ACOUSTIC RADIATION PROPERTIES OF ANCIENT GREEK THEATRE MASKS

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Abstract

Theatre masks were fundamental elements of the ancient Greek theatre tradition, having a dramatic impact on the artistic performance. Apart from the obvious change of the visual appearance of the actors, the masks also altered the acoustic characteristics of their voices. Therefore, both from the spectator's and the actor's point of view these masks significantly modified the acoustic events and inevitably transformed the overall theatrical experience. As the art of theatre evolved, the physical characteristics of the masks were transformed in terms of their size, mouth and ear openings and construction materials. Quite recently, masks replicating the original shape and structure of the ancient prototypes have been constructed based on the relevant literature and on archaeological findings. In this work, such a theatre mask is created in order to measure the corresponding acoustic characteristics. For this, the KEMAR manikin is used and the acoustic impulse responses are measured both from the listener's and the speaker's point of view. Based on semi-anechoic measurements the acoustic effect of the mask is presented for various azimuth angles and the spectral and timbral characteristics of the reconstructed mask are discussed. Two of the authors have already analysed the perceptual effect of the mask on the actors, while studying how they alter the overall artistic performance. In the present work, the above research results are discussed in relation to the obtained acoustic measurements, providing insights on the perceptual impact of the masks' employment.

Keywords

Theatre masks, Manikin measurements, Ancient acoustics

1. Introduction

Theatre masks were fundamental elements of the ancient Greek theatre tradition [1]. The function of the mask was crucial for the ancient Greeks and the mask was more than a typical theatrical gadget. During the Classical period ancient Greeks used the same word for the mask and the face: *prosopon*. And this didn't change until the second half of the 4th century BC when Theofrastos uses for the first time the word *prosopeion* to describe a mask [1]. Therefore, the vase paintings of the 5th century BC never represent an actor wearing the mask as it was considered indistinguishable from the actor's face. However, there are paintings showing the masks before or after the performance. In Fig. 1(a) a painting found in the Pronomos krater, ca 400 BC, illustrates some actors who have just finished performing in a satyr play. On the right side of the illustration, the chorus leader Papposelinus is holding his white long-bearded theatre mask [1, 2].

(a)

(b)

Figure 1 – (a) The chorus leader of the satyrs is holding his mask (from the Pronomos crater 400BC) (b) the constructed generic theatre mask on the manikin

Hence, a typical theatre mask gave the actor a *new face*, helping him to transform to a new identity.

On the other hand, the theatre mask apart from giving the actor a *new face* was also giving him a *new voice* and a new *self sound perception*. Classical masks had a helmet form and the mouth and eyes openings were rather small [1]. Such a construction inevitably changes the acoustic characteristics of the actor's voice both from the spectator's and the actor's point of view. Theatrologists, professional practitioners, actors and directors have discussed the acoustic effect of the theatrical mask by conducting unofficial experiments or by reporting their personal experiences from the use of the masks in contemporary artistic performances [1-6]. However, there is no study in the literature providing acoustic measurements of reconstructed theatre masks.

This work presents a first step towards the understanding of the acoustic properties of the ancient Greek masks. A generic theatre mask has been constructed trying to replicate the essential elements of the ancient Greek mask and not necessarily being exact to any specific mask type. For the construction, one of the authors (the mask-maker T. Vovolis) relied on archaeological findings but also on practical considerations motivated from his experience from masked theatre performances [1, 4]. The constructed theatre mask can be seen in Fig. 1(b) and is made of liquid stone plaster. The mask was measured under semi-anechoic conditions using the KEMAR manikin. The results show that (i) the mask realises an angle-dependent acoustic filter, (ii) the acoustic radiation of the actor's voice is significantly enhanced for the off-axis scenarios and (iii) the mask significantly boosts the actor's own voice in the entrances of his own ear canals. These preliminary results are in line with the reports of actors experiences in contemporary theatre performances employing such masks.

2. Method

2.1 Measurement setup

The measurements have been conducted using the 45 BM KEMAR dummy head. The sweep signals were transmitted through the built-in Mouth Simulator and recorded through: (i) the ECM8000 Behringer measurement condenser microphone for the far-field measurement and (ii) the KEMAR's in-ear microphones for the binaural measurements. The recordings were made at 48 kHz with a 16-bit precision using a RME Fireface soundcard connected to a windows desktop computer via a firewire interface. The software used for the acoustic measurements was WinMLS. For the measurements the source-receiver distance was 1m and three azimuth angles were tested as shown in Fig. 2. Since an anechoic chamber was not available, the measurements took place under semi-anechoic conditions. For each azimuth angle, measurements with and without the mask were obtained. Let $h_1(n)$ be the discrete-time impulse response measured in a certain azimuth angle when the mask is placed on the manikin and $H_1(k)$ the corresponding DFT (n denotes the discrete time index and k the frequency bin). Given that the mouth simulator and the microphone have a relatively flat frequency response, $H_1(k)$ (in dBs) can be expressed as:

$$20\log\left(\left|H_1(k)\right|\right) \approx 20\log\left(\left|H_{room}(k)\right|\right) + 20\log\left(\left|H_{mask}(k)\right|\right) \quad (1)$$

where $H_{room}(k)$ denotes the source to mic room frequency response and $H_{mask}(k)$ the mask filter function. A second measurement of the same setup, but for the manikin without the mask results to a frequency response $H_2(k)$ which corresponds to the combined room response $H_{room}(k)$ at the mic as is excited by the manikin source:

$$20\log\left(\left|H_2(k)\right|\right) \approx 20\log\left(\left|H_{room}(k)\right|\right) \quad (2)$$

By combining Eq. (1) and (2), the magnitude of the mask filter can be extracted through simple subtraction:

$$20\log\left(\left|H_{mask}(k)\right|\right) \approx 20\log\left(\left|H_1(k)\right|\right) - 20\log\left(\left|H_2(k)\right|\right) \quad (3)$$

Note that the above equations assume that the room is a Linear and Time Invariant (LTI) system. Clearly, this is a simplified approximation valid only for the high frequency reverberation components and for the late part of the room response [6], although it may also apply here for the 1 and 1/3 octave smoothed versions of $H_1(k)$ and $H_2(k)$.

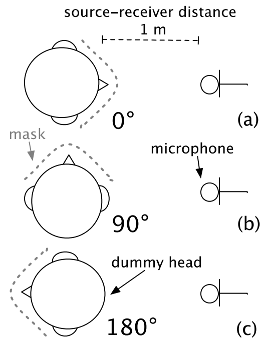


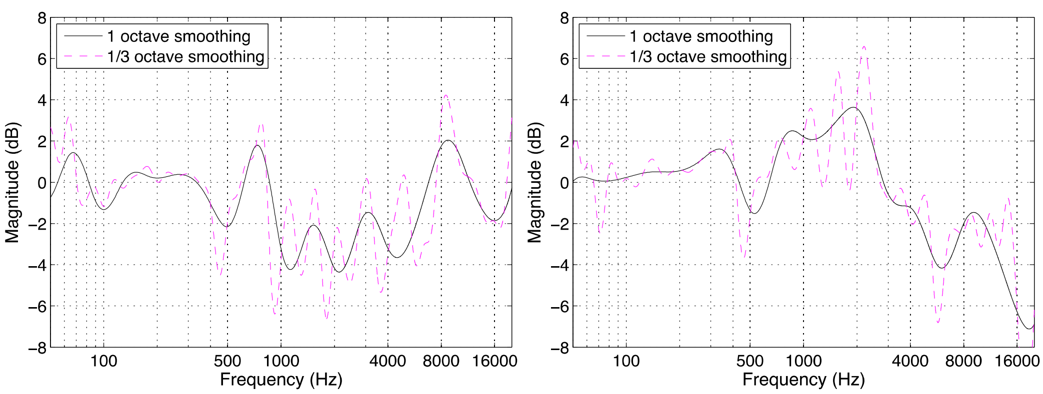
Figure 2 – Setup of the acoustic measurements for a source-receiver distance of 1 m and an azimuth angle of (a) 0°, (b) 90° and (c) 180°

3. Results

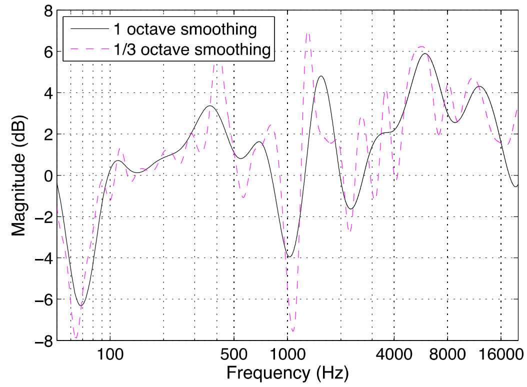
3.1 The frequency response of the mask

In Fig. 3 the smoothed frequency response of the mask is presented for azimuth angles of (a) 0°, (b) 90° and (c) 180° according to the measurement procedure presented in Section 2.2. For the case of 0° (see Fig. 3(a)), the mask boosts specific narrow frequency ranges around 70, 750 and 8000 Hz while attenuating the 1-4 kHz frequency range. For the case of 90° (see Fig. 3(b)) the mask has a low-pass effect and boosts the 0.6-3 kHz frequency range. In Fig. 3(c) two strong notches can be observed at 80 and 1000 Hz whilst the mask boosts mostly the mid and high frequency ranges. The 1/3 octave smoothed responses reveal a comb filtering effect in all tested cases.

The above measurements are in line with reports describing the listener experience of employing such masks in contemporary artistic performances. First, some reviews notice a resonance effect of the masked actor's voice while others refer to a "muffled" effect [1, 2]. The sharp notches/ resonances of the frequency responses for several radiation angles, as well as the comb filtering effect support such observations. Note also that the exact position of the notches/ resonances may vary if the speaker changes the position of the mask relative to his head. Hence, on one hand the mask makers could "tune" the mask to a specific actor's head and on the other hand the actor could "tune" his voice to the specific mask. Such detailed effects were clearly beyond the scope of this particular study.



(a) (b)



(c)

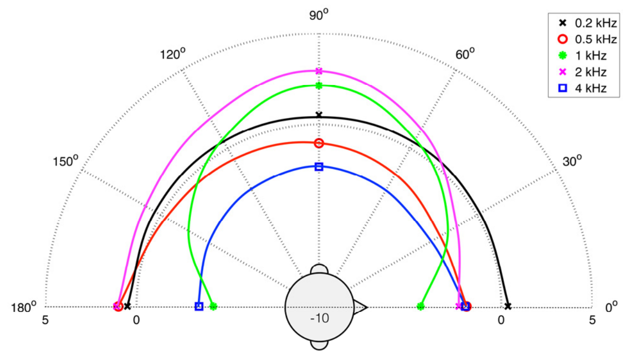
Figure 3 – Mask frequency response measured for a source-receiver distance of 1 m and an azimuth angle of (a) 0°, (b) 90° and (c) 180°

3.2 The acoustic radiation of the mask

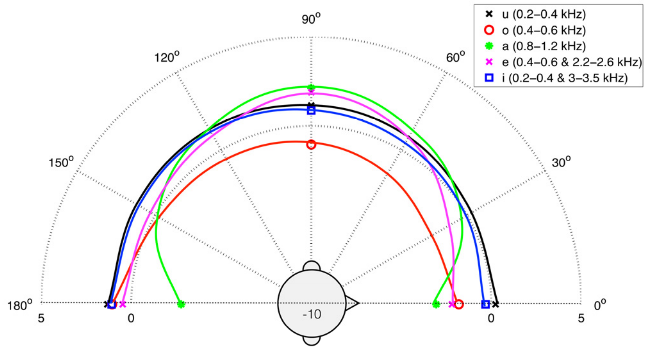
The data presented in Fig. 3 were used in order to extrapolate approximate mask polar diagrams showing the acoustic radiation of the mask for different frequencies. In Fig. 4(a) the approximate polar diagrams of the mask for 0.2, 0.5, 1, 2 and 4 kHz are shown. The mask seems to slightly boost the 0.2 kHz frequency region for all radiation angles, contrary to the 4 kHz region that is attenuated. The 1 kHz region is boosted on the sides of the actor's head and is attenuated on his back. The 2 kHz region is boosted on the back and on the sides of the actor while being attenuated in front. Finally, the 0.5 kHz region is boosted on the back of the actor and attenuated elsewhere.

Fig. 4(b) presents an approximate polar diagram showing the correspondence of the acoustic radiation of the mask to the frequency regions of the common vowel formants. Note that the vowels typically correspond to the "cries" highlighting important and dramatic moments in ancient Greek tragedies. It can be seen that for the off-axis cases, apart from the vowel "o" on the sides of the actor and the vowel "a" on the back of the actor, all other formants are significantly boosted. However, attenuation can be noted for the on-axis case where in principle the voice emission is anyway louder.

Most reports [1-5] refer to a boost on the off-axis speech level when the actors wore their masks, an effect that it has been verified here from the acoustic measurements, especially for the frequency regions corresponding to the formants of the common vowels. Note however that there is great uncertainty about the pronunciation of the ancient Greek language and since the ancient Greek vowel formants could have been generated in a different way to the Modern Greek vowels [7] used here for compiling the frequency regions in Fig. 5 [8].



(a)



(b)

Figure 4 – Approximate polar patterns showing the mask's radiation for (a) several frequencies and (b) for frequency regions corresponding to the common vowel formants

3.3 The binaural self-perception effect

In Fig. 5 the binaural self-perception effect (in the entrance of the left and right ear canals of the speaker, as measured by the manikin's in-ear mics) is presented for an azimuth angle of 0°, and clearly when the mask is fixed on the head, the above azimuth angle is the only realistic measurement condition. The mask significantly enhances the speech signal even when the ears of the speaker are not covered by the helmet-mask, as was the case of the generic mask here. Note, that it is unclear if such masks were covering or not the actor's ears. A strong boost in the high frequency region is noted which will be probably smaller if some artificial hair was adapted to the mask, as was the case in most masks pictured in ancient paintings. Clearly, in all cases, the binaural self-perception effect of the measured mask is pronounced and this may explain the difficulty of the actors to perform with such theatrical masks without proper training and lengthy adaptation [1-5].

4. Discussion and conclusion

The methodology and results here present a first step towards the understanding of the acoustic properties and functionality of ancient Greek theatre masks, even if there is some uncertainty concerning their exact replication via the studied generic prototype. From the results, appears that these masks could have an angle-dependent filtering radiation effect and in general, they would enhance projection and possibly speech intelligibility for the off-axis angles for the actor's voice. Furthermore, they significantly modify the actor's self-voice perception and could potentially result to an adaptation of his vocal delivery.

However, this preliminary work leaves many questions unanswered: how did the acoustic characteristics of the mask change with respect to different positions of the fixing the mask on the head of the actor? How did the actor perceive the other actors' voices on stage? What was the acoustic coupling between the mask and the ancient theatres? Would such off-axis acoustic effects benefit the actor's voice reflections on the stage walls when he was located on the stage (*proskenion*) i.e. at acoustically more adverse positions? What were the exact materials that these masks were made from? In a future work the authors will try to answer such questions by extending the present results and by using improved reconstructions of ancient Greek masks.

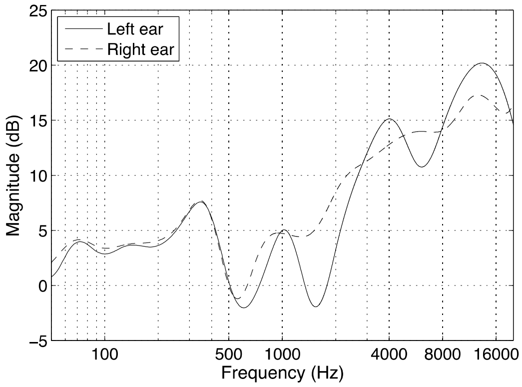


Figure 5 – Mask frequency response measured at the listener's ears for the left and right ear (1 octave smoothing)

References

[1] T. Vovolis, "Prosopon, the acoustical mask in Greek Tragedy and in Contemporary Theatre", Dramatiska Institutet, Stockholm (2009)

[2] C. Vervain and D. Wiles, "The Masks of Greek Tragedy as Point of Departure for Modern Performance", New Theatre Quarterly **17(2)**, 254-272, 2001

[3] A. Varakis, "Research on the Ancient Mask", Didaskalia **6.1**, 2000

[4] T. Vovolis and G. Zamboulakis, "The Acoustical Mask of Greek Tragedy", Didaskalia **7.1**, 2007

[5] A. R. Cohen, "Can You Hear Me Now? – Implications of New Research in Greek Theatrical Masks", Didaskalia **7.1**, 2007

[6] B. Blesser, "An interdisciplinary synthesis of reverberation viewpoints", Journal of the Audio Engineering Society **49(10)**, 867–903, 2001

[7] W. S. Allen, "Vox Graeca: A guide to the pronunciation of Classical Greek (3rd edition)", University Press, Cambridge (1987)

[8] A. Arvaniti, "Greek Phonetics: The State of the Art", Journal of Greek Linguistics **8**, 97-208, 2007