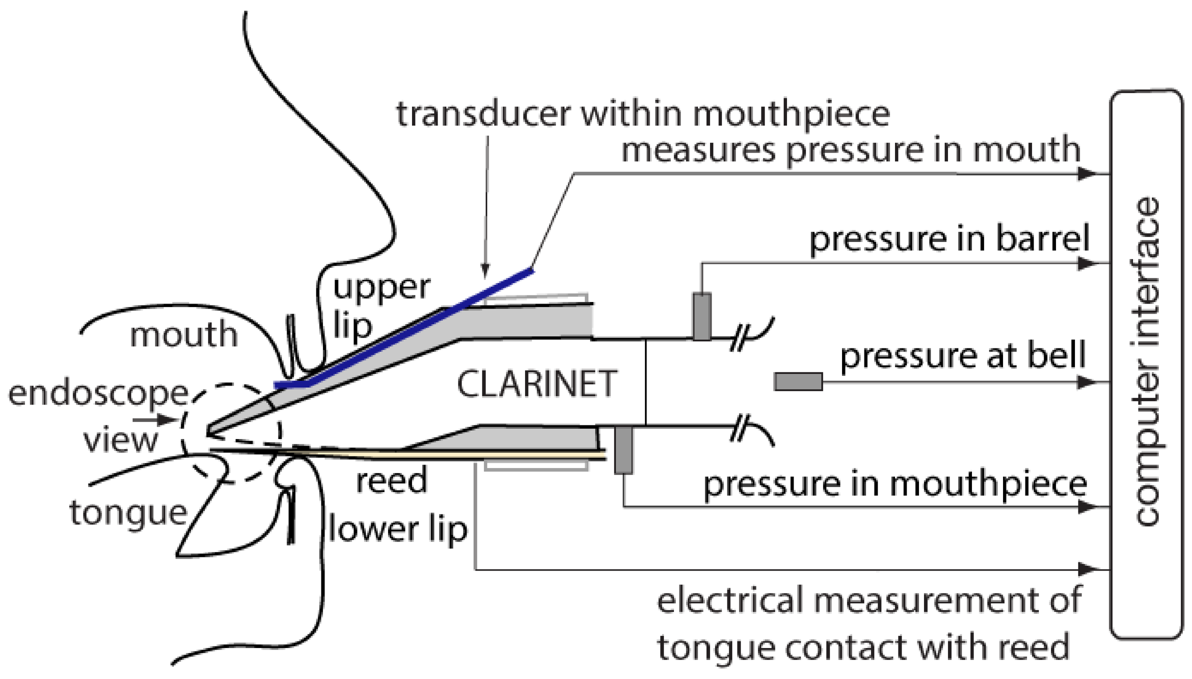
Tongue and reed motion producing initial transients in the clarinet

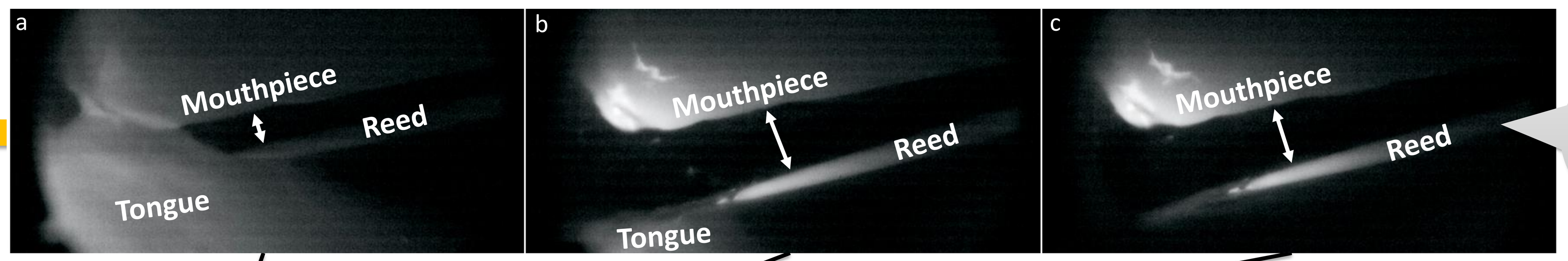
Lauren Inwood*, John Gray, Weicong Li, André Almeida, John Smith, Joe Wolfe
School of Physics, The University of New South Wales, Sydney, 2052, Australia

Initial transients (articulation) are important to musicians. • How do clarinettists use the tongue to start notes? • How does reed motion relate to sound? • Why does the standing wave grow and why is the rise exponential? • Is the mechanical energy of the reed involved?

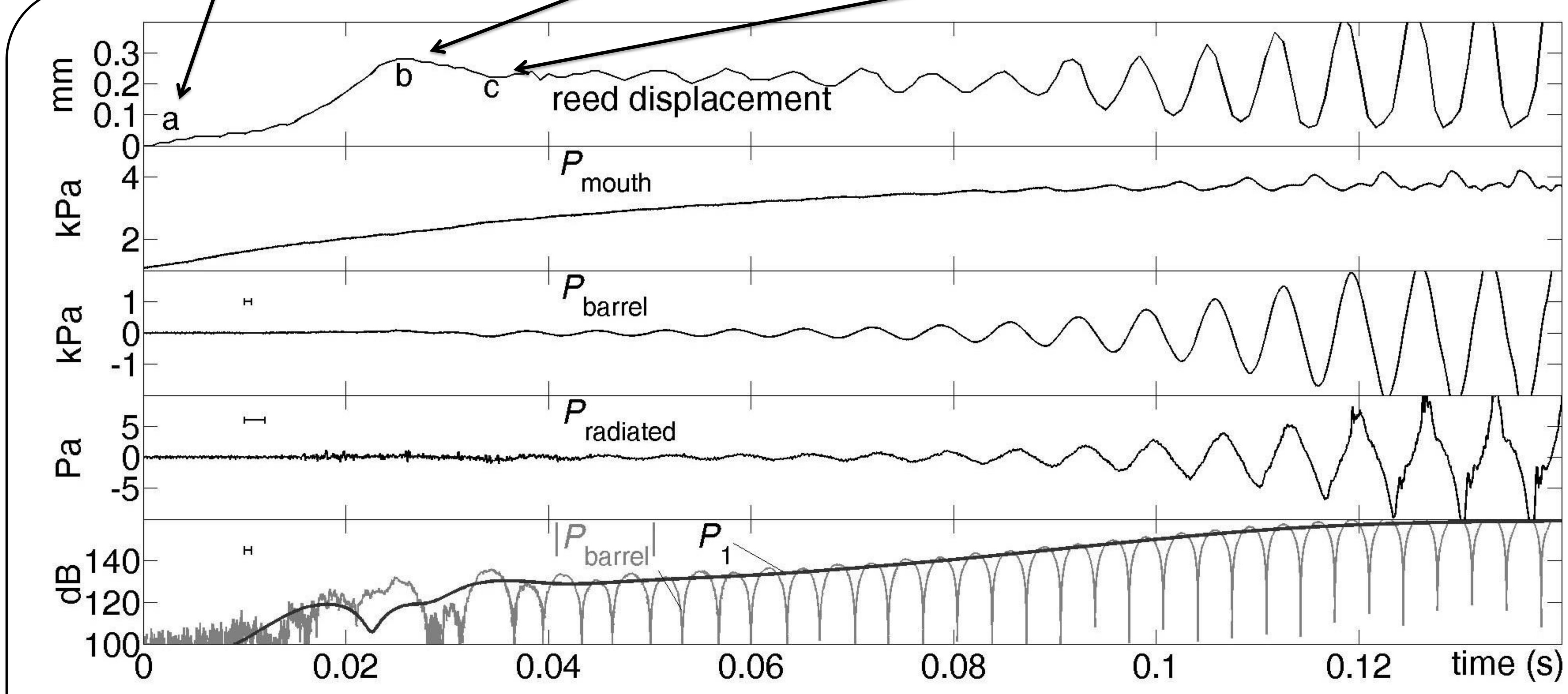
Materials and Method

Synchronised measurements of tongue position and reed-mouthpiece separation (1200 to 8000 frames.s^{-1}), mouth pressure, pressure in instrument and at bell.





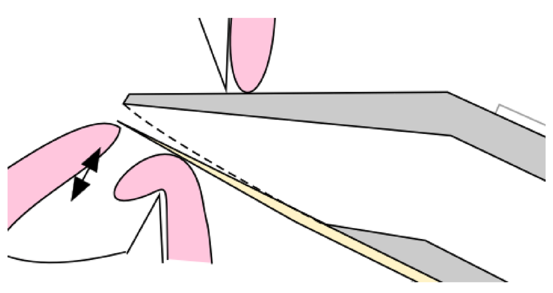
Ask me for videos and sound



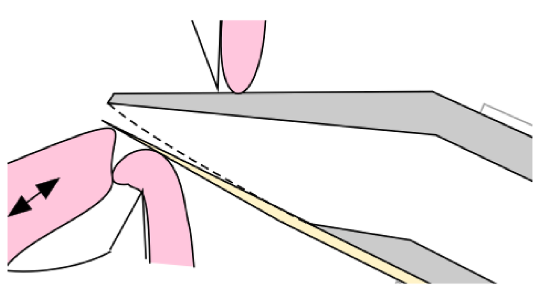
(a) Tongue closes reed against mouthpiece. **(a-b)** Saliva pulls reed past equilibrium position, then **(b)** releases it. **(b-c)** Reed elasticity returns it to equilibrium over 6 ms, reducing air flow into mouthpiece. (Reed+lip) is overdamped, so all of reed's kinetic and potential energy is lost. A pulse of reduced flow travels down the bore, is reflected and returns to reed. At each interaction with the reed, the pulse is amplified with a nearly constant gain, producing the exponential increase. Radiated sound has stronger high harmonics because the bell radiates these better. (Student subject, tip-to-tip tonguing technique.)

The **bars** ├┤ show (distance of microphone from reed)/(speed of sound). **Notes**: (i) Aperiodic behaviour before standing wave is established at $t \sim 0.04$ s. (ii) Exponential rise in fundamental, p_1 (0.065 s < t < 0.11 s) (iii) Mouth signal is smaller than bore signal because the acoustic impedance of the vocal tract is smaller than that of the bore. For exotic effects, however, players can make the mouth resonances dominate [2].

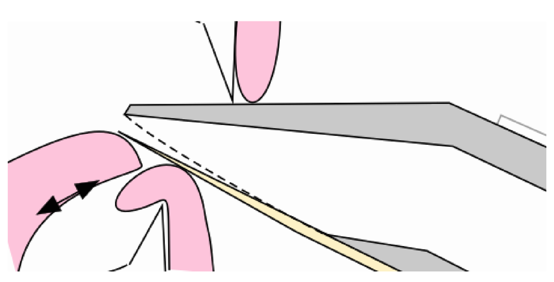
Tonguing styles and variation



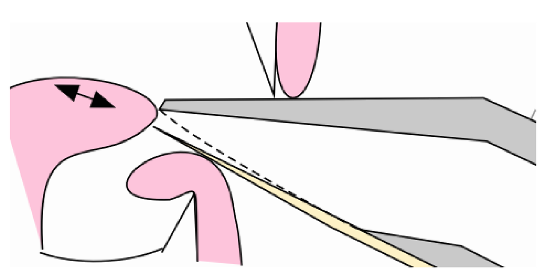
Tip-to-tip (1 expert, 1 student, 1 casual)



Anchor tonguing (1 casual player)



Tip-to-near-tip (2 students)



Edge-on (1 expert)

Normal Articulation

More experienced players use less tongue
Tip-to-tip: tongue pulls away approximately perpendicular to the reed
Anchor tonguing & tip-to-near-tip: 10-20º more acute

Pitch

No general dependence of tongue tip on pitch observed, but see [1] re. back of tongue

Dynamics

Louder (*ff*): more obtuse tongue release angle
Softer (*pp*): more acute angle for tip-to-tip

Accent

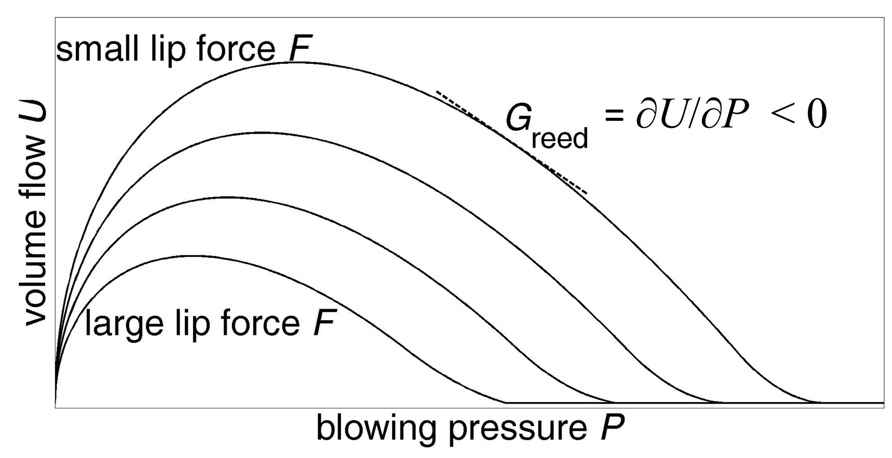
Tongue: faster, more active, "sweeping" motion
Larger initial reed-mouthpiece separation

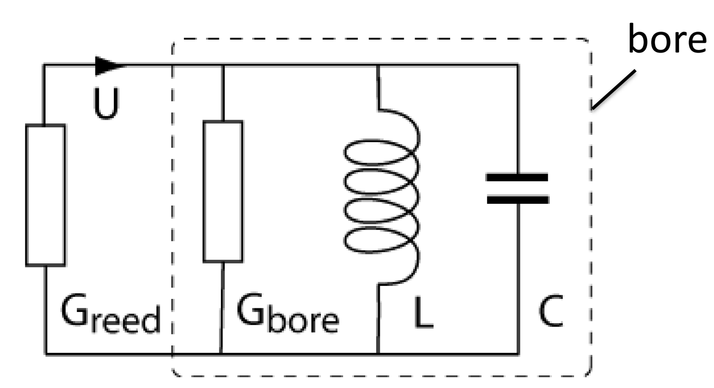
Staccato

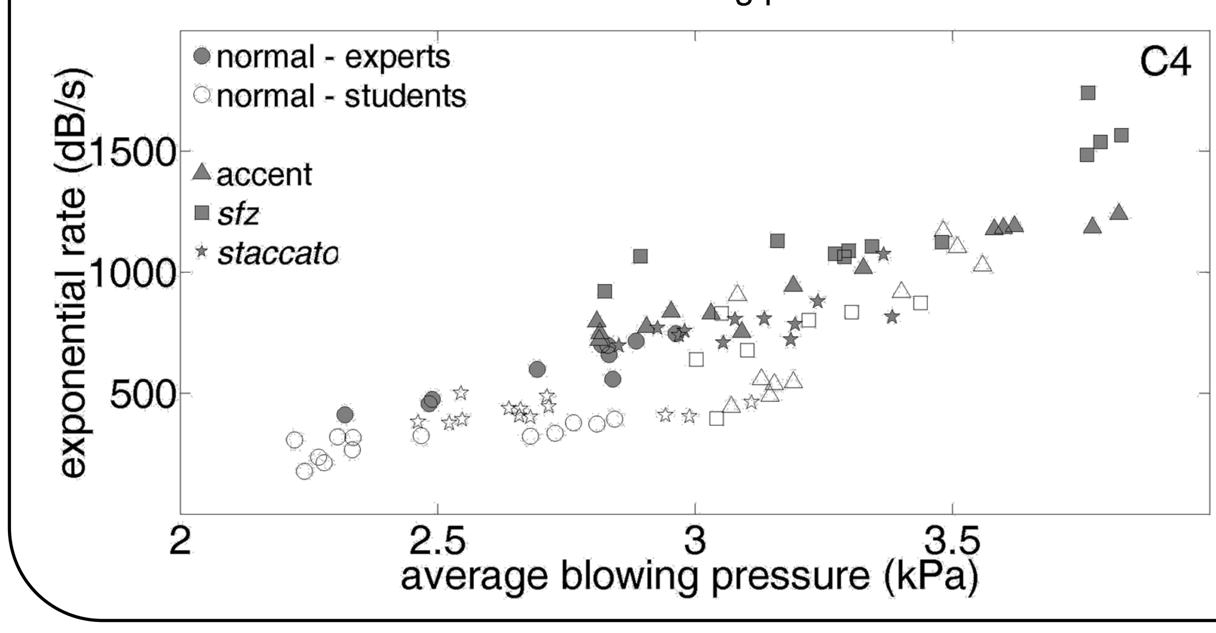
Variability among players: approx. half of subjects used a tongue touch to end the note

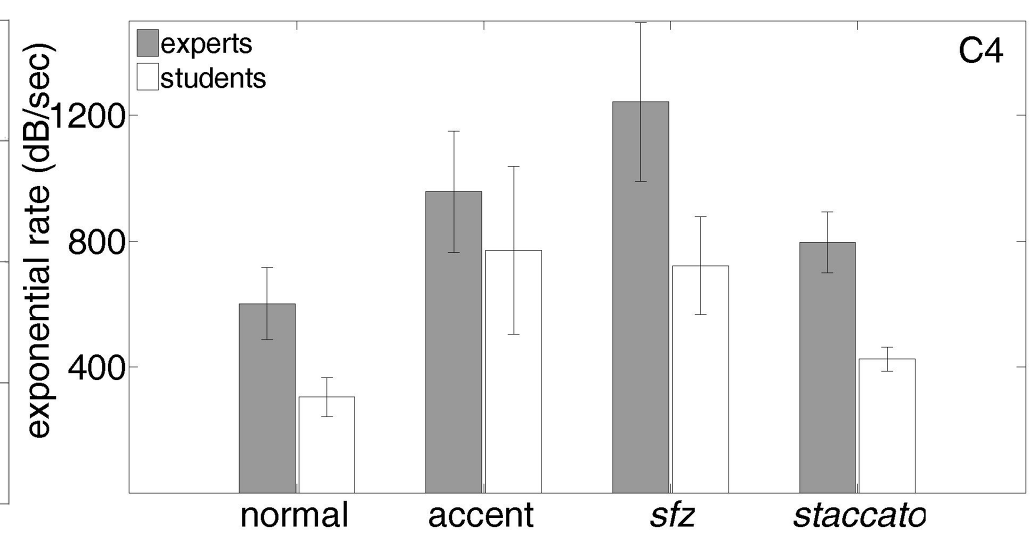
How does the reed 'amplify' an AC signal?

How does the air flow U depend on blowing pressure P and lip force F? At low P, the 'Bernoulli term' dominates: $P \sim \frac{1}{2}\rho v^2$, so $U \sim A(2P/\rho)^{1/2}$, where ρ is the density and A the aperture. But large P shuts the reed against the mouthpiece, so A and U go to zero. F also tends to close the reed: see graph. The negative $\partial U/\partial P$ region gives a negative AC conductance (region shown). The bore resonance behaves like a parallel G,L,C resonance in this circuit. Players vary the exponential increase rate by controlling P and F and thus G_{reed} [3,4].









Conclusions

- After release by the tongue, the reed, overdamped by the lip, quickly comes to mechanical equilibrium, losing all its mechanical energy.
- The sudden change in aperture produces a sudden change in air flow which, from multiple reflections, builds a standing wave.
- The negative AC conductance of the reed converts DC to AC power and, when large enough to overcome the (small) losses in the walls and (smaller) radiated sound, produces an attack that is exponential (until nonlinear terms dominate).
- Players produce different rise rates by controlling blowing pressure and lip force, which control reed conductance.
- They coordinate this with tongue release to vary the initial amplitude and attack duration.
- Players have qualitatively different tonguing styles, but can still produce similar effects.

References (most of these at www.phys.unsw.edu.au/jw/publications.html For simpler introductions, search 'music acoustics')

1. Anfinson, RE (1969). "A cinefluorographic investigation of selected clarinet playing techniques" *J. Res. Music Educ.*, **17**, 227-239.
2. Chen, J-M, Smith J and Wolfe, J (2009) "Pitch bending and *glissandi* on the clarinet: roles of the vocal tract and partial tone hole closure" *J. Acoust. Soc. America*, **126**, 1511-1520.
3. Li, W, Almeida, A, Smith, J and Wolfe, J (2016) **"**The effect of blowing pressure, lip force and tonguing on transients: a study on a clarinet-playing machine**"** *J. Acoust. Soc. America*, **140**, 1089–1100.
4. Li, W, Almeida, A, Smith, . and Wolfe, J (2016) **"**How clarinettists articulate: the effect of blowing pressure and tonguing on initial and final transients" *J. Acoust. Soc. America*, **139**, 825-838.

* This poster includes work from Weicong Li's PhD research, from undergraduate vacation projects of John Gray and Lauren Inwood, and earlier work by the other authors.