cartography to virtual reality –

is itself a process, through which, as Terpstra suggested, existing paradigms can be seen from new perspectives, even as regards sensory and emotional response, as in tracing fear of the spread of the plague.

For the VR reconstruction of the Valencian litany processions, three recent research projects have proved invaluable in their pioneering use of virtual spatial and acoustic recovery: Deborah Howard and Laura Moretti's spatial and acoustical analysis of Renaissance Venetian churches; Bissera Pentcheva's auralisation of the Hagia Sofia in her *Icons of Sound* project, which enhances understanding of the interplay of sound, light and space in Byzantine liturgy; and John Wall's recreation of the sermon-as-performance in the context of St Paul's churchyard.[6] Each of the three projects represents a different approach based on its starting point and objectives: 1) the recuperation of sound in existing acoustic spaces (Venice); 2) the auralisation of an existing acoustic space (Hagia Sofia); and 3) spatial and acoustic recovery of a lost space and building (St Paul's Cathedral and churchyard). With their overlapping but differentiated ways of using DH tools, these projects have interrogated existing paradigms of thinking from different perspectives and opened up new lines of inquiry in historical approaches to understanding performance-based, multisensorial events in the past and their impact on those present. The rapidity with which digital technology has developed in terms of sophistication in audio-visual content is abundantly clear from the gaming industry, and over the last couple of decades has quickly gained ground in archaeological projects relating to the sounds and spaces of the prehistoric period and classical antiquity, as well as more recent historical eras. While our experience of the past is always and inevitably mediated through the present, these three historically based projects, among others, have shown that digital technology is highly effective in bringing to the fore the relationship between sound and space in the past.

The *Soundspace* project, as in the Venetian churches project directed by Deborah Howard and Laura Moretti, aims to recuperate sound in both existing and non-extant acoustic spaces. It focuses on what, as they proposed in 2009, was the "missing dimension" from the early music revival: "the experience of the sound within the physical space in which it would have been heard" (Howard and Moretti 2009, xiv). Their study of the acoustic experience of Venetian churches aimed to give 'serious attention [...] to the ways in which the worshipper or spectator combines aural and visual sensations' (Howard and Moretti 2009, 5). For example, consideration of the visual and material aspects of how, in highly decorated buildings, such as the basilica of St Mark's, with its vast acoustic spaces and echoing reverberation "sumptuous surroundings could predispose the listener to detect the magnificent qualities of music" (Howard and Moretti 2009, 5). At the same time, they questioned the extent to which a reverberant acoustic might have been dampened by material objects such as tapestries, carpets, vestments and altar cloths, as well as the presence of people (the absorption co-efficient), and the effect on Early Delay Time (EDT) of building and decorative materials, such

as the uneven surface of the gold mosaics with which the walls of the basilica are lined (Boren 2010; Howard 2021).

The Venetian churches project's experimentation with acoustic measurements was primarily concerned with clarity of acoustic sound, and with how different musics, from plainchant to polychoral pieces by composers such as the Willaert, the Gabrielis and Monteverdi were central to musico-liturgical practice and might have impacted on the listener as worshipper and earwitness.[7] Their research would seem to confirm the thinking of contemporaneous Venetian architects, such as Jacopo Sansovino and fra Francesco Zorzi, as to the acoustic benefits of flat ceilings for the spoken voice (that of the priest or preacher), and of vaulted ceilings for musical performance (Howard and Moretti 2009, 6–7, 11). These aspects are clearly highly relevant to the *Soundspace* project, although here the movement of the procession will involve both interior and exterior acoustic spaces and the transition between them. Different perspectives from the two other acoustic recovery projects considered here help to interrogate findings as regards the reality – even the desirability – of acoustic clarity within the processional experience as the procession itself moved between different acoustic spaces and temporality through the lengthy duration of its performance, bringing together elements of Schafer's "hi-fi" and "lo-fi" environments for listening and communication.

The St Paul's Churchyard project, based at North Carolina University under the direction of John N. Wall, focuses on the sermon, though not delivered in the acoustic space of a flat, wooden ceiling within the nave of a church, but in the open-air environment of the churchyard of St Paul's cathedral as it was before the Great Fire of London of 1666. In this case, the challenge was to recover a "lost" acoustic space to analyse the sermon as experienced in performance, specifically John Donne's so-called Gunpowder Plot Sermon given in 1622 at St Paul's Cross (Wall 2014b).[8] DH tools were used to assess not only directionality, reach and audibility of sound in this context (Azevedo *et al.* 2013),[9] but also on its impact on the thousands who, according to contemporary accounts, filled the churchyard to hear the sermon.[10]

Of particular relevance to the *Soundspace* project is John Wall's research into the sermon as performance, as a dynamic event involving interaction between preacher and congregation, and how the unamplified human voice could capture and hold the audience's attention in an exterior acoustic space (Wall 2014a, 4).[11] A performance dynamic is similarly key to analysing the impact of processions on those present, in both indoor and outdoor spaces, likewise as to their duration and unfolding in time. Wall realised through the reconstruction of Donne's sermon that was performed with a semi-improvised structure occasioned by the intermittent sound of the cathedral bell as it chimed the quarter hours: at those moments the preacher would pause so as not to compete with the sound of the bell (Wall 2014a, 12–15). These brief interruptions meant that his vocal performance was heightened by a delivery of rhetorical impact, combined with his ability to engage with the congregation "emotionally as well as

cognitively" (Wall 2014b). The Paul's Cross project's experimentation with questions of timing and duration thus opened up new lines of inquiry as regards thinking of performance "in terms of time rather than space" that are particularly relevant to *Soundspace*'s objective relating to the significance of processional practice and the affective discourses inherent to it.[12]

Clarity of sound and intelligibility of words was key to the preacher's performance, and St Paul's churchyard provided a suitable acoustic space, but this combination would have been impossible throughout a moving procession. Indeed, for most people participating in or attending the procession, the sonic experience would have been distinctly lo-fi, with distance being variable and audibility usually short-lived. Only those positioned in close proximity of the sound-makers of the procession would have heard their words and musics with clarity in that hi-fi situation. Those at greater distance would nevertheless have been aware of the typology of sounds commonly associated with processional practice, and this would have been the overriding experience of most of those present. It is thus worth considering how and to what the extent the sounds of processions communicated and had an affective impact even at a distance and with low audibility.

The *Icons of Sound* project,[13] through its auralisation of the acoustic of the Hagia Sofia, posited interesting questions about the attainment and desirability of audibility in the context of buildings with exceptionally extended RTs, especially basilicas of vast size, such as the Hagia Sofia. The auralisation of the acoustic space of that building demonstrated that the relationship between sound and space was infinitely variable according to historical function and practice.[14] In the performance of Byzantine chant in the Hagia Sofia before the Fall of Constantinople in 1453, the highly reverberant acoustic resulted in other kinds of sonic effects in which clarity of text and/or music was eschewed in favour of a sustained, pulsating sound that was intrinsic to the acoustic characteristics of the building.[15] The acoustic complexity created by the reflection and scattering of sound through the presence of colonnades in aisles and galleries meant that the listener was enveloped in sonic resonance that, complemented by the shimmering of the gold mosaics and flickering light of candles, created, according to Pentcheva, a sense of spiritual transcendence that went beyond text and the specifics of melodic or harmonic detail. Pentcheva and Abel note that the interaction between harmonics and the sustained sonic energy, especially given the very slow absorption rate of the marble, created another kind of polyphony, a full, rich sound underpinned by the overlapping and dissolving of the notes of the chant melody (Pentcheva and Abel 2017, S340). Pentcheva argues that the musical style of Byzantine chant is attuned to its acoustic context so as to create an enveloping aesthetic experience in which "the texture of sound could at such times overwhelm the semantics" (Pentcheva 2021, 3). Stylistic features such as the use of melismas and intercalations – that is, the introduction of nonsematic or asematic sounds between the syllables of a word – further obfuscated meaning, and resulted in a blurring of the text in favour of "a sensually rich sound field" (Pentcheva and Abel 2017, S351). From this

perspective, textual unintelligibility was intrinsic to the performance of Byzantine chant, and attuned "participants' senses to the metaphysical" by creating the mood (*Stimmung*) of the space and making the performance of the liturgy propitious for an encounter with the divine (Pentcheva 2021, 2–3, 4, 7).

Conclusions

Sound is experienced in space, while acoustic space conditions sound production and the way sound is experienced by and resounds in the listener. Resonance in physical space creates embodied resonance, since sound "spreads in space, where it resounds while still resounding 'in me'" (Nancy 2007, 7, cited in Born 2013, 3). Sound, as part of a symbiotic or shared process of production and reception that takes place in acoustic space, is multi-faceted and participatory, whether experienced in public or private spaces. A sonic experience may be individual or shared: it may be contagious or it may reduce to silence; it may be familiar or it may be unknown, strange; it may be overwhelming or inspiring. Sound causes sensory reaction and usually results in putting cognitive and physical action into motion; in this sense, sound is quintessentially communicative, even when sonic clarity is not achieved.

The three studies briefly considered here address these issues through analysis – in different ways – enabled by spatial and acoustic recovery. They have opened up new lines of research that refine and problematise the historian's approach to the ways in which sound communicated, and what it might have signalled and informed in specific historical contexts. They have begun to address and contextualise issues arising from the dynamic role of sound in performance, and the extent to which resonance, at physical, sensorial and metaphorical levels, is key to understanding that role. For example, by focusing on audibility in the performance of ritual, it is clear that the vaulted spaces of cathedrals and churches also add resonance to musical performance (as recommended by Venetian Renaissance architects), in some instances at the expense of the clarity in the performance of polyphonic music.[16] The kind of sonic transcendence recovered by auralisation of the basilica of Hagia Sofia was clearly relevant to devotional and spiritual practice in early modern religious ritual.[17] In these projects, analysis of the relationship between space and sound presupposes the transferral of data from the resonant archive and the historical earwitness of primary sources to a digital environment capable of nuanced analysis involving temporal, spatial, kinetic, sensory and affective elements in order to generate potential new ways of thinking historically. *Soundspace* – especially, but not only through its recovery of the Valencian litany processions in their spatial and acoustic aspects – will confront directly questions of movement and liturgical choreography, of changing acoustic spaces, and of reach and audibility of sound and music in the processional context and what that might have signified for the acoustic community present during its performance. It is clear from earlier projects that, as regards interior spaces, assessment of changes in the absorption co-efficient occasioned by the use of

hangings, tapestries, carpets, vestments of heavy and highly absorbent materials is key to analysing audibility and clarity in speech and in multi-voiced music. Vaulted or flat rooves, smaller or more contained spaces such as side chapels, movement within and outside the choir or the transept will all need to be considered in the auralisation process. Exterior, open-air (i.e., roofless) spaces could – as in the case of St Paul's churchyard – offer a significant degree of reverberance afforded by the disposition of surrounding buildings or natural topography of the city. In the case of the procession, stations along the route, at which prayers were said and, on many occasions, polyphonic music sung, usually took place in entrances to ecclesiastical or civic buildings, that would have helped with the projection of sound. Even so, only those closest to the action – a privileged few – would have heard liturgical proceedings with any clarity, a situation exacerbated by the extended length of processions attended by possibly thousands of people.

A fundamental question arising from spatial and acoustic recovery in processions might relate, therefore, to the extent to which the whole performance of a procession, with the spectacle and symbolism of its paraphernalia, its highlighting of hierarchically significant spaces, and its use of intersensory stimuli of scent, illumination and sound, presupposed audibility, even at a lo-fi level. For example, polychoral singing offered a hi-fi experience for relatively few of those present, but would have been recognised, even at a distance and in lo-fi, as an aural signal of the solemnity of the ceremonial occasion. Similarly, the sound of bowed string-instruments, played by angel musicians (in many instances in Barcelona the blind *oracioners* of the city), heard fleetingly as a procession passed by, was nevertheless a transient evocation of the celestial music that signified a speedy and successful passage through purgatory thanks to prayer and charitable deeds (Knighton 2023). While in recent times, clarity, afforded by digital sound reproduction, and an unprecedented degree of audibility, achieved through headphones to the exclusion of all other sounds, have become an integral part of musical experience, these concerns would have been of less importance to the performative experience of historical processions, as the immanence of the *son-et-lumière* experience of hearing Byzantine chant sung in the highly resonant acoustic of the Hagia Sofia.

While it can be supposed that processional movement through emblematic spaces of the city heightened the multisensory impact of the procession as (im)material object and increased its capacity to create a sense of social connection, identity and collective memory, the *Soundspace* project aims to interrogate through digitally inflected research, how this dynamic worked in performance: physically, cognitively and affectively.

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Notes

1 Archival evidence is invariably patchy, often fragmentary, and, while sounds are indeed intimated in documentation – as, for example, payments to musicians or the presence of musical instruments in post-mortem inventories – records were not made with the sound historian in mind. Data extracted from the archive must always be contextualised through further and complementary research into the social groupings identified by Walraven.

2 Pentcheva defines auralisation as "the process of digitally imprinting the acoustics of a targeted space" on a performance, whether live (Pentcheva 2021, 8), or recorded anechoically.

3 See, for example, the Westminster Tournament Roll on https://www.npg.org.uk/collections/research/john-blanke-and-the-westminster-tournament-roll.

4 On the role of the trumpeter in Barcelonan civic ritual, see Kreitner (1992) and Raventós Friexa (2016).

5 The DECIMA project also resulted in the Hidden Florence Smartphone App that allows the user to experience Renaissance Florence through the eyes of contemporary characters while walking through the city. This App demonstrates that "a new way of understanding historical data" can be reached "through the embodied practice of movement and the kinaesthetic dialogue that is established between past and present" (Nevola and Rosenthal, 2016, 193–204).

6 Other projects of digital cartography and acoustic recovery and auralisation not considered in detail here include: *Hidden Florence* (2013), led by Fabrizio Nevola and David Rosenthal at the University of Exeter (hiddenflorence.org); *Paisajes Sonoros Históricos, c.1200–c.1800* (2015), created by Juan Ruiz Jiménez (historicalsoundscapes.com); *The Sound of 18th-Century Paris* (2017), led by Mylène Pardoen at the CNRS, Paris (archeoson.hypotheses.org); *Mapping Rome*, led by Erik Steiner at the University of Oregon, 2005–2020 (https://mappingrome.com/); *Okeghem 5.0 / 3D Saint Martin* of the CESR of the Université de Tours (https://ricercar.cesr.univtours.fr/ReViSMartin); and *Hearing Historic Scotland* (2020), led by James Cook (https://rke.abertay.ac.uk/en/publications/hearing-historic-scotland).

7 One of the unforeseen findings of the Venetian churches project, through experimentation in the different available performing spaces in St Mark's, relates to the performance space for Willaert's double-choir psalm-settings. These sounded most effective when performed in the two *pergole* or balconies on either side of the chancel, at the nave end, constructed by Jacopo Sansovino in 1540 and 1544 (Howard 2021, 143–146). These alterations to the fabric of the building meant that the doge, whose throne had been moved to a position just inside the chancel in 1535 would have been perfectly placed to hear this repertory, with its spatialised sound effects. The project demonstrated that liturgical choreography, the development of a specific musical idiom and the construction of specific performing spaces coincided in St Mark's in the 1530s and 40s in a deliberate and thought-out way (Howard 2021, 146).

8 The modelling of the churchyard was based on archaeology, old maps, street- and floorplans, paintings and engravings.The webpages for the St Paul's Cross project, based at Stanford University from 2010, can be consulted at https://vpcross.chass.ncsu.edu. A second project, not considered in detail here, develops further the notion of earwitness experience for those attending services within St Paul's Cathedral, see: https://vpcathedral.chass.ncsu.edu.

9 As Wall points out, while the preacher's voice heard in a field would have travelled only about 3 feet, the recovered acoustic reveals that in the churchyard it could have been heard quite

clearly up to about 140 feet from the speaker (Wall 2014a, 11). Other sounds intrinsic to the outdoor sonic environment (in particular, birdsong, and the sounds of barking dogs, horses' hooves and bells) also formed part of the auralisation (Wall 2014a, 3; 2014b, 12).

10 John Wall, in his study of the 17th-century sermon as performance, has pointed out that during this period it was obligatory to attend public sermons on Sundays, so that even though such figures may seem exaggerated, large crowds would certainly have gathered in this way (Wall 2014b, 1).

11 See, for example, a recreation of the 1622 sermon given by John Donne in St Paul's churchyard, the Cross Yard, in the visual model constructed by Joshua Stevens, rendered by Jordan Gray (Paul's Cross project website (https://vpcross.chass.ncsu.edu).

12 Izaak Walton, in his 1658 *Life of John Donne*, was among contemporary writers to describe the emotional impact of Donne's preaching, recalling how his delivery of a sermon preached not long after his wife's death "did so work upon the affections of his hearers, as melted and moulded them into companionable sadness" (cited in Wall 2014b).

13 *The Icons of Sound: Hagia Sofia Reimagined* project, led by Bissara Pentcheva, was begun in 2008 and completed in 2018; acoustic measurement took place in 2010. The project's web page can be visited at: https://live.stanford.edu/content/icons-sound.

14 Since 2020, when the Hagia Sofia again became a mosque, the research for the *Icons of Sound* project has taken on greater significance. As the acoustician for the project, Jonathan Abel, has pointed out: "digital technology becomes our only means to experience the fantastic building as an instrument of the human voice".

15 The RT of the interior of the Hagia Sofia is 10 to 12 seconds; on the convolution process used to imprint the impulse response (from the popping of a balloon) being modelled onto an input audio signal, see: Pentcheva and Abel 2017, S344.

16 It is notable that early vocal polyphony, for example, is generally recorded in reverberant spaces to produce what might be termed the "cathedral sound". This is one of the aspects explored further in James Cook's recovery of the acoustic of the royal chapel of Linlithgow Palace, and the auralisation of polyphonic repertory from the time of James IV of Scotland (1488–1513) for the "Hearing Historic Scotland" project.

17 This aspect calls for much further investigation and will form part of the third line of research of the *Soundspace* project: the identification of discourses relating to different sounds and musics and their intersensorial and affective impact.

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Chapter 13

Estimation of speech intelligibility in the past: Learning from Benjamin Franklin's experiment

Braxton Boren

Abstract

Among prominent acoustic sound sources in human history, one of the most socially significant was the practice of oration to large crowds before the invention of amplification. Such orations occur in military, religious and political settings, but they are not reported equally often throughout different nations and cultures. Traditionalist historians have tended to take such reports at face value, while sceptical historians tend to conclude that many or all such accounts were largely fabricated. However, even though the original sounds were not recorded acoustically, geometric clues, such as reported crowd size, measured physical lengths, and the speaker's training in elocution can allow a present-day analysis of such accounts. After inputting our best estimates of effective levels of the speaker and the ambient noise, computer simulations can map the sound across large crowds, allowing first-order estimates of the number of people who could have reasonably heard the speaker. For this type of investigation, the Speech Transmission Index (STI) is the best current tool for analysis as it includes both the speaker's level and spectrum, as well as background noise and sound reflections. It is argued that more consensus is needed across the archaeoacoustics community on the best practices for thresholds, noise levels and crowd densities in such studies. Some discussion is given to alternative STI-like metrics that could be adapted for past languages, dialects and accents and their effect on human speech intelligibility.

Keywords: archaeoacoustics, vocal acoustics, acoustic simulation, geometrical acoustics, outdoor sound propagation

Equations or paragraphs?

My father was a high school history teacher, and he inculcated his children with knowledge and love of history (whether or not we showed any particular aptitude for it). He had never learned much mathematics, and he had gravitated toward history because he loved reading and stories, of which the study of history provides in almost limitless quantities. As a child I loved the direct connection to the past that history provided, but the textbooks we used were so far removed from primary sources that it was often unclear who had determined the things we were to learn. Conversely, mathematics rarely provided any sort of relatable motivation to learn it, but there was a sense of immediate connection to the "primary sources" of the field – when you complete a geometric proof, you don't need to have read Euclid's Elements to get a sense of fundamental connection to the world of physical space around you.

At university I studied history, physics, musicology and music theory, never dreaming that all of these could be woven into a single line of investigation. By a fluke I was selected to study for a research Master's in the United Kingdom, on a project that required both acoustic computer modelling of musically significant Venetian churches in the 1600s as well as a familiarity with Renaissance music and theory. Though I had been bouncing from one field to another, somehow, these disparate areas all came together, and I felt I was able to make a contribution to our understanding of history in a way that I never could have had I merely studied history. Most of the important primary source materials had already been discovered, but application of quantitive modelling could provide new empirical evidence to the interpretative conversation.

Coming into a PhD programme, I did basic acoustic research for the first year, mainly helping with projects my supervisor was already working on. Then one fateful day I sprung on her the idea of doing something somewhat different: examining the intelligible range of the human voice through history. This chapter will give some background onto how and why I came upon this topic, what has been done so far, and where such research may be headed in the future. Throughout we can see that, just as the History of Science is a growing topic of academic study, so also the Science of History may itself become a necessary complement to the traditional ways of studying the past.

Benjamin Franklin, the first archaeoacoustician

In one of my father's high school American History courses, he had forced me (but notably not the rest of the class) to read Benjamin Franklin's autobiography, supposedly to see whether other students would like it in the future. Years later in graduate school, as I had started becoming interested in the role of sound in history, my father reminded me of a passage in the book where Franklin described his first encounter with the Methodist Anglican revivalist preacher George Whitefield.

Whitefield had attracted large crowds in London throughout the summer of 1739, and Franklin, as the publisher of the Pennsylvania Gazette, had published the accounts

of these gatherings from across the Atlantic when the first came to him. However, as the crowd estimates became larger and larger (from 50,000 to 80,000 depending on the site), Franklin the scientist was sceptical and refused to publish such numbers. However, Franklin did not end with scepticism – when Whitefield visited Philadelphia in November 1739, Franklin undertook perhaps one of the earliest systematic investigations of the range of the human voice, which he described as follows:

> [Whitefield] had a loud and clear Voice, and articulated his Words and Sentences so perfectly that he might be heard and understood at a great Distance, especially as his Auditories, however numerous, observ'd the most exact Silence. He preach'd one Evening from the Top of the Court House Steps, which are in the middle of Market Street, and on the West Side of Second Street which crosses it at right angles. Both Streets were fill'd with his Hearers to a considerable Distance. Being among the hindmost in Market Street, I had the Curiosity to learn how far he could be heard, by retiring backwards down the Street towards the River; and I found his Voice distinct till I came near Front Street, when some Noise in that Street, obscur'd it. Imagining then a Semicircle, of which my Distance should be the Radius, and that it were fill'd with Auditors, to each of whom I allow'd two square feet, I computed that he might well be heard by more than Thirty Thousand. This reconcil'd me to the Newspaper Accounts of his having preach'd to 25,000 People in the Fields, and to the ancient Histories of Generals haranguing whole Armies, of which I had sometimes doubted. (Franklin 1996, 84–85)

I would like to first go over the way in which this account can be used to update Franklin's experiment and provide an estimate using the same assumptions he was working with. Afterwards, I want to focus on some major themes that emerge from Franklin's approach and consider how these can still be seen as the foundation for understanding the role of speech in history in modern archaeoacoustic research.

From linear measurement to sound pressure level

Modern research into acoustics and psychoacoustics has to contend with the varied response of the human auditory system to sound at a wide range of sound pressure levels (SPLs). Since different microphones will produce different amounts of voltage in response to the same stimuli, all equipment must be precisely calibrated to generate the same dB level in response to the same amount of sound pressure (ANSI 1983, 3). Since this chain of calibration requires the existence of specialised laboratory equipment, there is no calibrated SPL data for sound sources prior to the 20th century, when the decibel was developed at Bell Laboratories. As a result, the question of intelligibility to a large crowd is difficult to answer or even to estimate for many historical accounts.

Though Franklin did not have an SPL meter, he did record a linear distance of intelligibility of about 100 m (Fig. 13.1). Since sound propagation through air is well understood, we can account for the inverse square propagation loss of intensity and model air absorption based estimated temperature and humidity. This allows us to guess pretty accurately the level of a sound source, if we know the level at the sound receiver.

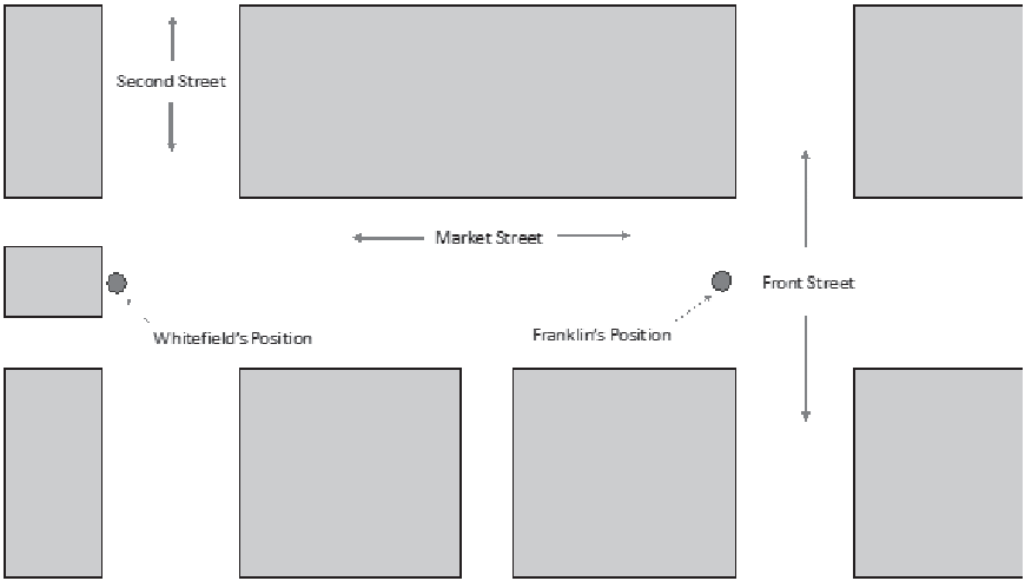


Fig. 13.1: Diagram of Whitefield's and Franklin's Positions in Philadelphia. Author's elaboration.

Of course, Franklin did not provide an SPL value at his position either; he merely recorded it as the point at which Whitefield's voice ceased to be intelligibile. But based on what we know about speech intelligibility, it will also be possible to estimate the source level using the Speech Transmission Index (STI). The STI is an index from 0–1, which consists of a weighted average of the total modulation of sinusoids at frequencies throughout the range of human hearing (IEC 2020, 46). Because of this, it accounts for the deleterious effects of both late sound reflections as well as noise on speech intelligibility.

In such a model other assumptions will have to be made, including the background noise at Franklin's position and that Franklin had no incidence of hearing loss. But within these constraints STI can be used as a proxy for Whitefield's on-axis time-averaged SPL at a distance of 1 m.

Franklin's exact position

If we take Franklin's reported density (2 square feet per person) and crowd estimate (30,000) directly, it would give an area of

$$30{,}000 \text{ persons} = \frac{A}{2\,\frac{ft^2}{person}}$$

giving a value of 60,000 square feet, or about 5,575 square metres. Assuming this as the area of a semicircle, this would yield a linear distance of

$$r = \sqrt{\frac{2(5575)}{\pi}} \approx 60 \text{ m}$$

which is about half the measured value from the old courthouse to Front Street, where Franklin records his position. Some have asserted that Franklin misremembered and actually meant the small alley halfway to Front Street (Liberman 2005), but this seems unlikely for two reasons: first, Franklin lived in Philadelphia for most of his life and was not likely to confuse one of its largest streets with a small alley (Letitia Court). Second, Franklin later mentions a similar thought experiment in *Poor Richard Improved* (1749) where he specifically mentions that a voice may be heard at a distance of 100 yards, suggesting that he remembered recording a value at least this large. Though the linear distance of 121 m to Front Street, if using Franklin's density estimate, would yield a much larger crowd estimate than 30,000, it seems more likely that Franklin calculated the higher number but reported the lower number, in keeping with his self-professed habit of advancing slowly and never professing anything that might be disputed (Boren 2014, 45).

The second question regards the noise in Front Street that Franklin reported, since this will bear significantly on the calculation of the STI. A separate analysis (Boren and Roginska 2012, 1–11) used the geometry of the site to predict sound diffraction around the corners from noise sources not visible directly at Franklin's position. This showed that at the frequency ranges most significant to speech intelligibility, Franklin would have had to have been quite close to Front Street itself (within 5–10 feet) to have heard significant masking noise, which was probably from carriages or the coffee house at that corner.

Modelling colonial Philadelphia

Since the courthouse where Whitefield was speaking no longer exists, a computer model was constructed to simulate the acoustic path from Whitefield's position to Franklin's position in the middle of Market Street, 6 feet from the edge of Front Street. The primary material composition of the area was determined through historical and archaeological research. The earliest map of the city that includes scaled drawings of buildings and streets in the Clarkson-Biddle map of 1762, which was used to trace the geometry of the area.

Most of the nearby buildings during Franklin's experiment no longer exist. As a result, the geometry was extracted from the Clarkson-Biddle map and other period drawings. The Clarkson-Biddle map describes the houses of the city as being made of brick. While most of these buildings no longer exist, the brick exterior of nearby Christ Church was completed during the 1730s and provides a good basis for the sizes of bricks that would have been used in the other buildings. This brick, along with glass windows and wooden doors visible in many drawings, accounts for most of the reflective surfaces on the buildings on Market Street.

The material composition of Market Street was made of gravel (Boren 2012), so measured absorption coefficients for gravel were incorporated into the model for the ground reflection from Whitefield's position to Franklin's. The Market Street area was modelled geometrically in AutoCAD first by tracing the Clarkson-Biddle map. This was scaled to the width of Market Street itself, which is 100 feet wide. Heights

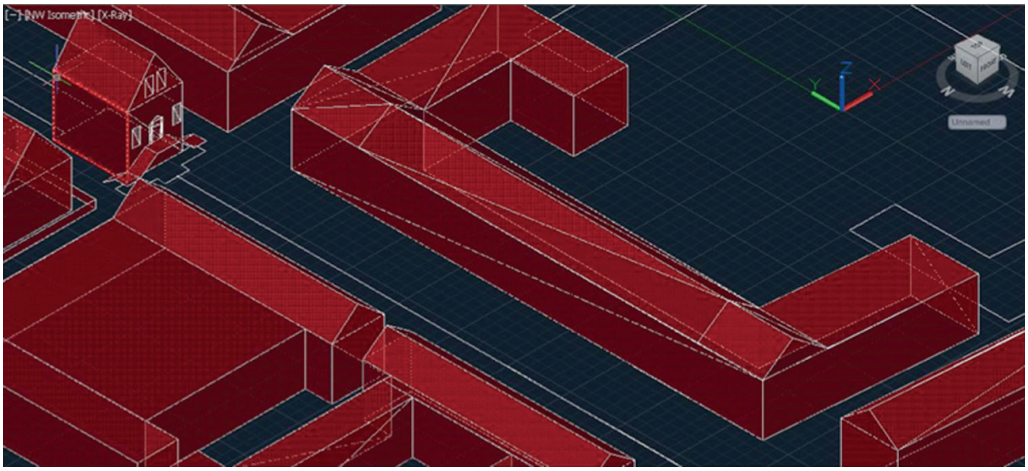


Fig. 13.2: CAD model of Market Street area in 1739. Author's elaboration.

were estimated by reference to period drawings. Based on these estimates, the trace was extruded into a final CAD model (Fig. 13.2) that could be imported as a DFX into CATT-Acoustic v.9.0/TUCT, a geometrical acoustic modelling programme based on cone-tracing algorithms (Dalenback 1996, 899–909).

A virtual source was placed at Whitefield's position with an IEC male standard spectrum, facing outward. A separate study (Boren and Roginska 2013a, 1–10) examined the role of different vocal production techniques on directivity patterns and determined that existing voice directivity datasets were sufficient for this simulation. As a result, the CATT standard male spoken voice directivity pattern was applied to the virtual source. A receiver representing Franklin was positioned in the centre of Market Street, 1.5 m from the edge of Front Street as previously discussed. Franklin's position was 1.75 m above the ground level, corresponding to his known height. Whitefield was also modeled at 1.75 m above the courthouse steps, about 120 m away from Franklin's position.

While outdoor acoustics tends to be simpler than the acoustics of fully enclosed spaces, the "urban canyon" from the courthouse to Front Street still contained several early reflections that would improve the intelligibility of Whitefield's voice. In a free field (i.e., a space with no reflecting surfaces), propagation loss is often approximated as "6 dB of loss per doubling of distance from the source" due to the inverse-square spreading of sound intensity over larger and larger area. Compared to a free-field model the Market Street model was about 7 dB louder at all distances, owing largely to a strong early reflection off the wooden doors of the courthouse. The absorption coefficients for all surfaces used in the model were based on measured values in the CATT database, shown below in Table 13.1. Since no measured scattering coefficient values were available for the surfaces used, scattering coefficients were based on CATT's recommended default surface scattering values, which assign a mid-frequency

Table 13.1: Absorption coefficients for surfaces in CATT Model.

Freq. (Hz) *Surface*	*63*	*125*	*250*	*500*	*1000*	*2000*	*4000*
Brick, 60 mm	0.14	0.14	0.28	0.45	0.90	0.45	0.65
Gravel	0.25	0.25	0.60	0.65	0.70	0.75	0.80
Audience Area	0.60	0.60	0.74	0.88	0.96	0.93	0.85
Windows	0.35	0.35	0.25	0.18	0.12	0.07	0.04
Wood	0.14	0.14	0.10	0.06	0.08	0.10	0.10

scattering coefficient of 0.1 to all surfaces, scaled for higher scattering at higher frequencies and vice-versa.

Background noise estimation

A review of historical sources (Boren and Roginska 2012, 6) concluded that the two most likely candidates for a noise source on Front Street were either human conversation around the corner or a horse and carriage moving down the street. Both sources were measured using an NTI XL2 Class 1 Sound Level Meter. The time-averaged levels for both of these sources were found to be very similar: measurements of conversational speech at 1 m in a dry acoustic interior recording studio (Boren and Roginska 2013b, 1–7) matched closely the International Electrotechnical Commission's (IEC) standard of 59.5 dBA for normal speech. Several different horses and carriages were measured at approximately 1 m on a gravel path by following behind the carriages with an SPL meter. The time-averaged L_{eq} of these measurements ranged from 60-63 dBA. The largest measured LA_{eq} values were used in the model and are listed in Table 13.1.

Noise sources were modelled as "near" and "far", experiencing respective attenuation of 10 dB and 15 dB, depending on their distance to Franklin's position. This yielded background noise levels of about 50 and 45 dBA, depending on the exact octave-band results used from Table 13.2. Because the carriage contained more energy in the most important octave bands for the STI (2-4 kHz), this virtual source yielded a louder "virtual Whitefield".

Table 13.2: A-weighted L_{eq} values for noise sources used in model.

Frequency (Hz)	*IEC Normal Vocal Effort*	*Carriage Noise*
125	51	57
250	57	54
500	60	58
1000	54	60
2000	49	56
4000	44	56
8000	39	51

Atmospheric conditions

The exact temperature during Whitefield's sermon is not known exactly. Whitefield recorded preaching from the courthouse steps on the 8, 9 and 10 November 1739 in his first trip to Philadelphia. Franklin recorded an additional sermon on the

following Sunday, 11 November. The US National Climatic Data Center does not possess any recorded temperature data for Philadelphia prior to 1767. Peter Kalm, the Scandinavian botanist, travelled throughout the American colonies 10 years later and spent time in Philadelphia during November of 1749. During this time, he recorded the morning and afternoon temperatures using the newly developed Celsius thermometer (Boren 2014, 66). His recorded temperatures give an average of about 5°C, similar to the November temperature in Philadelphia today. While this is not determinative of the weather 10 years prior, this clue was used to base the temperature and humidity data in the model on current normal values for Philadelphia in November: 4.5°C and 50% humidity, respectively.

Whitefield's simulated vocal level

The computer model was used to simulate the minimum SPL on-axis 1 m from Whitefield's mouth that would be necessary to generate a minimal value of the STI based on "near" and "far" background noise sources. The value of the STI that defines the threshold of intelligibility varies among different people: since STI is a classifier of the external acoustic system to the listener, actual subjective intelligibility will depend on the listener's hearing perception. An STI of 0.3 is usually seen as the value at which intelligibility becomes "bad" (IEC 2020, 72). Because of this, STI values from 0.2 (corresponding to better than average hearing) to 0.4 (corresponding to below average hearing) were simulated. There is no evidence that Franklin had hearing loss, and he was still relatively young (33) at the time. Because of this, the "normal" threshold of 0.3 is probably the best metric of his hearing. However, the higher and lower values are included as well, since this variable can later be included in simulations of Whitefield's crowds in London by using the minimum STI (instead of the maximum intelligible distance) to estimate how many people with identical hearing (i.e., how many Benjamin Franklins) could have heard Whitefield speak, as Franklin's original experiment did.

Since the noise level was slightly lower for the simulated conversation noise, simulations that used this background noise estimated a lower vocal level for Whitefield, from 86-93 dBA for a close noise source, and from 81-88 dBA for a far noise source. When assuming carriage noise, the simulation estimated Whitefield's vocal level from 90-99 dBA for a close noise source, and from 85-95 dBA for a far noise source.

The only acoustical factor not accounted for by a geometric model is atmospheric refraction. This may occur due to changes in wave velocity throughout a medium due either to wind or varying temperature. Wind data are of course not obtainable for the day in question but based on both Franklin's and Whitefield's references to the quiet of the scene, it seems reasonable to assume the day was not particularly blustery, especially since Whitefield's journals often mentioned the wind if it was an acoustical factor. Temperature gradient data are likewise unavailable, but under normal conditions the temperature is either steady or is in a "lapse" state, in which air gets colder with increasing elevation. This causes sound waves to bend

upward and attenuate faster, and this effect would have been increased due to Whitefield's elevated position. This means that adding any refraction effects into the model would only increase the simulated SPL for Whitefield's voice, which already approaches or exceeds the existing maximum measured values of vocal SPL discussed in Boren and Roginska (2013b, 5). The opposite effect, a temperature inversion that carries sound farther than normal, is rare and occurs chiefly at night or early morning, or sometimes after a rainstorm. Since there is no evidence of a temperature inversion, the total refraction effects on Franklin's experiment may be presumed to be minimal.

It is known that training (Mendes *et al.* 2003, 536) and youth (Kent and Rosenbeck 1987, 376) are both important factors for predicting maximum vocal output, and Whitefield had both in his favour as he spoke for hours per day though only 24 years old at the time. While simulated SPL values greater than those verified experimentally should be viewed with caution, the computer model predicts that Whitefield's average vocal level during Franklin's experiment could have reached 90 dBA on-axis at 1 m, on par with the greatest values recorded for trained vocalists (Boren and Roginska 2013b, 5). This suggests that Whitefield's reputation was well-deserved, as he was likely speaking near the long-term limits of the human voice.

Modelling Whitefield's sites in London

Whitefield's two most common sites to preach outdoors in London were the Moorfields, near present-day Finsbury Circus, and Kennington Common (now Kennington Park). Whitefield preached to multiple crowds at these sites estimated from 10,000 to 20,000, with the largest estimates of 50,000 for the Moorfields and 60,000 at Kennington Common. In addition, the largest crowd ever reported for his preaching was at Mayfair, near Hyde Park Corner. This was not a common location for Whitefield, but due to the extreme reported crowd size it was also simulated along with the two other more common sites.

Moorfields

Because of Whitefield's specific attachment to this area, there is also more specific historical data available as to his position there from Whitefield's journals and biographies (see Tyerman 1877, 267–271, 554–558). The Moorfields was divided into three portions, designated as the lower, middle and upper Moorfields. The lower Moorfields (today Finsbury Circus) was the largest portion, with more trees and greenery than the other two. Based on analysis of different accounts of Whitefield's preaching, it was determined that Whitefield most likely preached from the wall separating the upper and middle Moorfields.

The Moorfields was modelled geometrically using a Sketchup rendering of the ground area based on existing GPS data. Because the area of Whitefield's preaching has since been developed, no elevation data was available except for the heights of the buildings present there today. To check the topography, points were selected from

streets around the area on each side, which showed that the area was quite flat and lacked any significant changes in elevation. This was confirmed by an in-person visit to Finsbury Circus as it exists today.

The tree lines in the Moorfields were modelled based on those shown in John Rocque's 1746 map of London, with an assumed height of 5 m. Since unnecessary planes can reduce the accuracy of a geometrical acoustical model and are not generally recommended unless they are very close to an acoustic source, the tree lines were simplified as planes that were 10% acoustically absorbent and 30% acoustically transparent with a large mid-frequency scattering coefficient of 0.5, allowing half of incident sound through and providing few specular reflections. As this was not an important London neighborhood, few period prints or drawings depict the exact arrangement of the bordering areas next to the Moorfields. The buildings lining the edges of the Moorfields were modelled three stories (about 10 m) tall with a sturdy wood construction on their facades with a low mid-frequency scattering coefficient of 0.1. It will be noted, however, that the precise reflective characteristics of these buildings only become acoustically relevant if it is predicted that the edges of the open ground could hear Whitefield clearly. The audience occupying the entire area of the site was modelled based on an average density of two persons per square metre. The question of the correct density will be addressed later, but as this is the densest audience value for which measured absorption data were available, it was not possible to use a denser value at any rate. In addition, since humans are more efficient absorbers at low densities, the extra Sabine absorption per unit area will not increase greatly as density is increased beyond a high amount. In addition, since these environments are reasonably free field and lack reverberation effects, even a slight change in crowd absorption should not significantly affect the STI calculations, which depend much more on the direct sound level and background noise in these cases.

Kennington Common

Kennington Common was unfortunately not included in Rocque's map of the city, but another map of the Common and surrounding area showed that the common occupied essentially the same space as the park does today. This makes Kennington Park the least-developed and best-preserved of the sites being modelled.

As with Moorfields, Kennington was modelled in Sketchup based on the existing GPS data. It is the most topographically varied of the three London sites, containing a slight hillock towards its centre. This is still a very slight variation from a perfectly flat plain, however. Based on period images and descriptions, the Common did not have buildings close to it that could act as potential boundary reflectors. Since the area was a Common in 1739 (as opposed to a park today), Kennington would have been used for livestock grazing and would have most likely lacked trees, unlike its current layout. The extant map of Kennington Common also does not indicate any trees, and thus none were included in the Sketchup model. The lack of trees or

buildings makes Kennington the closest to a free field of the three sites investigated, containing also the most raw area for fitting in a large crowd independent of acoustical factors.

Mayfair

On 1 June 1739, Whitefield reported that he

> preached in the evening, at a place called Mayfair, near Hyde Park Corner. The congregation, I believe, consisted of near eighty thousand people. It was by far the largest I ever preached to yet. In the time of my prayer there was a little noise, but they kept a deep silence during my whole discourse. A high and very commodious scaffold was erected for me to stand upon, and though I was weak in myself, yet God strengthened me to speak so loud, that most could hear, and so powerfully, that most, I believe, could feel. (Boren 2016, 179)

Since this is the only time Whitefield preached at this location, it is possible that he was influenced by the different visual layout of the space and overestimated the crowd size, whereas presumably he and others could give more studied estimates for spaces where they had seen many different crowds on different days. However, his insistence, along with the reference to a constructed scaffold, seems to indicate that the sermon was a special occasion and that a large crowd may have gathered. As a result, the Mayfair area was also modelled in Sketchup based on the outline in Rocque's map.

London crowd simulations

To test the range of Whitefield's voice, each of the three sites was simulated in an acoustic computer model. Each simulation was carried out under 'base' conditions: 11.5°C, 50% humidity, with Whitefield's orientation directly forward (0° elevation). After the base conditions had been evaluated, these three variables were altered systematically to predict any differential changes that these factors might have had on the previous simulations. In the Mayfair model, where Whitefield mentioned preaching from a scaffold, additional simulations also investigated the role of added height to his maximum crowd size.

Based on these simulations, Whitefield's preaching was simulated at each of the sites at a level from 85–90 dBA, with crowd noise levels from 50–55 dBA. For each simulation, the Minimally Intelligible Area (MIA) was calculated, which was based on the STI value in the Phildelphia model to predict the vocal level used: for instance, if an STI of 0.3 would predict a vocal level of 90 dBA, then the 90 dBA simulation's MIA included all area for which the STI was at least 0.3. This is in keeping with Franklin's experiment, as it maintains the connection between Franklin's perception of speech intelligibility in the models of both Philadelphia and London. The crowd density was assumed to be two persons per m^2, lower than Franklin's estimate based on newer research on crowd estimation (Watson and Yip 2011, 105–106). As a result, the crowd estimate is simply the MIA multiplied by two. The larger values, based on a vocal level of 90 dBA, are shown below in Table 13.3.

Since the 50 dBA condition can be considered somewhat optimistic for a large crowd, we can see that even under these optimistic acoustic conditions that Whitefield could not be heard by 60,000, let alone 80,000. However, the estimates of 50,000 could be plausible when his voice was at its best, and the crowd was relatively quiet. Finally, this model does not account for all the heads and torsos in the crowd that might have blocked his voice, which would reduce the total number who could hear him if they were shorter than those in front. In such a case the higher elevation of a scaffold could make a bigger difference in total intelligible crowd size.

Table 13.3: Final intelligible crowd estimates for London sites, vocal L_{eq} = 90 dBA.

Location	*50 dBA Noise*	*55 dBA Noise*
Moorfields	50,200	20,600
Kennington	54,600	19,200
Mayfair	55,400	20,400

While such an optimistic model could be more questionable, like Franklin we can also step back from the most extreme possibility and contextualise this prediction: most of Whitefield's crowds through his lifetime were reported as 20,000 or fewer, and under optimistic assumptions those numbers do seem acoustically plausible.

A broader view of Franklin's experiment

Having gotten into the weeds of the specifics of Franklin's experiment, I would like to step back and notice a few things about how he framed the problem and how it might influence our understanding of this same question today.

The generality of the problem

Franklin explicitly mentioned that his experiment was motivated not so much by the specific situation he had doubted (i.e., Whitefield's London crowds) but rather all such large gatherings in the past, notably the many general's harangues included in classical history which he had encountered. Whereas analysis of a specific enclosed musical space may be highly dependent on the characteristics of both the space and the musical content, the open-air oration is an acoustic system with fewer free variables.[1] Franklin recognises that in Whitefield's live preaching he has not just a current celebrity but also a test subject who may serve as a proxy for many great orators of the past whose voices are no longer available, and that the data from this speech also bears on his assessment of ancient speeches.

The simplicity of the problem

Franklin also mentions that the sermons Whitefield repeated often on his travels were

> so improv'd by frequency Repetitions, that every Accent, every Emphasis, every Modulation of the Voice, was so perfectly well turn'd and well placed, that without being interested in the Subject, one could not help being pleas'd with the Discourse, a Pleasure of much the same kind with that received from an excellent Piece of Musick. (Boren 2016, 169)

Though Whitefield's voice was known for being exceptionally loud, Franklin recognises that absolute sound pressure level (SPL) is not the only relevant factor in speech intelligibility, and his distance-based metric for intelligibility implicitly records not only the level but also the enunciation of particular consonants, in a similar way to the STI (IEC 2020, 21–22). So, in addition to an individual speaker's SPL, there may be some additional intelligibility for those trained in precise elocution. Since any simulation of a past orator lacks recordings or SPL measurements, it is probably wisest to try to combine these two factors into a single quantitative estimate, as the STI does.

The interdisciplinarity of the problem

While modern scholars debating the historicity of such speeches rely only on textual evidence (with perhaps a vague hand-waving allusion to acoustics) (Hansen 1993, 169; Pritchet 1994, 76). Franklin's inherent curiosity and interdisciplinarity allowed him to seamlessly transition from narrative to equation in the same argument. In the same way, anyone drawn to the study of archaeoacoustics must lean into their interdisciplinarity rather than pretending to be perfectly siloed in the sciences or humanities. Presumably, if we had given ourselves wholly to quantitative science or to traditional history, we could have gone farther in a single direction at the expense of the other. But, instead, we find ourselves drawn to both fields: we are the utility infielders, the red mages, the superposition of two vectors (choose your metaphor). This interdisciplinarity has its weaknesses as well as its strengths, and we ought to be honest with ourselves about both.

The uncertainty of the problem

Finally, though Franklin's experiment has a crowd density value that is much too high, he himself mollifies this error by underreporting his final prediction for Whitefield's intelligible crowd size. Though the semicircular radiation pattern Franklin used in his model would (with his high density estimate) predict a crowd of over 100,000, he himself only reported "more than Thirty Thousand". While this may seem strange to modern readers, it is very much in keeping with Franklin's own self-professed "Habit of expressing my self in Terms of modest Diffidence, never using when I advance any thing that may possibly be disputed" (1996, 13). While Franklin's data provide an invaluable quantitative reference in a field full of speculation, there was still a large margin of error on any specific crowd estimation (and in fact modern photographic crowd estimation still has a large margin of error, though obviously less so than Franklin's experiment (Watson and Yip 2011, 105).

Attempting to adopt Franklin's posture of epistemic humility, my simulation work to recreate Franklin's experiment produced many specific quantitative estimates of intelligible crowd sizes under many different scenarios, some optimistic and others pessimistic. While any particular simulation was theoretically defensible under its own assumptions about vocal level, crowd noise, crowd density, etc., it was the broader

picture provided by a range of simulations that was most helpful for historical analysis. It is difficult to achieve high precision in a single estimate, but the simulation with the most optimistic plausible values (intelligible crowd size of about 55,000 with STI ≥ 0.3) can serve as an upper bound on reasonable speculation, meaning that the actual crowd was almost certainly not so large. We can be most confident that the largest crowds attributed to Whitefield (from 60,000 to 80,000) do not seem to be acoustically possible under any set of plausible assumptions.

Applications of Franklin's model

Whitefield was a unique example because based on Franklin's recorded experiment Whitefield's on-axis SPL was probably close to 90 dBA, which is approximately the highest value recorded for trained vocalists (Boren 2016, 188). As a result, he is a good proxy for the largest intelligible crowd that could have gathered in the era before electronic amplification. For a densely packed crowd that also kept very quiet (as Franklin attested Whitefield's listeners often did), a value of 30,000 does seem plausible at least over portions of the speech, depending on the background noise profile. However, on other occasions opponents of Whitefield purposefully disrupted his sermons with noise (Tyerman 1877, 116), which would have greatly reduced the range of his sermon. Just raising the background noise level from 50 to 55 dBA reduces the intelligible area by more than 50%. Geometrically, this is the result of the crowd's area increasing as the square of its radius: the last 5 dB of additional signal-to-noise ratio increases the radius a little, but the additional area around the speaker is increased greatly. In the same way, any slight reduction in speaker level or crowd noise quickly destroys any possibility of intelligibility for a large portion of the crowd's area.

As Franklin's usage shows, it may be most useful to zoom out from the specific example of Whitefield's sermons and see what this sort of model can tell us about other significant speeches and orators in history for whom we do not have Franklin's data to extrapolate an effective SPL. I have published other studies of battlefield speeches that adapt this model to also account for specifics of these speeches, including the different formations of soldiers at attention, the presence of cavalry, and the greater noise present during battle. In some cases (such as Caesar's reported harangue at Pharsalos (Boren 2018, 10) cannot be possible even under the most optimistic acoustic scenarios. Others (such as post-battle speeches when the army is gathered more densely) may have been possible under certain assumptions about the speaker's voice and the background noise level of the audience. In the case of Elizabeth I, the old "STI female" standard was used (Boren 2019, 5), which was found to provide slightly worse intelligibility in a free-field oratory setting, contrary to the widespread belief that female voices were generally easier to understand (IEC 2011, 42). The IEC may also agree, as the most recent STI standard has removed the STI female standard entirely (IEC 2020, 7).

Areas in need of consensus

When I began working in this area in 2011, I was the only person I knew interested in this topic, apart from some early analysis of intelligibility in reverberant spaces (Katz and Wetherill 2005, 2196; Bonsi *et al.* 2013, 50–51). In the past five years, however, more researchers have been drawn to similar historical orations, and their models have often differed from my own in some significant ways. I will highlight a few dimensions of such studies where I believe the archaeoacoustics community needs to reach more consensus about the best practices for future speech intelligibility modelling. This can be seen as regards to calculation metric and crowd density.

Calculation metric

While D50 or C50 might be appropriate in a reverberant space with no noise, a more generalised metric will be better as such studies are often concerned with noise or reverberation. Witt and Primeau (2018, 84) do not use the STI at all, but instead use only broad-spectrum signal-to-noise ratio as a proxy for the Speech Intelligibility Index (SII). However, the SII seems poorly targeted for general archaeoacoustic research as it does not account as well for reverberation effects as does the STI (Kates and Arehart 2005, 2224). One of the strengths of the SII, namely that it allows the specification of a listener's hearing threshold, is not as useful for archaeoacoustic work since such data is unknown for the past – if anything, we can usually assume that listeners in the past would have had less noise-induced hearing loss than modern listeners.

A recent study by Kopij and Pilch (2019, 340–349) also uses the STI, though as will be seen, differs in some other assumptions about the modelling process. However, it is my opinion that the STI is the best metric to account for a variety of settings (indoor and outdoor) and noise conditions that may be present. I believe the archaeoacoustics community should unite around the STI in such situations so that different simulations and settings can be more easily compared across historical periods. When I was setting up my simulations, I informally polled many professional researchers and acousticians about what the threshold of intelligibility should be within the STI and frustratingly received a large range of opinion: some told me to not accept anything below 0.5, while others thought values as low as 0.1 should be used. I split the difference, using 0.3 as the minimal threshold of intelligibility, which divides "Bad" and "Poor" intelligibility in the IEC standard (IEC 2020, 73). However, Kopij and Pilch use a higher threshold of 0.45, which obviously lowers the simulated crowd size in all cases. Some standardised value should also be agreed upon here to compare like to like across different simulations.

Noise levels

While the study of Whitefield above assumed background noise levels between 50–55 dBA, the work by Witt and Primeau (2018, 81) uses a much lower value of 20.7 dBA. A somewhat lower value makes sense because their model of Chaco Canyon is less

densely populated, but this value may be still too low if any environmental noise from wind or human movement is considered. For comparison, Bo *et al.* measured background noise for the Greek amphitheatre at Tyndaris at 34 dBA while the site was quiet and unoccupied (2016, 4).

Kopij and Pilch also use a range of values, from 36 to 55 dBA (2019, 345), more like the simulations of Whitefield's crowds above. However, even for any specific dBA level, there is an assumed spectrum of octave-band noise levels that could lead to somewhat different STI predictions for the same overall dBA value. This leads me to argue that there is a need for a consensus from the archaeoacoustics community on both overall levels and target spectra for at least the following four case scenarios:

1. Quiet, empty outdoor settings, no wind
2. Empty outdoor settings with some wind noise
3. Crowd gathered, exceptionally quiet
4. Crowd gathered, with some crowd noise from low whispers or movement

Presumably any crowd noise will be approximately equal to wind noise, and a loud crowd will largely negate the need for any simulations as intelligibility will be very poor across most of the relevant surface area.

Crowd density

Franklin's original experiment assumed a density of about five persons per m^2, equivalent to what crowd statisticians call "mosh pit" conditions (Watson and Yip 2011, 106). I argued this was too great a value and used a much lower value of two persons per m^2 instead in my simulations of Whitefield's speeches (Boren 2016, 184–185). However, in this same scenario Kopij and Pilch (2019, 345) used a much greater density factor than I did, applying a novel method of assigning higher density in greater STI bands, as crowd science shows that density usually spreads out farther from the source. There is no doubt that this general method comes closer to the density distribution in a large gathering, but further research will be required to see whether the arbitrary assignment of density by STI bands improves the overall crowd estimate than a simpler single average density for the entire crowd. In any case this choice will obviously have a large effect on the final crowd size prediction, and the archaeoacoustics community should reach more consensus on how crowd density should be applied.

On the other hand, I also think there is more room for specific context to determine reasonable values here: given the presence of women's hoop skirts and a pious religious revival during Whitefield's sermons, I argued that "mosh pit" conditions may have been a bit generous in that case, and that a lesser densely factor should be considered. In the case of Caesar's army (Boren 2018, 9), we have better data about how Roman infantry stood when in formation, which provided more specific information than a general standard might.

Sound propagation through crowds

As mentioned above, the models here (and Franklin's, implicitly) all assume a crowd of point receivers with direct lines of sight to a point source. However, in a real crowd, some people will be taller than others, and some will have the direct sound path obscured by those in front. In such cases, the height of a speaker (like the case of Whitefield's scaffold at Mayfair) may be significant, whereas in a mainly free field model the height would only make the source slightly farther from all listeners.

One way to address this would be to carry out a Monte Carlo simulation of random heights for a large crowd of spherical heads at a distribution of heights from roughly 5 feet to 6 feet tall. By tracing paths from a source at different heights, it would be simple to calculate the percentage of listeners with one ear's path obscured, two ears' path obscured, or clear paths to both ears. This may be a rather stable percentage, or it might be highly dependent on the speaker height and exact arrangement of the crowd.

A more robust method would involve modelling the complex system of sound bending around multiple heads, either through a Finite Elements Method (FEM) model or an acoustic scale model. Such an approach could estimate the attenuation by octave band as the sound reaches farther into the crowd. This could in turn be used to estimate STI reduction above that prediction by a GA model.

Conclusions

The advent of broadly available acoustic simulation modelling can allow much better quantitative analysis of historical speeches and intelligibility, but such tools need to be understood within the limits of what they can and can't tell us. While they cannot definitively prove every recorded speech as "true" or "false", by applying ranges of plausible assumptions relative to the historical narratives, we can qualify our understandings of some speeches and rule some scenarios out entirely. It appears that the STI is the best tool to handle a broad range of source speaker levels, background noise levels, and environmental reflection and reverberation values. But STI models from different researchers can still fluctuate by an order of magnitude or more within different assumptions about appropriate thresholds, noise level, and crowd density. I believe the archaeoacoustics community should form an official committee to establish best practices standards in many of these areas, with the understanding that the range of possible values will continue to expand as the historical scenarios being studied similarly expands.

Future work

I have covered what I believe are the major assumptions that still need to be clarified in current applications of the STI to historical speech modelilng. However, we should also be mindful of the ways in which the current state of the art (i.e., the STI itself) can still be improved. The introduction and then repealing of the "STI female" standard

is a good example of this: while the old standard was clearly insufficient, do we need better standards (and standard spectra) for modelling female voices? As we strive to include more women's voices in our study of history, the better understanding of literal women's voices is surely an area that deserves more careful attention. In addition, the STI itself originally claimed a certain amount of universality with respect to different languages since the perceptual tests upon which it was based used simple phonemes. However, more recent research shows that the same STI value in an environment may result in very different intelligibility scores for different spoken languages (Galbrun and Kitapci 2016, 79). Some larger-scale variables, such as the relative percentage-balance between vowels and consonants in each language, may affect the final matrix calculation which is optimal for an STI-like metric in each language. For this reason the current IEC standard uses different higher thresholds for "bad" intelligibility depending on the language familiarity of the listener (IEC 2020, 72). More advanced treatment of speech intelligibility in the past may need to consider the language spoken, or even historical evidence about the shifts in pronunciations over time.

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Note

1 Some significant variables that do remain include important early reflections or atmospheric temperature inversions, which may sometimes be deduced from available documentary evidence.

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