Chapter 11

Acoustics and the Human Experience of Socially-organized Sound

Ian Cross & Aaron Watson

To what extent are 'standard' architectural and environmental acoustical measurements applicable to contexts outside those that are governed by nineteenth- and twentieth-century western preferences in speech and music performance? Can we apply those 'standard' measures to the practices of cultures other than those of the recent west? In other words, can we use the information represented in these measurements to understand the substance of social activities involving sound in cultures and periods other than our own? At the least, these measurements appear to relate to dimensions of the human experience of sound that might represent real uniformities in the human experience of social sound (though these may be valued positively or negatively by members of different cultures). At a first approximation we can treat the data that these measurements afford as reflecting constraints on the human experience of socially-organized and directed sound. Hence they might allow the assessment of the feasibility of highly-specific types of sound-producing behaviours, both speech and musical, group and individual, as well as allowing inferences to be made about the degree to which acoustically-functional characteristics of archaeological sites and spaces might have been intentionally incorporated in their design and construction.

The role and effect of sound and the human experience of sound in archaeological environments is severely under-researched. Sound is a primary source of information about the world, and the human experience of sound shapes many of the ways in which we interact with the world and with each other. Yet sound has generally been a missing dimension in archaeological research, an omission that has only recently been challenged (e.g. Dams 1984; Reznikoff & Dauvois 1988; Devereux & Jahn 1996; Watson & Keating 1999). As a modern discipline, archaeology is predicated upon the sensory domination of vision in our own society (see Pocock 1981; Porteous 1990; Rodaway 1994), and there has been a tendency to project this bias into the past. Furthermore, sound is evanescent, and for most of human history (never mind prehistory) its basic nature has been poorly understood. Indeed, it was not until the end of the nineteenth century that accounts of sound enabled its physical basis to be predictively understood and the perception of sound to be explored productively (e.g. Sabine 1921; Rayleigh 1945).

This paper is primarily concerned with outlining a methodology by which the acoustics of ancient buildings and spaces might be further elucidated. Pilot studies at Neolithic monuments in the British Isles (*c.* 3800–2000 BC) have suggested that these places were conducive to the creation of dynamic multisensory experiences, affording acoustic effects such as echoes, resonance and standing waves (Watson & Keating 1999; 2000; Watson 2001a,b). While it could be argued that these effects are simply a fortuitous by-product of architecture that was originally intended to serve quite different purposes, it seems unlikely that acoustic effects would have gone unnoticed in prehistory. The application of a detailed research methodology could reveal further evidence to support this possibility. For example, might those sites that can be identified as having had ritual or specialized roles (for instance, the presence of 'art' or evidence for the symbolic treatment

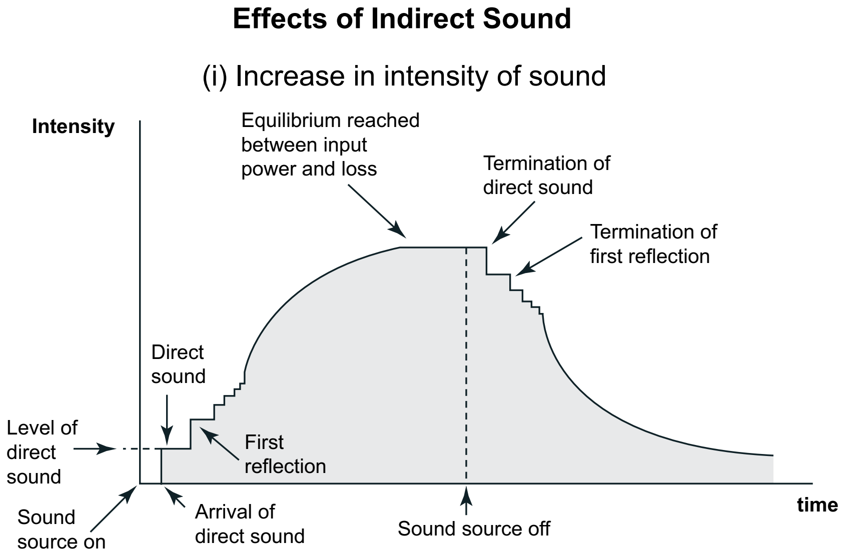

Figure 11.1a. *Increase in sound levels arising from summation of indirect (reflected) sound energy and direct sound energy from source.*

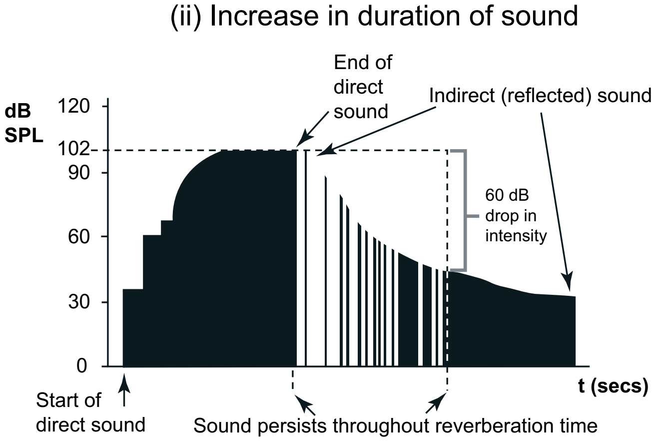

Figure 11.1b. *Extension of apparent duration of sound because of longer path length (hence later arrival) of indirect sound relative to direct sound.*

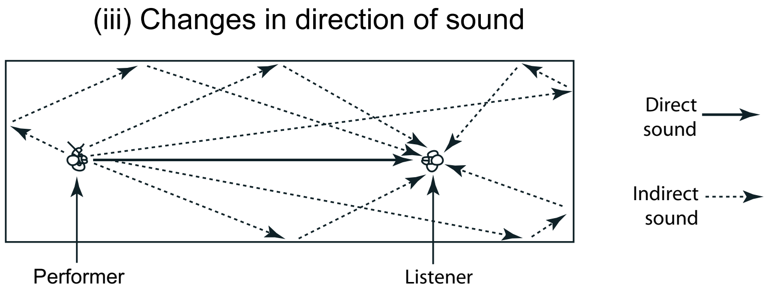

Figure 11.1c. *Potential apparent changes in direction of sound arising from reflections distant from source.*

of the dead) privilege certain types of sound-producing behaviours? Contrasted against the experience of sound in the wider landscape or within structures that display entirely different evidence (for instance, places of industry or habitation), this has the potential to enrich interpretations of how ancient buildings or spaces were used. There is also a possibility of gaining an insight into the extent to which acoustical considerations contributed to the design and construction of ancient sites.

In this paper we shall review the effects of spaces on the behaviour and experience of sound before considering the utility of 'standard' measures of sounds in architectural spaces for an understanding of sound in archaeological contexts.

Concepts and methods

Over the last century a range of methods have been developed for quantifying the acoustics of different physical environments and interpreting their appropriateness for different types of sound production and reception. These methods have been applied with increasing success to predict the behaviour and the experience of sound in situations where it is 'foregrounded' (as in the alleviation of environmental sound intrusion, or in the specification of designs of spaces for speech and music performance).

When a sound is encountered in the open air in a horizontal plane landscape, the sound that reaches a listener proceeds by a direct path from the sound source. For sounds in an enclosed space a listener will receive not only the direct sound but also the sound energy that is reflected from the surfaces of the enclosed space. The boundaries of the space will have three principal effects on the experience of sound; sound intensity is likely to increase, sound duration is likely to increase, and apparent sound direction may be altered (see Rasch &

Plomp 1982). This occurs in part because the our auditory systems integrate sound energy over small but finite time windows (thus summing a fraction of the reflected sound energy with that received direct from the source) and in part because of the complex nature of the cues that the ear relies on in ascribing location to a sound source. In a semi-enclosed space (e.g. with no roof and only partial walls or other obstructions), to these effects one must add the likelihood that the boundary elements will attenuate sounds external to the site and may change their frequency spectrum.

Current approaches to the acoustics of architectural spaces measure a range of parameters that correlate with the three principal effects outlined above and that can be employed to extend our understanding of how such sites and spaces might be used. The value of applying such standard measures lies largely in the fact that their application allows current knowledge of acoustically-centred uses of spaces to be brought to bear on the interpretation of sound in archaeological contexts. The huge reservoir of acoustical measurements of contemporary and historical built structures that exists provides a very secure foundation for making inferences about the usability of archaeological spaces for different sound-producing behaviours, and should afford insight into the contemporaneous perception of such spaces as acoustical environments.

However, a couple of caveats must be entered here. Current acoustical measures are largely predicated on particular uses of spaces that involve a collective focus of auditory attention, as in concert halls or lecture theatres. As far as we know, there is little that appears to be known about the acoustics of spaces that is related to, for instance, collective sound-producing and perceiving behaviours. Moreover, there may be acoustical features of archaeological spaces and sites that current approaches would tend to treat as undesirable (such as the presence of flutter echoes, or resonances). When such features are quantified in current measurements that quantification tends to be carried out with a view to minimizing their effect rather than to exploring how they might impact positively on the experience of sound in the spaces that give rise to them. It seems very likely that these features could have been regarded as desirable by the builders or users of these sites and spaces, yet current measurement techniques offer little guidance as to how they should be assessed and interpreted.

Some 'standard' architectural-acoustical measures

The 'standard' measures that may be applied provide information about specific dimensions of the experience of sound in enclosed spaces (specifically, loudness, duration and spatial impression). Note that loudness, duration and spatial impression are all psychological attributes of sound in enclosed spaces. Standard 'objective' measures address the physical aspects of sounds in spaces that correlate with these psychological attributes; hence loudness would be assessed by means of measurements of intensity, duration in terms of measurements of temporal extension and spatial impression by measurements of the directions from which reflected sound reaches a listener. These objective measures include: total sound level; objective clarity (C_{50} [speech] or C_{80} [music]; reverberation time; early decay time; and objective envelopment (Barron 1993).

Intensity

Total sound level is a measure of the increased intensity of the acoustic signal that occurs in any enclosed space with reflective surfaces. This corresponds to the total sound level at the measurement position minus the sound level of the direct sound measured at 10 m from the sound source. It is expected that different locations in any given site are likely to yield different total sound level values, and on each site a range of measurements would have to be taken.

Temporal effects

Objective clarity is a measure of the ratio of direct sound to indirect sound in an enclosed space; high levels of clarity indicate high levels of direct sound relative to indirect sound. It can be measured so as to correlate with perceived speech intelligibility (C_{50}, where the direct sound is defined as including all indirect sound occurring within 50 msec of the direct sound) or with the perceived 'distinctness' of music's structure in time (C_{80}, where the direct sound incorporates all indirect sound occurring within 80 msec of the direct sound). Again, clarity can be expected to vary across a space so multiple measurements will be taken at each site.

Reverberation time is the classical measure of the effect of an enclosed space on the perceived duration of a sound, and is defined as the time taken for the acoustic signal to decay by 60 dB from the cessation of the direct sound. Though similar to clarity, it provides an index of the 'liveness' of a space, and hence its suitability for types of activities involving sound that proceed at different paces. Measurements of *Reverberation time* should be supplemented by measurements of *Early decay time*, which provides an index similar to reverberation time but one that appears to correspond more directly to the subjective judgments of reverberation when the decay in a space is not completely linear (a feature that is likely to vary between sites).

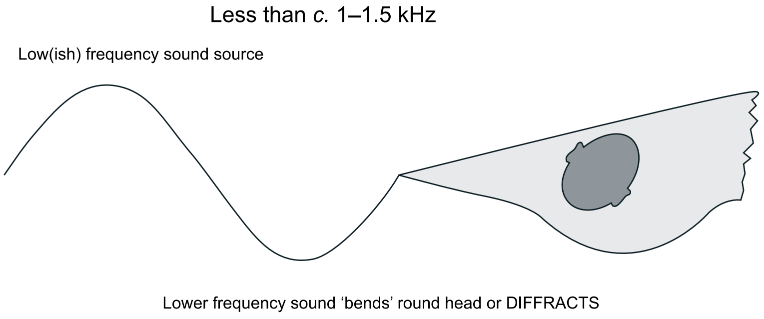

Figure 11.2a. *Low frequency sound (below* c. *1.5 kHz) from lateral directions may 'bend' (diffract) round head, hence there is no significant difference in sound energy level reaching each ear.*

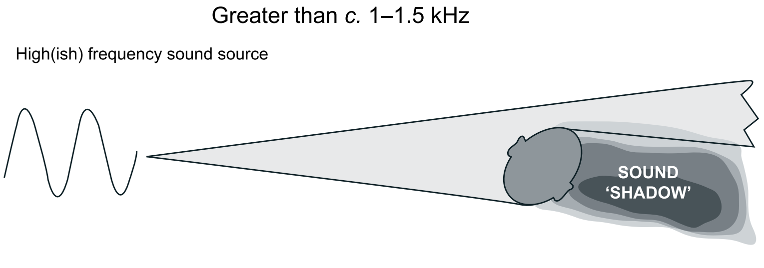

Figure 11.2b. *High(ish) frequency sound (above* c. *1.5 kHz) from lateral directions allows formation of 'sound shadow' (inter-aural sound energy level difference) as sounds with wavelengths that are short relative to inter-ear distance round head (hence higher frequency sounds) will not diffract round head.*

Spatial effects

Objective envelopment, or *early lateral energy fraction*, is a measure of the ratio of early energy arriving at a point from lateral directions to total early energy arriving at that point (early energy being defined as within 80 msec of the direct sound). This gives an index of the perceived spatial configuration of a space on the basis of acoustical cues and is likely to relate to the degree to which a listener can, or cannot, orient themselves in that space on the basis of sound alone.

The measurements derived in respect of the above parameters must be interpreted relatively, to some extent. While they rely on certain 'absolute' levels (for example, a decay by 60 dB from the end of the direct sound in defining reverberation time), it is very likely that the inhabitants of the pre-modern world encountered everyday soundscapes (a term coined by the Canadian composer R. Murray Schafer as an auditory analogue of the term landscape) that were very different from those of the modern urban world. They were thus likely to have been sensitized to features of those everyday soundscapes (see McFadden & Callaway 1999) in ways that may have shaped their responses to sound in special, sacred or monumental sites. Hence it would seem important at least to obtain measurements of sound levels that are likely to be representative of the sonic environments of the users and inhabitants of the archaeological sites in question, perhaps in the form of measures such as LA*eq*. LA*eq* is a standard measure of the loudness (L) of environmental sound averaged over a time period, with different frequency bands weighted according to the dB(A) scale (hence A*eq*) so as to relate to the sensitivity of the human auditory system; this provides an index of averaged and perceptually normalized environmental sound level.

Assuming that this can be done, it should be possible (in conjunction with other types of archaeological information) to use these standard measures to derive information about the probable temporal textures of sound used in spaces and sites, as well as about the disposition of participants. From *Total sound level* one can obtain an index of the 'strength' of the acoustic signal in a space, which could be compared to measurements in local contemporary domestic structures (either measured or estimated) as well as to measurements of environmental sound levels (LA*eq*) in each locale. It is likely that the total sound level within a completely enclosed site (whether constructed, such as the chambers of Newgrange or Maeshowe, see Watson & Keating 1999, or naturally occurring, such as Pech-Merle or Escoural, see Dams 1985) will be very significantly greater than at any other point in the locale, suggesting that it would have been an appropriate location for communal activities involving sound. In contrast, total sound levels in semi-enclosed sites (e.g. stone circles such as Stonehenge, Avebury or the Ring of Brodgar: see Watson & Keating 2000; Watson 2001b) tends to be highly variable according to measurement position, suggesting possible loci and disposition of participants for activities involving sound.

From measurement of *Clarity* in its two forms one can legitimately make inferences about the suitability of a space or site for speech, or for activities involving 'heightened speech' (as in declamation) or music. Such inferences can be buttressed by measures of *Reverberation time*, as a long *RT* (or long *Early decay time*) will seem to 'smear' or 'blend' sounds over time, making it more suitable for sound sequences that are either slow in pace or that require a degree of blending it time to achieve their efficacy (typically found in a range of ritual and liturgical contexts in the present day), while a short reverberation time is likely to enhance the experience of rapid sound sequences and of speech intelligibility.

It is somewhat more difficult to understand how measures of *Objective envelopment* might be interpreted. While this will provide an index of the perceived spatial configuration of a space on the basis of acoustical cues, and perhaps indicate the degree to which a listener may be able to orient themselves in that space on the basis of sound alone, the irregular configuration of most archaeological sites and spaces is likely to mean that this measure will be extremely variable in any given site, and perhaps of less importance than measurement of other features that might impact on the impression, or on the 'localizability', of sounds in such spaces. These other features include echoes, flutter-echoes, resonances, 'filter' and partial sound occlusion phenomena, and while these may be measured their interpretation may be less securely grounded in current architectural-acoustical data than are measures relating to intensity and temporal effects.

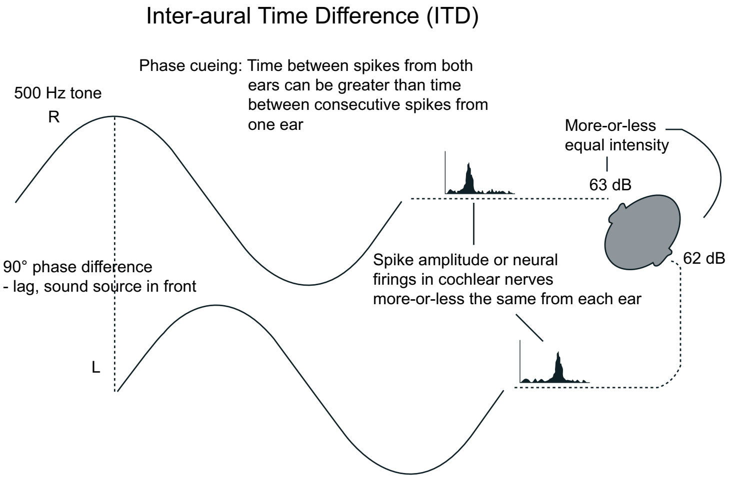

Figure 11.3a. *For low-frequency sounds from lateral directions, there may be no significant inter-aural intensity level difference although there is a difference in the time of arrival of the sound energy at each ear. Detection of the neural response to this inter-aural time difference may be used by a perceiver to localize the sound source.*

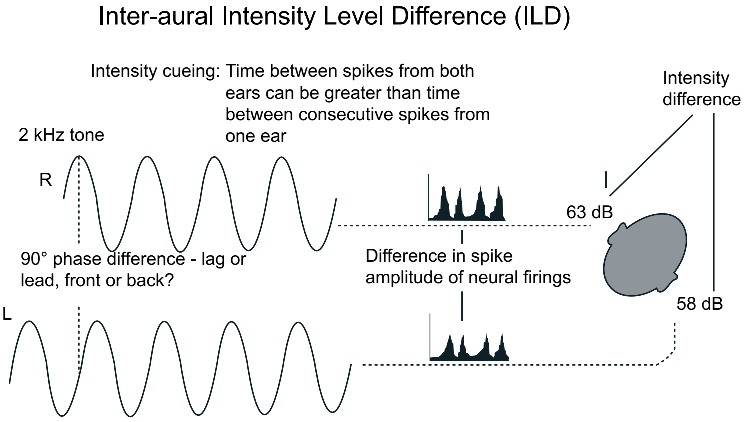

Figure 11.3b. *For higher frequency sounds from lateral directions inter-aural time differences provide ambiguous cues as to location, and inter-aural intensity level differences may be used to localize sound.*

Echoes, flutter-echoes, resonances, 'filter' and partial sound occlusion phenomena tend to be viewed as 'undesirable' phenomena in current architectural-acoustical contexts, and research that bears on these focuses on their suppression rather than on their exploration or exploitation. However, it is highly likely that these types of phenomena which are likely to give rise of 'aural illusions' would have been highly valued in some pre-modern contexts and hence would have been exploited. In order to interpret measurements of these phenomena it seems necessary to consider not only the acoustics but also the psychoacoustics of spaces, and in particular the psychoacoustics of sound localization. As we shall see, this is a complex area involving the interaction of at least two perceptual mechanisms and it may well be that each instance of such phenomena would have to be interpreted in part on its own terms.

The psychoacoustics of space and location

The human experience of the location of a sound is governed by mechanisms that compare inter-aural time difference (ITD) and inter-aural intensity level difference (ILD) — see Grantham (1995); in effect, we localize sound in our perceptions by using as cues the differences in loudness, or the differences in time of arrival, of sound waves at each ear to infer the location of the source from which the sound waves originate. In the horizontal plane, ITDs are dominant cues for localization of low-frequency and broadband sounds while ILDs are dominant cues for localizing high-frequency sounds. In the vertical plane, localization cues derive from the interferences in the incoming sound waves that arise from reflections from the folds of the pinna, the external ear, which will differentially affect different frequency bands, boosting some and reducing others; these pinna-based spectral cues

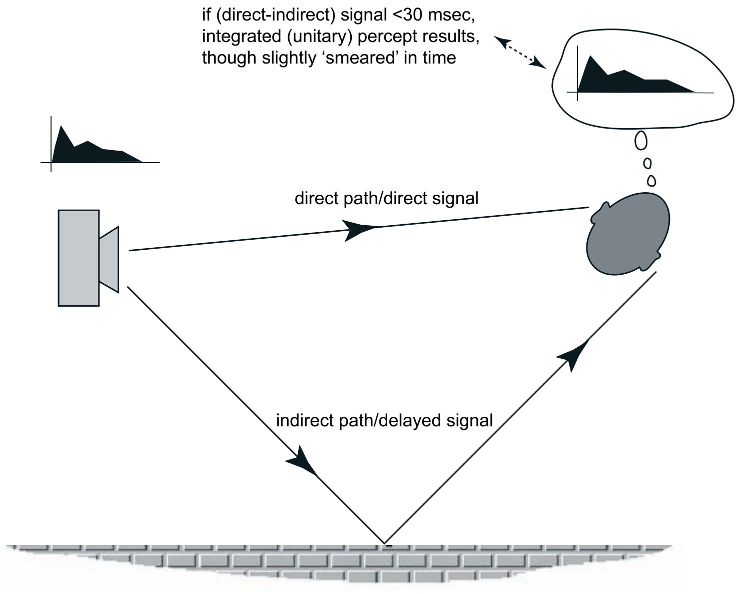

Figure 11.4a. *When indirect (reflected) sound energy reaches the perceiver within 30–35 msec of direct sound, both inputs are likely to be integrated into a single percept.*

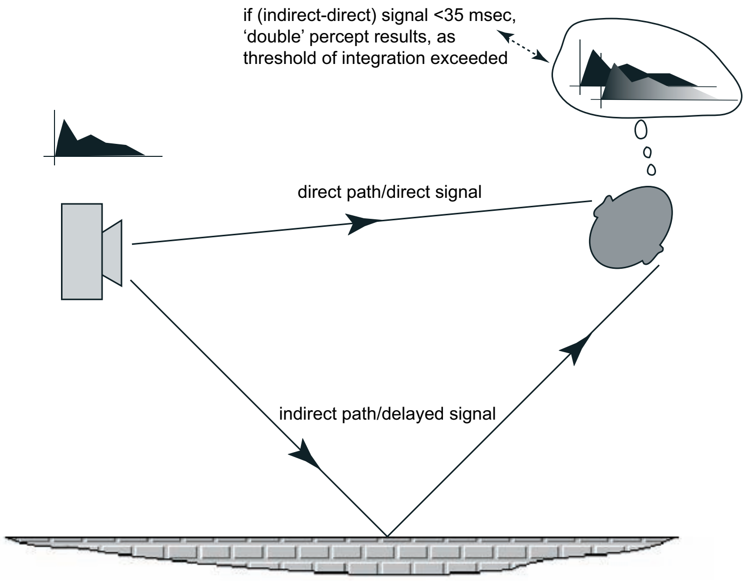

Figure 11.4b. *When indirect (reflected) sound energy reaches the perceiver later than 30–35 msec after the direct sound, the inputs will not be integrated and a double percept is likely to result.*

(peaks and notches) are only really effective for sounds containing a significant energy component above 7 kHz. At present it appears that the most parsimonious explanation of detection of a moving sound source (or of the impression that a sound source is moving) seems likely to be based on comparison between successive applications of processing of the 'static' soundfield (the 'snapshot' hypothesis), limited by the localization resolution (the MMA, Minimum Auditory Angle).

Even in a free field, where a listener experiences only the sound arriving direct from the source, the operation of these processes of localization may sometimes result in ambiguous percepts; understanding how these psychoacoustical processes operate in the localization of sound sources becomes yet more complex when the influence of indirect, reflected sound is taken into account. In part this arises because of the need to consider the effect of the temporal grain of the human auditory system on the experience of sound in reflecting environments.

When sound is encountered in a space with reflective surfaces, if the time delay between the direct and indirect sound is less than *c.* 30 msec, the sound energy is integrated and a single unitary percept results. If the time delay is greater that *c.* 30–35 msec, then a double percept will be experienced; if the time delay is significantly greater than 35 msec and the first reflection to arrive is substantially more intense than any subsequent reflections, a clear echo will be experienced. The 30 msec integration threshold is effectively the threshold of generic perceptual event integration at the neural level (Pöppel & Wittmann 1999); in other words, 30 msec appears to be the limit of temporal resolution, or the basic 'grain', of human temporal perception.

In general one can say that when the time interval between successive reflections is much less than 30 msec a space's reflections will contribute to the experience of the sound in a synthetic rather than analytic manner. Hence, when a resonance is encountered in the audio range (having a frequency of greater than 20–30 Hz), frequencies in a signal at and around integer multiples of the resonance frequency will be enhanced relative to the other frequencies in that signal. This will, at the least, 'colour' the sound significantly, altering its perceptual characteristics, and this is a phenomenon that could certainly have been exploited in certain sites and spaces (as suggested in Reznikoff 1988). However, when a flutter-echo is encountered, the time delay between successive reflected signals is usually greater than 30 msec, corresponding to a more-or-less sub-audio or infrasonic 'resonance'. In these instances the perceived behaviour of sound may be more complex, depending on the signal that elicits the flutter-echo; the rapid and decaying succession of flutter-echoes that are produced may be interpretable as the movement of a single sound source, as a 'coloration' of the original signal, or conceivably as a 'fractionation' of the original sound into a succession of discrete sounds with a motion component. Similarly, the 'filter' or partial sound-occlusion effects that may arise in a partially enclosed site such as a henge or stone circle may be experienced differently according to the perceiver's location and according to the eliciting signal; it may be that some diffraction effects give rise to apparent sound-source motion, or colour sound in perceptual significant ways.

Seemingly anomalous behaviours of indirect sound such as resonance, echoes, flutter-echo or filter effects can give rise to auditory illusions because of the ambiguity of the cues afforded to a listener by the behaviour of sound waves in particular auditory environments. So for example, a resonance at a particular location in an enclosed or semi-enclosed space might lead to a sound produced at a particular pitch being startlingly louder than sounds produced at other pitches, this increase in amplitude being achieved with no extra effort on the part of the sound's producer. In the case of an echo, a sound produced in a particular location appears to be 'answered' from another location (see Waller this volume). In spaces that give rise to flutter-echoes, on occasion a sound may appear to elicit another, quite different sound that seems to move in space.

Here, the standard measures seem to fail; as far as we are aware the 'effects' in question have received little attention from acousticians other than as undesirable phenomena to be suppressed in any architectural design. However, as suggested above, it is very likely that such effects may have been viewed positively in pre-modern times, being exploited in the use of certain acoustical spaces, particularly those that can be interpreted as having ritual or liminal attributes and uses. Accordingly it seems that a case-by-case approach is necessary here, taking account of all the conceivable sound-producing practices and that might have been employed and exploring each site's acoustical particularities in the light of an understanding of human perceptual processes. For example, it seems likely that any sub-audio frequencies elicited as flutter echoes by brief, sharp-onset acoustic signals in reflective environments will be experienced as modulations of the original signal, although how that will impact on the overall perception of the signal remains to be elucidated. One can suggest that a viable approach might involve the exploration of any differential behaviour of sub-audio (less than 20 Hz), low-frequency (less than 1.5 kHz) and high frequency (greater than 1.5 kHz) sounds in different acoustical environments, as well as the exploration of the ways in which complex sounds with significant and discrete components in each frequency region are consequently experienced.

The discussion so far has remained at a theoretical level, being confined to outlining some acoustic measures and features in respect of which the acoustics of ancient spaces might be elucidated. To put some flesh on these theoretical bones, and to give an instance of how acoustical effects that are difficult to quantify using standard measures might have impacted on the perceptions of people in the past, we will now cite an example of a subtle acoustical effect discovered accidentally in the course of a project which the first author undertook with Ezra Zubrow and Frank Cowan in which the potential of Upper Palaeolithic flint blades as sound-producing objects was being explored (see Cross *et al.* 2002).

A case study: lithophones and the numinous

For safety reasons, flint knapping was conducted out of doors, in a courtyard in the Music School in Cambridge. As the knapper, Frank Cowan, was producing the blades another member of the team, the present first author, was informally testing each new blade by suspending it by a nodal point between thumb and middle finger and tapping it with a flint percussor. While tapping he happened to turn round so that he was not directly between the sound source (the blade) and the two parallel walls constituting the long sides of the rectangular courtyard. Suddenly, a single tap on the blade was followed by a high pitched flutter — an animate sound seemingly located some distance from the sound source — that appeared to recede into the distance. The effect was quite unearthly; though out of doors and in the full afternoon sun, it seemed that the tapping had suddenly awoken some real yet invisible entity — perhaps a bird, or at least an avian spirit? — that evanesced, disappearing somehow into the (brick) boundary walls.

A few more taps and flutters and some hard thinking and what was happening became evident. The reflected sound from the two parallel walls (about 7.2 metres apart) was setting up a standing wave in the form of a 'flutter echo' which gradually died away. The source of the standing wave was the sound produced by tapping the blade, a high pitched tone (the mean frequency of all blades tested was about 6.2 kHz) with a sudden onset, hence the 'flutter echo' took the form of a fluttering sound with repeated sharp onsets and a high though unclear pitch, the flutter itself having a periodicity of around 42 msec (or 1/24th of a second). The apparent difference in location of the flutter echo from the sound source, and its apparent fading into the distance are likely to have derived from the complex cues that the phenomenon affords to the human auditory system.

In this situation it is conceivable that the flutter echo initiated by a rapid-onset and high-pitched sound afforded a complex signal with periodic modulations of amplitude. The location of the listener closer to one reflective surface than the other might have afforded a decrease in signal level with each increase and decrease of the overall amplitude envelope that was different at each ear (i.e. significantly greater decrease with each periodic change in amplitude envelope at one ear relative to the other). Alternatively, differences in the absorptive or diffusing characteristics of the two parallel reflective surfaces sustaining the flutter-echo (one was a plane brick wall, the opposite wall being partially brick and partially glass) might have afforded such regular laterally-biased intensity decrements. Either of these two possibilities could have led to the sound appearing to have a motion component. Indeed, it is likely that this 'illusion' is likely to occur only forparticular types of initiating sound in quite specific auditory environments; here, contingently, the sharp-onset high-frequency lithic-percussive sound produced in an environment with a strong flutter-echo would be the ideal 'fit' for such an effect. Notwithstanding these hypotheses, elucidating these issues fully would require considerable experimental research.

The fact that we were able to account for the effect in hard scientific terms did nothing to dispel the 'magical' qualities of the sound; much of the rest of the day was devoted to exploring the slight differences in apparent location, and in apparent direction of disappearance, of the flutter echoes produced by a range of blades tapped in different locations in the courtyard. By standing at a specific orientation in a given location with a given blade one could reliably repeat the effect, continually 'evoking' the same 'entity' that reliably 'disappeared' into the walls in a specific direction. While this effect was elicited in a modern architectural space bounded by (mainly) brick walls, it can in theory occur in *any* space bounded by parallel hard surfaces; all that is required is that the initial sharp sound — and the listener — be placed between two parallel, sound-reflecting surfaces, which need not by large in area. Indeed, it is likely that even in a bounded space of which the surfaces are noticeably irregular (such as a naturally formed cave), one or two points in that space will fall on a line between two surfaces that are both plane and parallel and hence afford the elicitation of a flutter-echo.

It was notable that even when fully in possession of a viable scientific explanation for the phenomenon, the effect was numinous. In the absence of any conceptual framework within which to articulate such an explanation, the phenomenon must appear self-evidently super-natural; an invisible, perhaps avian, entity, its presence warranted in sound, suddenly appears when evoked by a tap on the flint blade, then journeys off rapidly into the distance, always seemingly in the same direction but never in a direction that one could quite securely identify or follow. The resonances with many recent and extant ritual practices, where birds may constitute the mediators between living and dying (e.g. Feld 1980) or a bird may constitute the form in which a shaman journeys in a spirit quest (e.g. Balzer 1996), and the appearance of bird-headed human figures in some early rock art (see e.g. Clottes & Lewis-Williams 1998) appear noteworthy, and lead us to speculate that 'shamanistic' practices, conducted in appropriate acoustical environments, might have constituted a situation within which flutter-echoes — possibly generated by sharp high-frequency impulses of the type produced by flint percussors — could have been exploited. Indeed, this speculation fits well with the suggestions by Reznikoff (1988) and by Waller (1993) that there is a close relationship between the locations of at least some Upper Palaeolithic rock art and the acoustical properties of those locations, in particular, their resonance and echo characteristics, though further research and experiment is certainly required before any formal hypothesis can be developed.

It has been suggested (Devereux 2001) that this close relationship was motivated by the 'disorienting' effects of the low frequencies of at least some of the resonances, certain of which are infrasonic (below *c.* 20 Hz), though the experimental evidence in the literature that would support this is at best contentious.[1] It would seem that the exploitation of the complexities of the human response to complex acoustical phenomena such as flutter echoes may constitute a more viable explanation of this relationship, particularly in view of the illusions of sound displacement that appear to be associated with these types of resonances. It should be noted that acoustic illusions may appear to be especially powerful as the acoustical cues that give rise to these have no visible correlates; in effect, acoustic phenomena such as echoes, resonances and flutter-echoes — all of which are deemed 'undesirable' in terms of contemporary architectural acoustics — can be powerful mediators of a sense of mystery simply because their sources lie *solely* in the acoustical domain.

Conclusions

In this paper, we have sketched out some possible methods for acoustic research in archaeological contexts and have outlined a case study to emphasize how, once acquired, technical data requires interpretation. The application of objective acoustical research will not in itself reveal the perceptions of people in the past. Although we can make an educated guess about the physical and psychophysical basis for numinous phenomena, exemplified by the flint lithophone example, clarification of its perceptual basis would take a considerable amount of empirical and multidisciplinary research. The moral of the story is perhaps that although we are in a position to make considerable progress in identifying and defining the pre-modern experience of sounds in archaeological sites and spaces through the application of 'standard' acoustical measures, rather more work remains to be done to further elucidate the meanings, emotions or powers that ancient soundscapes embodied for the people who encountered them. It is critical that, alongside the application of rigorous methods, acoustical investigations acknowledge the social contexts within which sound may have been experienced, and remain aware that it is easy to impose modern cultural understandings and experiences onto past societies. In conclusion, an archaeology of sound will necessitate the application of detailed research techniques applied *in conjunction* with active and informed interpretation; the alternative is to risk hearing only echoes of ourselves.

Notes

1. Negative effects of infrasound appear to be reported by Mohr *et al*. (1965). However, this finding is contradicted by the later report of Harris *et al*. (1976), who note that the previous study had conflated negative effects of extremely high levels of low-frequency sound (between 20 and 100 Hz) with putative effects of infrasound (vibration energy at less than 20 Hz); the latter study found no deleterious effects of very high levels of infrasound on human performance. In addition, the impact of infrasound may vary significantly between individuals (see Nussbaum & Reinis 1985).

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