

[Supplementary material]

Sounds of Etruria: aural characteristics of the Tomba dell'Orco, Tarquinia

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Acoustic protocol: sound sources

Typical sound sources used in acoustic science to measure reverberation include exponential sine sweeps, bursting balloons, pistol shots, and handclaps (ISO 3382; Papadakis & Stavroulakis 2018). Hand claps were chosen for the present study largely due to logistical concerns. The delicate nature of the tomb paintings greatly limited the time spent inside each burial chamber. Half of the tombs also lacked electricity and had long steep dromoi. Therefore, the use of a laptop computer to produce an electronic signal was ruled out. The cognitive-acoustic goals of the study also made human-generated sounds more suitable than synthetic sources. Following Fletcher (2013), the handclaps were implemented to span across low-high frequencies (between 26 and 15.566 Hz) using different hand positions, three of which were flat and two cupped. While omnidirectional dodecahedron speakers are commonly used in acoustic science, their cost and cumbersome nature made them unsuitable for the present study. Moreover, the goals of the study necessitated a sound source that could reproduce accurate low frequency sounds. The two-way directionality of the BOSE device correctly reproduced frequencies below 1000 Hz, which is rare with inexpensive omnidirectional speakers (Papadakis & Stavroulakis 2018). The precision of the BOSE sound source was assessed in several ways. For example, the device's frequency response was accrued inside an anechoic chamber, therefore providing a way to assess its performance (Till 2014). The secondary assessment of real-time speech and musical performance offered additional reference data.

Musical scenes represent the second most common narratives in Etruscan tomb paintings. In fact, musical instruments are depicted 129 times in sixth–third century BC tomb paintings across 52 tombs in Tarquinia alone. (Li Castro 2017: 508; Martinelli 2007; Lawergren 2007; Jannot 1979). The instrumental and vocal sound sources utilised for the digitalised recording were accrued from five sources. One goal involved instrumental clips in outdoor settings without additional instrumentals, nor extraneous sounds limiting the need for extensive

editing before fieldwork. String instruments (chordophones) from the lyre family are depicted in 34 tomb paintings (Li Castro 2017; Lawergren 2007). Two were used for the study, a concert kithara for the digital recording, and a chelys-lyra for the secondary protocol involving a live musician. The concert kithara clip was performed by Michael Levy using a replicated Greek concert kithara, and obtained from, Luthieros Music Instruments.

Different trumpets are depicted 18 times in Tarquinian tomb paintings and seven times in Orvieto (Porano). The sound clip of the lituus was retrieved from The European Music Archaeology Project, as part of a project that studied two litui, one *in situ* on the Pian di Civita in Tarquinia, c. 675 BC and a second lituus, c. 600 BC found in front of Tumulo II of Sodo in Cortona. A facsimile of the lituus was developed by Peter Holmes and performed by Alberto Morelli with an experimental mouthpiece (Bonghi Jovino 1986, 2007; Paolucci & Sarti 2012; EMAP 2015; Li Castro 2017). Another type of aerophone, the double pipes, or double tube reed aerophone, (sometimes erroneously identified as a ‘double flute’) is the most common instrument depicted on tomb walls 67 times in Tarquinia (Li Castro 2017). The double pipes is also displayed in two tombs outside of Orvieto in the Commune of Porano (Orvieto). Two sound clips of the double pipes were obtained, both different reproductions of the Greco-Roman aulos housed in the Musée du Louvre (Hagel 2013). The first was performed by Callum Armstrong, and the second by Stefan Hagel, as part of The European Music Archaeology Project (EMAP 2015).

The inclusion of vocals for the digitalised recording and documentation of live speech was debated because the Etruscan language is no longer spoken. Vocal frequencies range person to person. Nevertheless, the human voice tends to have a fundamental frequency range between 77 to 482 Hz for males, and 137 to 634 Hz for females. A vocal melody performed in an outdoor setting in acapella was included (Mills & Zara 2014).

Intentionality and the Tomba dell’Orco

Greek and Latin authors such as Vitruvius (*De arch.* 5.5.1) and Pliny the Elder (*NH* 11.270) describe the exploitation of sound in architectural settings and this knowledge was likely understood in Etruscan literate circles (Stoddart & Whitley 1988; Tuck & Wallace 2020). Multiple constructs inside the Tomba dell’Orco seem to indicate that sound was considered during the construction of the tomb space. For example, the use of marble dust on the walls likely enhanced sound propagation throughout the tomb (Singh 2016; Andrew Barnard, *pers. comm*). Contrasting ceiling designs, and the placement of the corridor-like dell’Orco III between dell’Orco I and II are further notable, as is the positioning of the trapezoidal base in

dell'Orco II, where reverberant qualities are heightened at low frequencies. The numerous niches located throughout the tomb and loculi in dell'Orco I are also of note, particularly when contrasting their rounded nature with the linearity of the coffered ceiling in dell'Orco III. The consistency of such changes, each shaping auditory perception, is striking. Yet, many constructs were probably driven by goals unrelated to sound. The marble dust on the tomb walls for example would have created a smoother base for the paintings. Specific tomb paintings and/or spatial constructs may have further dictated construction choices (Torelli 1983; Roncalli 1997). The multigenerational use of the Tomba dell'Orco is consistent with the majority of chambered tombs in Tarquinia from the fifth century BC. A cognitive-acoustic analysis of additional tombs with similar architectural features will provide a more thorough understanding of the acoustic significance of the Tomba dell'Orco and other chambered tomb spaces in Etruria.

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