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Neolithic monuments: sensory technology

John Was[a] and Aaron Watson[b]

[a]Independent scholar, London; [b]Department of Archaeology, Durham University, Durham, UK

ABSTRACT
An examination of Neolithic monuments across the British Isles reveals how they may function as sensory technologies and how the auditory effects generated by these structures can profoundly impact upon our perceptions and responses. To consider the auditory properties of a site we must actively produce sound to energise its acoustic qualities. This 'active' interaction prompts a broader consideration of our past and present relationship with Neolithic monuments. We suggest that these sites be re-imagined as reactive spaces, fuelled by the actions and thoughts of people within. As such, monuments are potentially vibrant and still-active technologies that can transform perception and generate dynamic multisensory experiences.

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Introduction

In this paper we explore the idea that Neolithic monuments function as sensory technologies. In particular, we will examine how monumental acoustics transform the listening environment and impact upon people's experience. A consideration of sound in this context also prompts an intriguing interpretation of these structures. Sound is ephemeral. It arises as a product of real-time activity and is sustained only as long as that activity is maintained. To consider the auditory properties of an archaeological site we must actively produce sound to energise its acoustic qualities. In turn, this interaction prompts a broader consideration of our relationship with Neolithic monuments in the present, alongside how they might have been used in the past. We suggest that these sites be re-imagined as reactive spaces, fuelled by the actions and thoughts of people within. As such, monuments are potentially vibrant and still-active technologies that can transform perception and generate dynamic multisensory experiences. What monuments once did, they may still do.

To explore these ideas we will draw upon acoustic measurements at sites across the British Isles, examining some of the ways monuments 'react' to sound and in doing so modulate auditory experience. In particular, we will

CONTACT Aaron Watson a.watson@monumental.uk.com

consider three examples of how acoustic phenomena can be generated within these places and examine their impact upon human perceptual and response mechanisms.

Example 1: the looming effect

Perceptual auditory cues denoting motion in the environment are determined by intensity change, left and right ear inter-aural variations, spectral variation and changes in reverberation (Handel 1993; Rumsey 2001). When a sound source is neared or approaches it will be perceived as growing in intensity and due to diffraction and absorption effects its frequency spectrum will change, gradually featuring larger numbers of higher-order harmonic components. The balance of direct signal to reflected signal will also increase. Rising sound intensity invokes a fundamental behavioural response to an impending encounter. This is sometimes referred to as the 'looming' response (Bach et al. 2008; Tajadura-Jiménez et al. 2010). In an investigation of the looming response Seifritz et al. (2002) used fMRI scans to determine which brain regions are active in processing auditory stimuli with approach characteristics. Sounds with rising intensity were found to activate a distributed neural network sub-serving attention, space recognition, movement, auditory motion perception, and emotion.

The looming response is triggered involuntarily and is found in most animals. It is presumed to have evolved as an advanced warning and response mechanism. Resulting behaviour generally involves orientation, attention and arousal, but in certain situations can elicit more powerful outcomes. These so called 'fight/flight' responses prepare an individual for extreme action through the priming of locomotory systems, altering of physiology and precipitating evaluative responses in the form of emotional reactions such as fear (Cosmides and Tooby 2000). Outcomes may include the suspension of medium and long-term goals and the suppression of more immediate motivations such as hunger, thirst and pain. Communication protocols can change, causing an individual to emit an alarm cry, or be paralysed and unable to speak. There can also be distinct physiological changes. Gastric mucosa turn white as blood leaves the digestive tract, adrenalin spikes; breathing and heart rate may go up or down depending on whether the situation calls for flight or immobility (Cannon 1929; Tomaka et al. 1997). Specialised learning systems can also be activated, as research into fear conditioning indicates (see Mineka and Cook 1988; LeDoux 1995; Pitman and Orr 1995).

While essentially involuntary, the looming response can be modulated by higher reasoning and, in particular, by consideration of the identity of the sound producer (Tajadura-Jiménez et al. 2010). For example, if the sound source is believed to be benign or friendly then the response may manifest emotionally as excitement rather than fear. Through placing the event in context, higher reasoning can also attenuate the overall level of response;

we are approached by sound sources all the time and do not need to react in an extreme fashion in every case. Nonetheless, the capability of the looming response to affect us strongly should not be in doubt. Its impact has been recognised by composers and musicians over the centuries, and the instruction 'crescendo' (defined as an increase in intensity) is one of the most common creative devices used to elicit responses in listeners in most musical cultures and styles.

The arrangement of some monumental settings enables looming-type effects. Fieldwork has shown that people vocalising or playing musical instruments while moving along the stone-lined passages that lead into chambered mounds such as Maeshowe in Orkney (Figure 1) create a very dramatic crescendo for listeners in the central chamber (Watson and Keating 2000, 261). Even for listeners with a modern understanding of acoustic physics, an unseen sound source that rapidly builds in loudness and intensity creates the distinct impression that an invisible and powerful force is approaching.

Another example is the henge monument at Avebury in Wiltshire (Figure 2). Here, a pilot study has profiled the acoustic properties of the substantial earthen ditch and bank (John Was, unpublished data). These earthworks were found to act as an efficient sound barrier by blocking sounds with frequencies above 10 kHz. Sounds with frequencies ranging between 450 Hz to 10 kHz were attenuated by an average of 40 dB, and for frequencies under 450 Hz, an average 20 dB drop. Conversely, entrances through the bank allow full bandwidth sounds to pass largely un-attenuated. Two of the entrances are

Figure 1. Looking down the passageway that leads to the chamber inside Maeshowe. (Photo: Aaron Watson.)

Figure 2. The henge earthworks and Southern Entrance at Avebury. (Photo: Aaron Watson.)

approached by stone avenues, and compacted ground alongside the Kennet Avenue suggests that people repeatedly walked this route (Ucko et al. 1991, 190).

The Kennet Avenue did not lead directly towards the Southern Entrance into Avebury. Rather, its path veered away from the monument as if to pass it by altogether. This trajectory denied participants a direct line of sight into the henge until they reached a dogleg that turned the avenue into alignment with the entrance, suddenly affording a clear view of the interior framed by earthworks and standing stones (Thomas 1993; Barrett 1994). This striking visual experience (Figure 3) may once have had a significant auditory counterpart. As the blocking effect of the bank diminishes, sounds emerging from the monument rise in intensity by as much as 40 dB over a short distance. This 'crescendo' peaks at the moment when the interior of the monument is visually revealed for the first time. We suggest that this rise in sound intensity would have produced a looming response in people moving along this processional route. Unfortunately, the effect is now difficult to recreate as a road passes through the Southern Entrance and the interior of the henge is partially occupied by a medieval village.

Sound attenuating and filtering effects have also been documented at Stonehenge (Watson 2006; Watson and Crewdson 2009). Similar to the bank at Avebury, the outer circle of sarsens abruptly attenuates higher frequencies while allowing low frequencies to pass around them and travel for some distance. The strength of this effect depends upon the location of the listener relative to the gaps between the stones, but overall generates a contrasting

Figure 3. Two large stones are framed through the Southern Entrance at Avebury. (Photo: Aaron Watson.)

acoustic experience between listeners inside or outside Stonehenge (Figure 4). Sounds reflected inside are amplified and enhanced, while sounds emerging into the outside world are softened and distorted (Watson 2006). It would be possible for a listener to experience significant intensity and timbre variation

Figure 4. The outer sarsen circle at Stonehenge, with sunlight emphasising Stones 1 and 30 which likely define an entrance. (Photo: Aaron Watson.)

experienced as looming effects passing from the outside to the inside of the monument. For a listener approaching Stonehenge when sounds were being produced from within, the experience would not be that dissimilar to certain moments in modern dance music clubs: the effect is like the opening up of a 'filter' on a dance record, where sounds go from quiet to loud and dull to bright – a common technique used to heighten the musical tension before an explosive release for dancers.

Looming effects are produced simply by the movement of a sound source in relation to the listener or vice versa and will operate in the absence of any structure Neolithic or otherwise. But the evidence suggests monumental architectures are able to encourage and enhance these effects by promoting certain trajectories of movement for people in and around the structures, by filtering and modulating the frequency spectrum, by introducing reflected sound, and by combining sound and visual cues.

Example 2: sensitivity to vocal sounds

Speech is arguably one of the most powerful abilities that human beings possess (Ladefoged 2000). It provides an intimate, intangible link between one mind and another and can communicate detailed information about our perception of things in the world while simultaneously expressing how we feel about them: a transient coalescence of meaning and feeling. As a living expression of knowledge and our intentions, the power of speech bestows upon us an abstract means to change the world and the behaviour of the people within it. It is perhaps not surprising then that a defining feature of audition in humans is the way perceptual systems have evolved to process speech, becoming finely tuned to recognise micro-variations in the acoustic characteristics of vocalisation. This heightened sensitivity is exploited by many language forms to communicate a wide range of semantic and emotional information, with only minor changes in inflection able to denote large variances in meaning. Combinations such as variation in tone, timing and emphasis (often collectively referred to as 'prosody') are considered responsible for communicating emotional detail. In addition to prosodic cues evidence suggests emotion is communicated within the timbre of single sounds. Lazarus (1991), LeDoux (1996), Ekman (1999) and Scherer (2001) have all suggested that there are acoustic templates allowing for the rapid automatic processing of emotional cues. More recent studies add support to this including Bostanov and Kotchoubey (2004) examining non-verbal emotional vocalisations, and Goydke et al. (2004), who found that the brain is able to perform rapid identification of subtle timbral differences associated with different emotional expressions. A study by Spreckelmeyer et al. (2013) suggests the brain is able to discriminate tones differing in emotional expression at a pre-attentive level. They note that the ability to process emotional information rapidly is probably the result of 'the high evolutionary benefit that might be afforded by the rapid decoding of emotional information from single tones or human calls' (656).

Pitch-height alone can imbue sound with universally recognisable characteristics. A lower-pitched voice is typically thought to be an indicator of maturity (for both male and female) and denotes qualities associated with age such as authority and sagacity. This is unsurprising since male and female voices get progressively lower with age as vocal chords get slacker and lengthen. Studies also suggest that simple pitch information can communicate emotional states such as dominance and submissiveness. Bolinger (1964) showed that high or rising vocal pitch is associated with politeness, deference, and submissiveness, whilst low or falling vocal pitch is associated with authority, aggression, and confidence. Morton (1994) examined the vocalisations of 54 animal species and concluded that aggression is usually communicated with low-pitched sounds, whilst high-pitched sounds signify passivity and friendliness.

It seems reasonable to state that subtle nuances in vocalisation can convey complex information and emotional detail. Therefore, the capacity of an acoustic environment to modulate vocal characteristics may suggest that it has a potential to precipitate a significant, meaningful experience for the listener. An interesting example was found at House 1 in the Neolithic village of Skara Brae in Orkney. This contains a stone-built 'dresser' which has a stone seat positioned in front of it. The dresser was acoustically profiled by comparing spectra sampled in a variety of locations around the interior of the house (Figure 5). It was found that resonant cavities within the dresser subtly affect the vocal timbre of a speaker occupying the adjacent seat, but not in other locations – a bit like how the cavity of the body of a violin or guitar acts as a resonator to amplify the vibration of the strings. The impact of the dresser is to make the voice sound rounder, slightly louder and deeper in pitch. A similar effect was also detected in front of the dresser in a reconstructed house adjacent to the nearby visitor centre and also during fieldwork in House 7. One interpretation of the dressers in Orkney Neolithic houses is that they were used to display special artefacts and acted as a backdrop to the occupant of the stone seat from the perspective of a visitor entering through the doorway (Richards 1990). Lit by flickering light from the central hearth, the voice of the seated individual would have been transformed, potentially emphasising their authority, power and prestige.

Skara Brae is not an isolated case, and the effects of monumental acoustics upon the voice are widespread and facilitate a range of effects. The resonant frequencies of many enclosed chambers appear to coincide with fundamental vocal frequencies in the 95–120 Hz bandwidth, with the majority clustering around 110 Hz (Jahn, Devereux, and Ibison 1995; Devereux and Jahn 1996; Devereux 2001, 2006). West Kennett long barrow (Figure 6) is estimated to have first-order resonances in the chambers between 66–138 Hz (John Was,

Figure 5. The interiors of House 1 (top) and House 7 at Skara Brae showing the central hearth in the foreground with acoustically resonant dressers beyond. (Photos: Aaron Watson.)

Figure 6. John Was undertaking archaeoacoustic measurements within West Kennet long barrow in 2005. (Photo: Aaron Watson.)

unpublished data). These frequencies will amplify the fundamental frequencies of the male human voice, but it is also possible that tangential and oblique modes of resonance and higher order harmonics will produce resonant peaks across both male and female vocal auditory bandwidth. Fieldwork at Maeshowe, Newgrange and Camster Round has suggested that these sites have principle resonances between 80 and 400 Hz.

At Stonehenge our own research has demonstrated the action of reflections to enhance the clarity of speech. Results indicated three strong early reflections with delay times of 0.025 sec, 0.033 sec and 0.042 sec. Each produced a similar spectral response with the largest peak at 6.1 KHz followed by peaks at 4.6 KHz, 3.2 KHz, 2 KHz, 1 Khz and a smaller peak at 7.7 KHz. The overall effect is an enhanced clarity of voice with the early reflections reinforcing the original voice with delayed versions and adding 'presence' in the form of an upper middle-range frequency boost. In some contrast to the austere, overpowering, even claustrophobic experience of the surrounding stones, due to these effects, voices in the interior of Stonehenge are surprisingly strong, bright, and airy. At other sites, resonant frequencies were found to interfere with the voice. This was often heard during acoustic fieldwork at chambered monuments, and sometimes resulted in severe distortion to speech and discomfort to the speaker (Watson 2001b, 186). This precipitates a transformation in the voice which would have been difficult to understand in the Neolithic, and is surprising today.

Example 3: reflections, echoes and rhythms

Stone is highly effective at reflecting sound. Sound reflections can give rise to a range of acoustic effects including interference patterning resulting in resonant pitches, reverberation, and echoes. In enclosed chambers resonant frequencies can be strong and if the sound levels are high this can result in the distortion of certain pitches. When the correct pitch is sounded (the one coinciding with resonant frequency of the space), the enclosed chamber will fill and resonate loudly in response as if the pitch has magically unlocked a hidden connection to the space. In some circumstances resonant effects can even create pitched sounds from noise. If the signal is loud enough produced by a drum for example, the amplification of resonant frequencies can lead to the perception of a residual pitch, non-existent in the original noise signal. This can sometimes be experienced in stairwells where clapping ones hands sets up a resonant standing wave and we hear a low pitch sound reverberating around us. The effect can be quite a significant for a listener, since pitched sounds are strongly correlated with animate and more specifically human sound-sources (Kruth and Stobart 2000).

Reflections can also produce effects in open monuments. Investigations have explored sound pressure and frequency around the best preserved sectors of Stonehenge, with a sound-source placed in the centre (Watson 2006). Figure 7 shows how the relative amplitude of three sound frequencies vary at one metre intervals along a line leading from the central loudspeaker

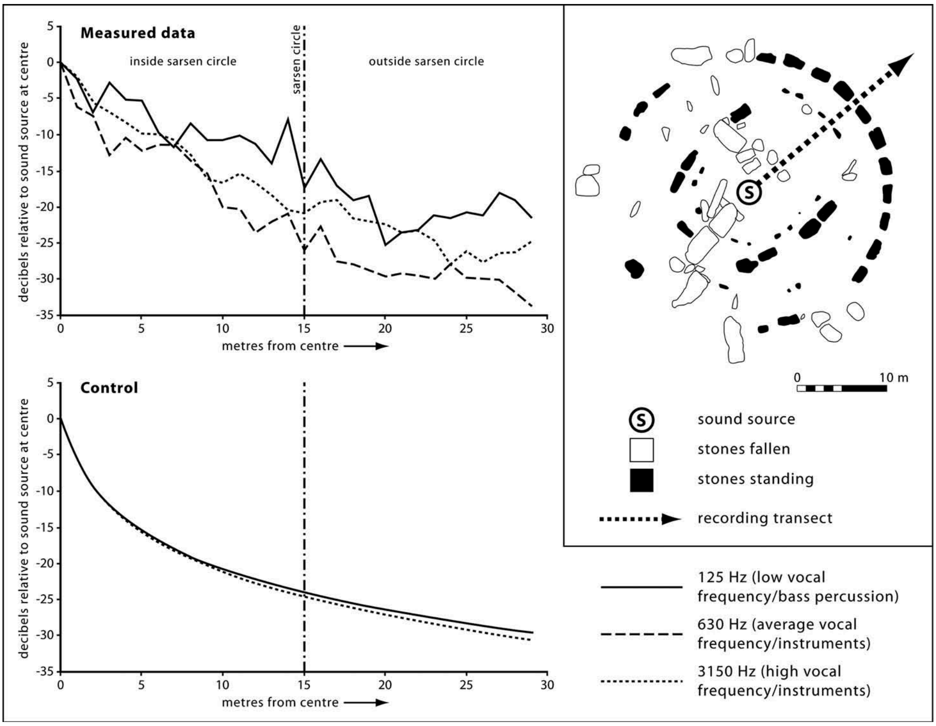

Figure 7. Systematic measurements inside Stonehenge recorded by Aaron Watson and David Keating in 1998. Plan of the stones after Cleal, Walker, and Montague 1995.

out through the outer sarsen circle and towards the Heel Stone. The surviving stones of Stonehenge very effectively contain higher-frequency sounds within the interior, and amplify them, suggesting the effect would have been further emphasised when the monument was complete. A series of distinctive peaks and troughs indicate standing waves, caused by constructive and destructive interference as sound waves are reflected between the large stones. This can produce unnerving effects as sounds can become detached from their source, change in amplitude and pitch and behave in counter-intuitive ways such as becoming quieter as a sound source is approached (Watson and Keating 1999, 329–330; Watson 2001a, 186). One example was observed by a listener standing between stones 1 and 30 (see Figure 4), facing towards the centre of Stonehenge where a second person was striking wooden drumsticks together in a regular rhythm (Figure 8). Intriguingly, the sound appeared to come predominantly from the extreme left and right of the observer, rather than the direction of the sound source itself. In addition, the timing of these disembodied sounds did not coincide with the visual timing of the sticks being struck. This contrived both to create an illusion of disconnection between sound and vision, and also for the production of sound in locations where no sound producing sources were visible. The complex reflections within Stonehenge mean that reflected sound, disconnected in time and

Figure 8. Aaron Watson striking wooden drumsticks to generate echoes inside Stonehenge. (Photos: John Was.)

space from the event producing it, distorts the listener's expectations of cause and effect. Even to a modern observer, who can rationalise these phenomena through a scientific knowledge of reflections and echoes, the experience is compelling.

In terms of echoes and reflections a listener may separate the initial sound from the reflected sound depending upon the extent to which it is temporally and spatially displaced. A reflected sound arriving back within 50 milliseconds of the original sound tends to be perceptually fused, such that one is not perceived as distinct from the other. With delay times above this threshold, reflected sounds are perceived independently from the original (Rumsey 2001). While our perceptual apparatus will analyse these delayed sounds as separate events, other auditory cues such as almost identical timbre and an understanding of cause and effect will encourage an interpretation that one sound is simply a delayed version of the other. The experience may become more confounding, however, when a number of sounds are produced simultaneously and it is difficult for the listener to keep track of every individual sound and its corresponding echo. One possible outcome is a perception that there are additional, invisible or unidentified sound producers present. In some cases even individual sounds can be ascribed origins other than those of the sound-makers. There are ethnographic accounts in which instrumentalists create a division between cause and effect such that they believe the sounds issuing from their own instruments are attributable to the voices of spirits rather than their own actions (e.g. Tuzin 1980, 1984). In short, echoes can present perceptual instances that in certain circumstances can be creatively interpreted to suggest contra-factual and even supernatural interventions.

Another significant phenomenon associated with echo effects is the establishment of a beat. If the sound producer is stationary, the time separating the source sound and the subsequent echo from a reflective surface will be consistent (the speed of sound being constant at approximately 344 m/s under normal atmospheric conditions). If the sound is repeated with a timing corresponding to the echo delay time, then a beat will be produced alternating between the sound and its echo. The echo not only dictates the tempo, but differences in loudness and timbre between original and reflection will create an accent in the beat, and hence a 'rhythmic' quality rather than a straightforward repetitive pulse. This is of interest because there is a range of evidence linking auditory rhythm and physical 'entrainment' responses, which in turn suggests that echoes and the rhythms they enable may have a significant impact on the sound producers and listeners. The most common motor response to auditory rhythm occurs in music where people will physically move in synchrony with the auditory experience, including tapping the foot, nodding the head or bodily swaying (Clarke 2005). Indeed, a number of studies demonstrate the close relationship between the neural processing of auditory timing cues and the neural processing controlling bodily movement. Halsband, Tanji, and Freund (1993) suggest the possibility of a significant physical motor component to the mental representation of auditory rhythm. Janata and Grafton (2003), Harrington, Haaland, and Knight (1998) and Rao et al. (1997, 2001) have shown that there are identical neural mechanisms controlling both physical activity and the perceptual encoding of auditory event timing. Ivry and Keele (1989) and Ivry, Keele, and Diener (1988) demonstrated how damage to the cerebellum adversely affected both motor timing and discrimination of auditory intervals. This evidence suggests a fundamental link between the perception of auditory rhythm and mechanisms controlling bodily movement, which would certainly offer an explanation for a tendency to physically respond when we hear rhythmic sounds. Entrained movement is a powerful means of synchronising and controlling large numbers of people (Jackson 1968; Bloch 1974; Schafer 1993, 31). As such it is likely that hosting rhythmic auditory experiences may have a significant impact for a wide range of communal activities.

There are many examples of Neolithic monuments that produce echo effects. At the Ring of Brodgar in Orkney the surviving monoliths of the circle produce very distinct echoes, especially in response to sharp percussive sounds (Figure 9). If a participant moves around the interior of the circle while clapping their hands, or beating sticks and drums, these sounds reflect from the stones around the circumference. At the perimeter of the monument the sound they

Figure 9. A view through the standing stones at the Ring of Brodgar towards the encircling hills beyond. (Photo: Aaron Watson.)

hear is chaotic, but as the player nears the centre the echoes synchronise and appear to originate from all around. It is possible to generate a beat with a tempo of circa 198 bpm, and ratios thereof, when standing at the centre of the monument. This creates rhythms with an effect that must have been even more distinctive in the Neolithic when more stones were standing. Even in the present day, the effect creates a strong impression that it is the stones that are making these sounds, and that they have their own agency (Watson and Keating 2000, 260). Similar effects have been noted at other large stone circles including the Inner Circles at Avebury (Watson 2001a), and can even occur when a site is poorly preserved or the listener is subject to adverse weather conditions such as wind or rain. The megalithic and stone-built facades of chambered cairns such as Pentre Ifan in Pembrokeshire and Camster Round in Caithness are also very capable of echoing sounds made in their forecourts. Linear arrangements of stones in rows or avenues can produce a distinctive staggered echo. This was noted by the authors at both Achavanich and the Hill O'Many Stanes in Caithness, despite the stones of the latter site being very low to the ground. A dramatic effect is created by shouting or striking a drum near to the Dwarfie Stane in Orkney, with reflections from a nearby arc of cliffs echoing like thunder (Watson and Keating 2000, 261).

Cognitive context

While the monuments themselves are responsible for transforming the sensory environment, we need to acknowledge the role of what we might term 'cognitive context' upon how these experiences are then interpreted and responded to by the listener. For example, if we walk down a busy street during the day we may hear many looming-type sounds, which result in nothing more than cursory considerations. Late at night however we are more sensitive to potentially hazardous events and the same looming sounds can precipitate quite different and much more pronounced responses in us. The cognitive context that a listener brings to bear at the time of listening will therefore have a great impact on the interpretation of their experience of sensory phenomena, and the behavioural responses that follow. As such, the impact of monumental structures upon experience can only be estimated in conjunction with a consideration of the personal, social, and cultural constituted sensitivities, interests, and beliefs of people at the time of their use. Archaeological research suggests that Neolithic monuments were venues for ceremonial events, including rites of passage, the treatment of the dead or marking the transition of the seasons. This would suggest the presence of a potent conceptual context of specified meaning and heightened importance for those using the sites. In these circumstances the role of sensory experience afforded by monumental structures, and any resulting psychological effects, are more likely to have exerted a powerful impact upon participants.

Discussion

In this paper we have considered the idea that Neolithic monuments can function as sensory technologies. We have examined three ways in which their architecture transforms the listening environment, and the possible impact this may have on people's experiences at these sites. In the case of the looming response, the monuments are not only able to enhance the effect but in doing so mark the sensory experience of crossing a threshold so that movement from outside to inside, or from one point of the monument to another becomes invested with visceral sensation and emotional import. The second example focused upon what is probably one of the most important sounds for humans – vocalisation. Monumental acoustics can transform the sound of the human voice in diverse ways, sometimes distorting, sometimes adding clarity. Crucially, in transforming the voice, these structures have the power to transform the speaker, or at least our perceptions of them. In the final example, we examined how echoes produced by monuments can create contra-factual experiences, and precipitate rhythmic qualities that have a range of behavioural outcomes, including dismantling our perceptions of cause and effect and the encouragement of unified, cohesive activities in large numbers of people.

While this paper focuses upon sound, a more complete picture can be achieved by considering how auditory, visual and other sensory information might act in concert. The experiences precipitated by monuments are inherently multi-sensory, combining qualities such as touch and texture (Cummings 2002; MacGregor 1999), colour (Gage et al. 1999; Jones and MacGregor 2002), contrasts between darkness and light (Bradley 1989; Jones 1999) and relations with the wider landscape (Tilley 1994; Watson 2001b). Participants might also be required to adopt unfamiliar postures in order to negotiate confined passageways and entrances (Thomas 1990, 175).

Perhaps the strongest effects are those that combine sound and vision. We have described how looming sounds at Avebury and Stonehenge combine and enhance a visual 'reveal' as participants move between the Avenue and henge. Furthermore, exciting new work in the field of archaeo-optics is revealing that many chambered monuments are capable of optically projecting animated images of the outside world into their chambers – without the use of a lens (Watson and Scott, forthcoming). This raises the potential for extraordinary luminous images of landscapes and people to occur in conjunction with acoustic effects such as the looming response, vocal enhancement or echoes (Figure 10).

Neolithic monuments have been interpreted as places that afforded participants a change in status akin to a rite of passage or a journey between worlds (Richards 1992). Such transformative properties could have been augmented by the impact of multisensory experience. Indeed, the manifestation of inexplicable forces within these places need not be explained as solely myth or imagination; the sounds and visions we have described are tangible and measurable. It may be that archaeology is only just beginning to understand the potential for these structures to generate sophisticated, awe inspiring and other-worldly immersive experiences.

In closing, we suggest that perhaps it is no longer adequate to regard monuments as inert structures that can be classified solely according to their architectural features. Their capacity to transform sensory experience and precipitate powerful responses in people redefines them as reactive places, and their formal descriptions should perhaps take these functional attributes into account. In doing so it is apparent that some of the acoustic effects we have outlined are shared between places that are often classified as fundamentally different kinds of structure. For example, the format of the sarsen phase at Stonehenge has parallels with the wider tradition of stone circles, and yet when it is considered as an acoustic space the occurrence of looming effects and resonance are rather more reminiscent of a chambered site. If we were to classify monuments according to the experiences they embody, rather than architectural configuration, we might have to fundamentally redefine the basis upon which they are categorised and understood.

Encounters with monuments in the present are often passive and contemplative, yet the ideas we have outlined suggest the potential for rather more compelling, enlightening and thrilling engagements. It is remarkable that after several millennia many Neolithic monuments retain the potential

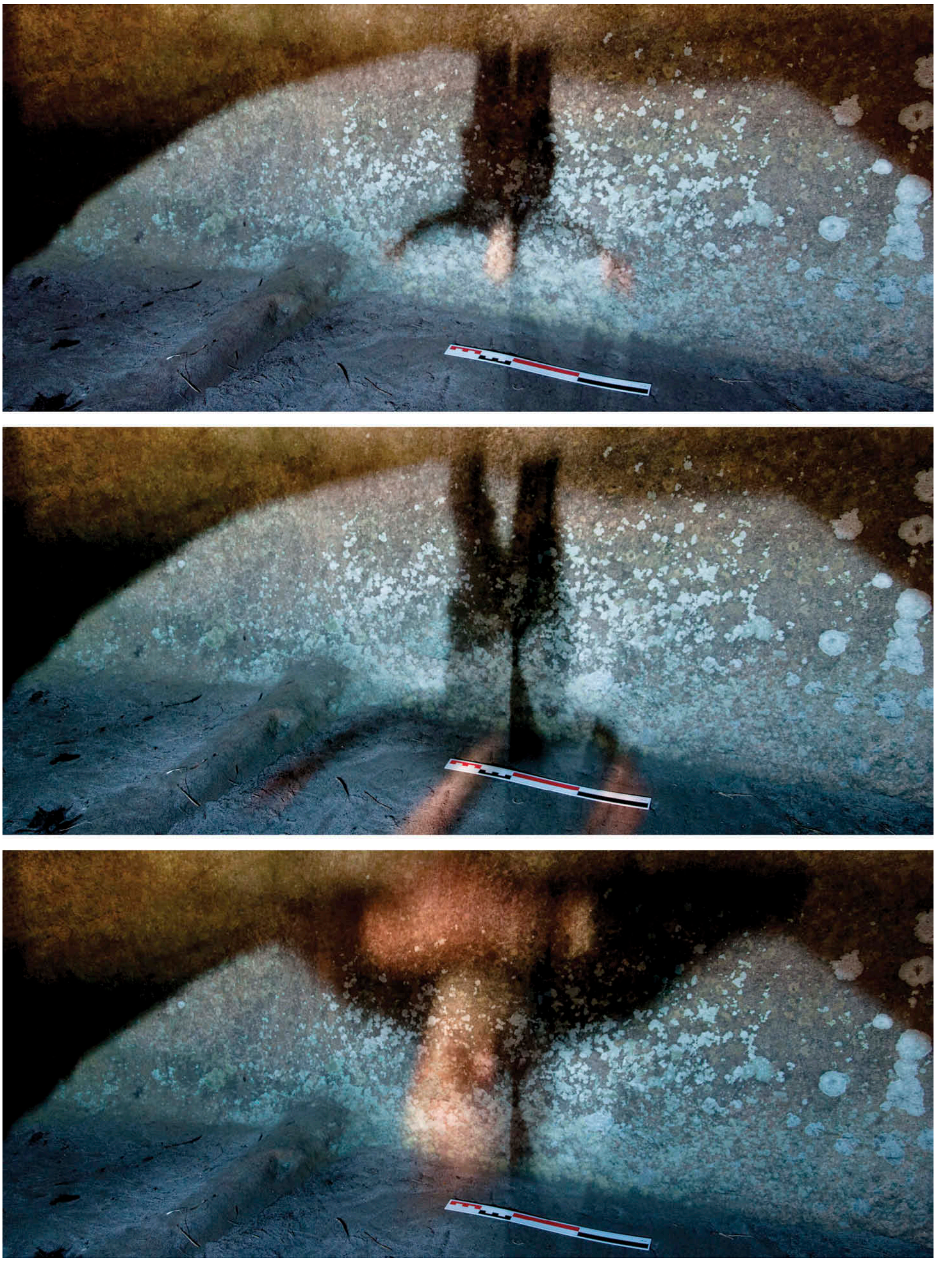

Figure 10. Long exposure photographs showing inverted images of a moving human figure optically projected onto the chamber wall inside the Dwarfie Stane in Orkney. (Photos: Aaron Watson.)

to deliver marked sensory and psychological effects. This opens the possibility for new and creative forms of experimental engagement to reactivate ancient architecture, thereby unveiling an immediate and vibrant connection with the past.

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Disclosure statement

No potential conflict of interest was reported by the authors.

Notes on contributors

John Was is a composer and musicologist. Since completing a PhD in behavioural musicology in 2010 his research has explored the psychological, neurological and philosophical principles underpinning what it is to be human and musical. A parallel life-long fascination with Neolithic monumental structures has engendered a fusion of interests resulting in acoustic research and creative interpretation of ancient and modern auditory experience at these sites.

Aaron Watson is an archaeologist and artist. Since completing a PhD in archaeology in 2000 his research has explored the multisensory experience of Neolithic and Bronze Age monuments and landscapes. He is presently conducting fieldwork in the Lake District alongside an investigation of light and optics within chambered cairns. He is an Honorary Fellow in archaeology at the University of Durham (www.aaronwatson.co.uk).

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