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Acoustics of the Chelys – An ancient Greek tortoise-shell lyre

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ABSTRACT

The acoustics of an authentically reconstructed ancient Greek tortoise-shell lyre, known as Chelys, is investigated for the first time. Modern experimental methods are employed, such as electronic speckle pattern laser interferometry and impulse response, to extract the vibrational behavior of the instrument and its main parts. Additionally, the emitted sound from the instrument was recorded, under controlled conditions, and spectrally analyzed. Major findings include the concentration of the emitted sound between 400 Hz and 800 Hz, with an amplitude modified in a manner consistent with the experimentally measured vibrational characteristics of the instrument's sound box and bridge. The experimental results validate the historical evidence that Chelys was used in Greek antiquity as an accompaniment instrument to the human voice.

1. Introduction

Archaeological evidence shows the importance of music and musical instruments and the significant role they played in the daily life of ancient Greeks. This forms the main stimulus for our research, which is to evaluate the acoustical characteristics of the ancient Greek instrument known as the Chelys. We apply modern techniques in order to understand the acoustical properties of Chelys in relation to its use in Greek antiquity.

The Greek tortoise-shell lyre (Chelys) was first depicted on hydriai (water pots) dated from the late 8th century B.C [1]. The instrument's name is derived from the ancient Greek word for tortoise, "chelys", since the carapace or shell of a tortoise was used in the construction of its sound box [2]. However, the words lyre and Chelys have been interchangeably used for this instrument in antiquity throughout Greek inhabited regions. In this article, the word Chelys will be used to avoid confusion with instruments of the same family with similar characteristics, such as the barbitos lyre. The Chelys was a very important musical instrument in ancient Greece. Its origin in mythology is attributed to the god Hermes, who was the first one to craft such an instrument according to the 4th Homeric Hymn to Hermes. There is also a plethora of textual and linguistic evidence as well as graphical evidence and artistic representations, that the Chelys played an important role in the education of young children, and that it was used in various activities, such as weddings, symposia, komoi (activities with men dancing) and ceremonies in ancient Greece [3–6].

The instrument has a sound box made of a tortoise shell covered with ox leather (Fig. 1). Two wooden bars, named peichis, were attached to the sound box using nails placed in the inner side of the carapace, from which the instrument could be held. The upper ends of these two bars were joined through another crossbar, known as the zygon. The upper ends of the strings were fastened at the zygon, along with wooden pegs known as kollopes. The other ends of the strings were held through a pi-shaped piece of metal, the so called chordotonos that was placed at the bottom of the sound box. The Chelys uses seven strings, although there are references that sometimes more strings were used. The strings were made out of sheep intestines and they were placed with ascending order, in terms of frequency, with the lower pitched string being the closest to the player. The other parts of Chelys included a donax, a stick placed between the leather and the tortoise shell. Despite not being explicitly justified by the historical evidence, it is believed that donax was present so as to allow the carapace to withstand the pressure imposed to it by the leather as well as to help the peichis attachment to the inner shell. The strings vibrations were transferred to the sound box via a wooden bridge (magas) whose lower side was pressed against the leather. Finally, the strings were plucked with a plectrum.

Similar research studying the acoustical properties of other ancient musical instruments (e.g. Chinese bells, stone chimes, mbira) have already been performed and published [7–11]. Most of these studies include either the theoretical evaluation of the

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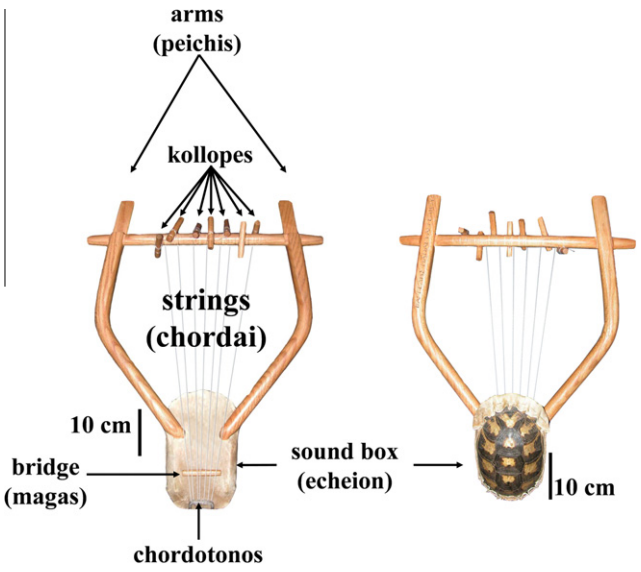

Fig. 1. Photograph of front (left) and rear (right) view of reconstructed Chelys lyre with 10 cm length indication. String order (from left to right – front view) E3–F3–G3–A3–B3–C4–D4.

acoustical properties or the study of instruments that have been preserved up to present date. Consequently, the reconstruction of an ancient instrument based upon valid historical evidence makes the present study challenging and non-trivial. Previous studies of the lyre Chelys have only reconstructed the instrument without further investigation of the acoustical behavior of the instrument [12].

Various methods have been used for exploring the acoustical properties of systems and more specifically of musical instruments. A widely used mechanical method is the impulse response. In this method, the secondary response of the system after an appropriate and controlled force input (such as that of an impact hammer) is monitored. The final aim is to measure the transfer function of the different parts of the musical instrument and their acoustical contribution. Another method is non-destructive laser optical holography, which provides valuable information for the spatial distribution of the different normal modes, their central frequencies and the Q-factor of these resonances. Both these methods were used for the acoustical characterization of the Chelys. Complementary to the above methods, the Chelys' emitted sound was recorded at different frequencies (notes). The data of the sound recording were analyzed in the context of the aforementioned mechanical and optical methods.

2. Reconstruction and experimental methods

2.1. Reconstruction

For the reconstruction of Chelys, information can be drawn from minor textual and linguistic evidence, graphical evidence representations and most importantly, archaeological findings. Unfortunately, only a few archaeological findings of Chelys exist. Predominantly, the only parts of the instrument that are preserved are associated with the sound box [13]. Incomplete examples of the Chelys have been found in Greece (at Argos, Arta, Arkadia and Corfu island) and in Italy (at ancient town of Lucifero). A part that was found in Elefsina, Greece, is exhibited in the British Museum [12,13]. Although reconstructions of the Chelys have been made over the years [12,13], only a few have approached a level of authenticity since the reconstruction of the Cheyls is non-trivial. For this reason, it is essential to detail the decisions made in the reconstruction. The reconstruction was made after taking into account all the existing historical evidence. All the sources were carefully studied, so that each part of the reconstructed instrument was as close as possible to an exact replica of the original.

Fig. 1 shows both the front and rear view of the reconstructed lyre. The carapace used for the sound box belongs to the large variety of Greek tortoise *Testudo Marginata*. The peichis are made of oak wood and the same type of wood is used for the kollopes. Nails are used to secure the bars firmly to the body. The front end of the sound box consists of ox leather. The wooden bridge (magas) is simply supported on the lower part of the sound box and it is held firmly to the sound box by the tension of the strings. It is worthwhile mentioning that although the magas is placed on the front of the sound box, the front of the sound box has no connection to the rear part of the sound box. Seven strings derived from dry sheep intestine are used and they are struck by a plectrum made from walnut wood. The plectrum has a metallic tip to ensure correct plucking of the strings. The tuning is based on the Phrygian mode [14,15] from note E3 to D4.

2.2. Recording the radiated sound

The recordings of the emitted sound from Chelys took place at the recording studio of the Department. The studio reverberation time is 0.37 s in the 500 Hz octave band, which lies within the proposed range [16]. A condenser studio microphone (Neumann U89i, Georg Neumann GmbH, Berlin, Germany), that has a flat frequency response from 200 Hz to 2000 Hz and almost flat in the rest of the audible acoustic spectrum, was placed 20 cm away from Chelys, in order to be outside the near sound field for the frequencies of interest. For the recordings, an analog audio production console (TASCAM M5000, TEAC America, Inc., Montebello, California, USA) was used and the sound files were stored in a PC through a PCI sound card (Lynx ONE, Lynx Studio Technology, Inc., Costa Mesa, California, USA). The instrument was tuned according to the Phrygian mode which consists of the musical notes E3 (164 Hz), F3 (174 Hz), G3 (195 Hz), A3 (220 Hz), B3 (246 Hz), C4 (261 Hz) and D4 (293 Hz). Small deviations were observed from the desired tuning frequencies, and these were attributed to the instrument sensitivity to different string tension and ambient conditions, such as temperature and humidity. The strings were plucked by an experienced string instrument player who used a plectrum. There are no conclusive archaeological findings on the

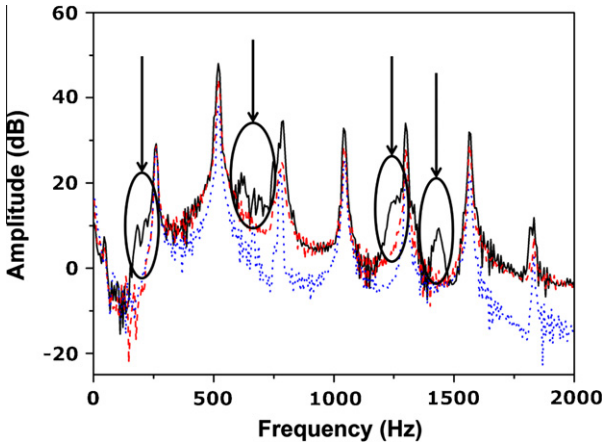

Fig. 2. Note C4 FFT spectrum up to 2 kHz for various time intervals after plucking of the string; continuous line for 0.0–0.1 s, dashed line for 0.1–0.2 s and dotted line for 0.2–0.3 s. Encircled regions contain frequencies outside the main harmonics content which appear only for the first 0.1 s.