An ultrasound investigation of Didgeridoo articulations

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1. INTRODUCTION

The didgeridoo is an instrument native to Australia, traditionally made out of a eucalyptus tree naturally hollowed out by termites. These days, didgeridoos are made from a wide range of materials, including bamboo, glass, cactus, or even PVC pipe. They are simple tubes, 1-2 meters long, with bees-wax at one end serving as the mouthpiece. They have no holes or moving parts; to create different sounds players can change the amount of airflow from the lungs, manipulate their oral cavity, or even sing into the didgeridoo as they play (Schellberg & Langham 1994).

Past research on the didgeridoo has focused on vocal tract resonances (Tamopolsky et al. 2006), lip motion (Fletcher et al. 2001) and the acoustic properties of didgeridoos themselves (Amir 2004). However, no research has yet been done on how players manipulate their tongues to create different sounds. The goal of this study is to fill this gap, using ultrasound imaging (Gardner & Stone 2009). We focus on circular breathing and five typical didgeridoo vocalizations, termed here undulation, piston, alveolar trill, alveolar ejective and velar ejective. We hope that this preliminary articulatory investigation will increase our understanding of the tongue articulations used in didgeridoo playing, and will also provide a valuable visual tool for teachers and learners of the instrument.

2. METHOD

A single adult male (one of the co-authors) participated in the experiment, who has been playing the didgeridoo for approximately 3 years. Using a GE Logic E ultrasound machine with an 8C-RS convex transducer fixed under the chin, tongue articulation was recorded during circular breathing and 5 sounds of interest, described in detail below. Figure 1 illustrates the experimental set-up: with the help of a microphone stand, the player held the transducer fixed under his chin with one hand. The other hand stabilized the didgeridoo, which was supported by a box at a relatively horizontal angle - necessary in order to maintain the chin in an orientation suitable for fixing the probe. In addition to the ultrasound recording, the audio signal was recorded for acoustic analysis (not presented here) using a Senheiser ME-55 directional microphone (with a K6 capsule).

The video and audio signals were synchronized through a Mackie 1402-VLZ3 mixer and captured on an external PC computer using Sony Vegas Pro 8. From the ultrasound video, sequences of stills were extracted illustrating the tongue trajectories in each sound of interest. These are described in detail in the following section.

Fig. 1. Experimental set-up.

3. RESULTS

The following stills are taken from the ultrasound video recordings. They all represent a midsagittal (from the side) view of the tongue; the white line towards the top of the image represents the tongue contour, with the tongue tip on the right. Circles have been superimposed on the tongue contour to help view the shape of the tongue.

Figure 2 illustrates tongue movement in circular breathing, a method which allows didgeridoo players to play indefinitely, without needing to pause for air. The cheeks are initially extended, providing the extra air space that is needed for this articulation. The tongue first moves towards the back of the mouth (A-B-C), until it has completely blocked off airflow at the back of the mouth (D). At this point the cheeks begin to tense and are made smaller, aiding to push out the air that is required to maintain phonation. As soon as the oral cavity has been closed off (D), the velum is lowered, allowing the player to breathe in through their nose while simultaneously blowing out from their now closed off oral cavity. The tongue then acts as a syringe (E-F-G-H), gradually pushing air out of the mouth at a rate that is fast enough to maintain phonation, but slow enough to allow the player to breathe in a sufficient amount of air. While the tongue tip is still closing off the oral cavity (H), the velum is lowered, allowing air to flow from the lungs to the oral cavity once again.

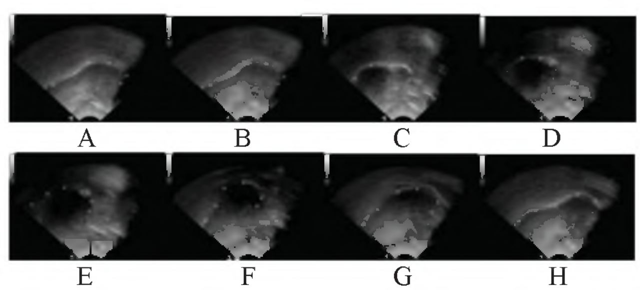

Fig. 2. Circular breathing.

In addition to circular breathing, the articulations required for five typical vocalizations were recorded. The first one is termed the “undulation” (Figure 3). The articulation begins with the tip of the tongue at the alveolar ridge (A). As the articulation continues, the tongue body moves back through post-alveolar (B), palatal (C) and velar (D) regions. The undulation can be a cyclic articulation, so even before one cycle has been completed, the tongue tip raises in anticipation of the next undulation (E). Throughout this articulation, the tongue is narrow enough for air to pass by the sides of the tongue.

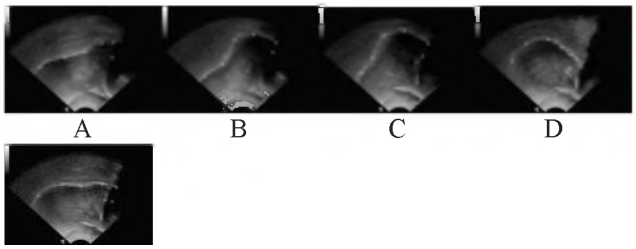

Fig. 3. The undulation.

Unlike the undulation, the "piston" (Figure 4) is a quick moving articulation. Its amplitude is mainly determined by how much volume change there is in the mouth and how quickly this occurs. The tongue begins in rest position (A), and is extremely retracted during the first part of the piston articulation (B) - a less retracted tongue would produce less amplitude. The tongue then shoots forward in the mouth (C), filling the entire oral cavity and causing a high amplitude burst - a slower movement of the tongue would produce smaller change in amplitude or no difference in amplitude at all. At this point, there is a complete stop at the front of the mouth. The tongue body begins to take on a concave shape as the air pressure builds up behind it (D), before the next articulation begins.

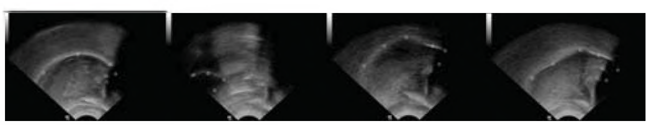

Fig. 4. The piston.

The "alveolar trill" (Figure 5) used in didgeridoo playing is very similar to that used in speech. From a rest position (A), the tongue is extended and flattened (B), and trilling occurs at the tongue tip (C). Acoustically, the effect of the trill can sound like a growl, and this is often what it is called by didgeridoo players.

Fig. 5. The alveolar trill.

Many different stops are used in playing the didgeridoo, differing in intensity and place of articulation. The last two sounds described here are the alveolar and velar ejectives. In the alveolar ejective (Figure 6), the tongue starts in rest position (A) and moves forward to form a closure at the alveolar ridge (B), at which point a complete stop of airflow is created simultaneously in the oral cavity and at the glottis. The larynx is then raised, resulting in a sudden increase in oral pressure behind the tongue, giving it its unique shape (C). The tongue is then pulled back from the alveolar ridge (D), allowing air to rush out of the mouth. Shortly thereafter, the glottis opens and larynx lowers to provide continuous airflow from the lungs once again.

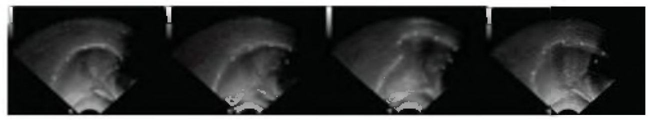

Fig. 6. The alveolar ejective.

The velar ejective (Figure 7) is similar to the alveolar ejective (Figure 6), except that the oral closure occurs in the velar region (compare Figure 6B and 7B). In Figure 7, frame A represents the initial rest position; frame C the release of the velar closure.

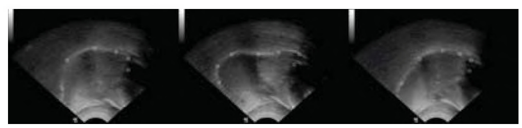

Fig. 7. The velar ejective.

4. DISCUSSION

As far as we know, this study provides the first direct articulatory view of the tongue articulations used in producing some of the typical vocalizations of the didgeridoo. We hope that this study will act as a useful guide to teachers and learners of the didgeridoo, as well as to others who are interested in understanding the articulatory basis of the didgeridoo's acoustic properties.

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