

# Effect of the shape of mouth pressure variation on dynamic oscillation threshold of a clarinet model



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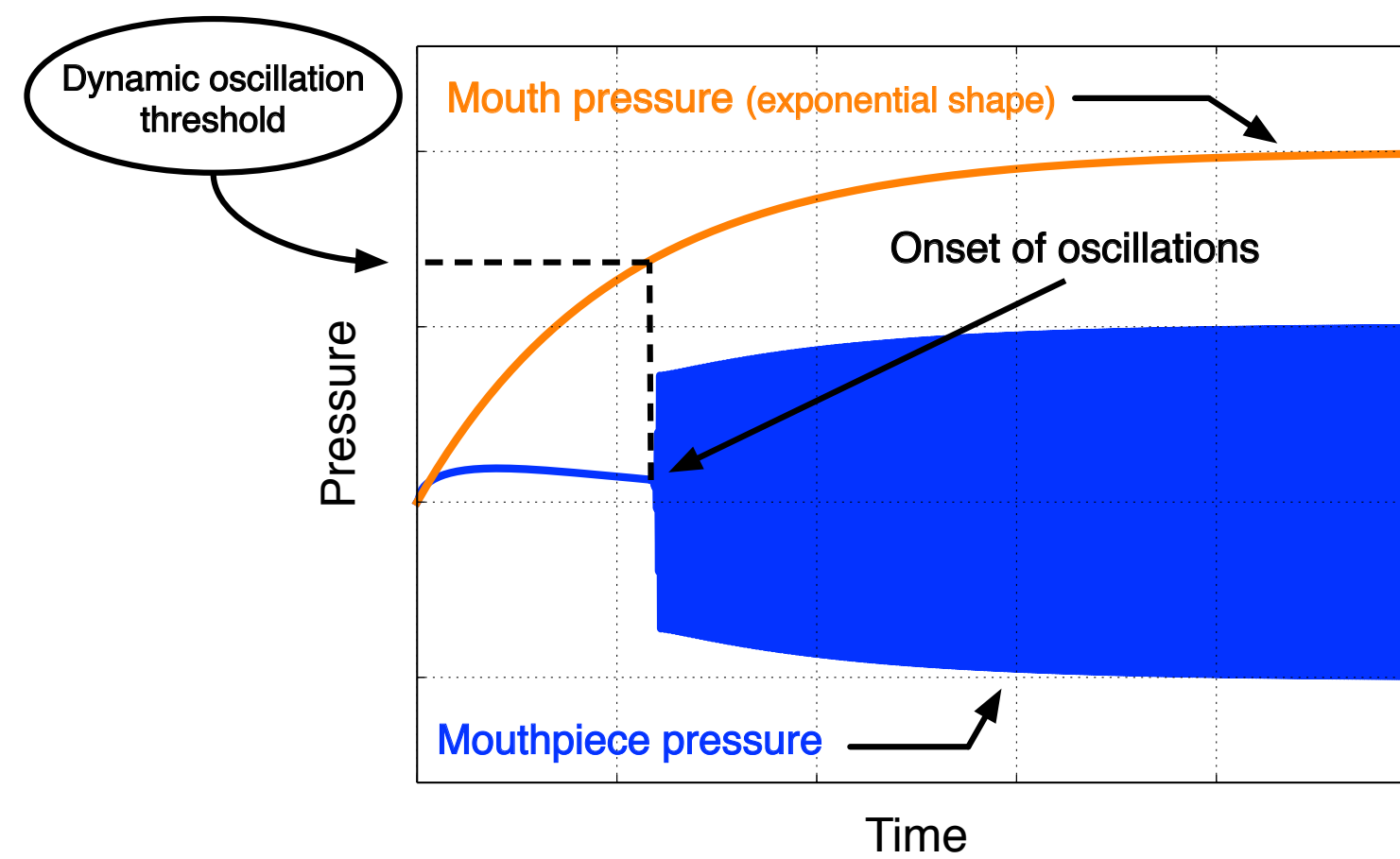
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## Context and aim of the work

### General Context

Study of attack transient in clarinet playing by analysis of a model of sound production



**Aim:** analytical prediction of the dynamic oscillation threshold\* for an achetypal (exponential) profile of time-varying mouth pressure

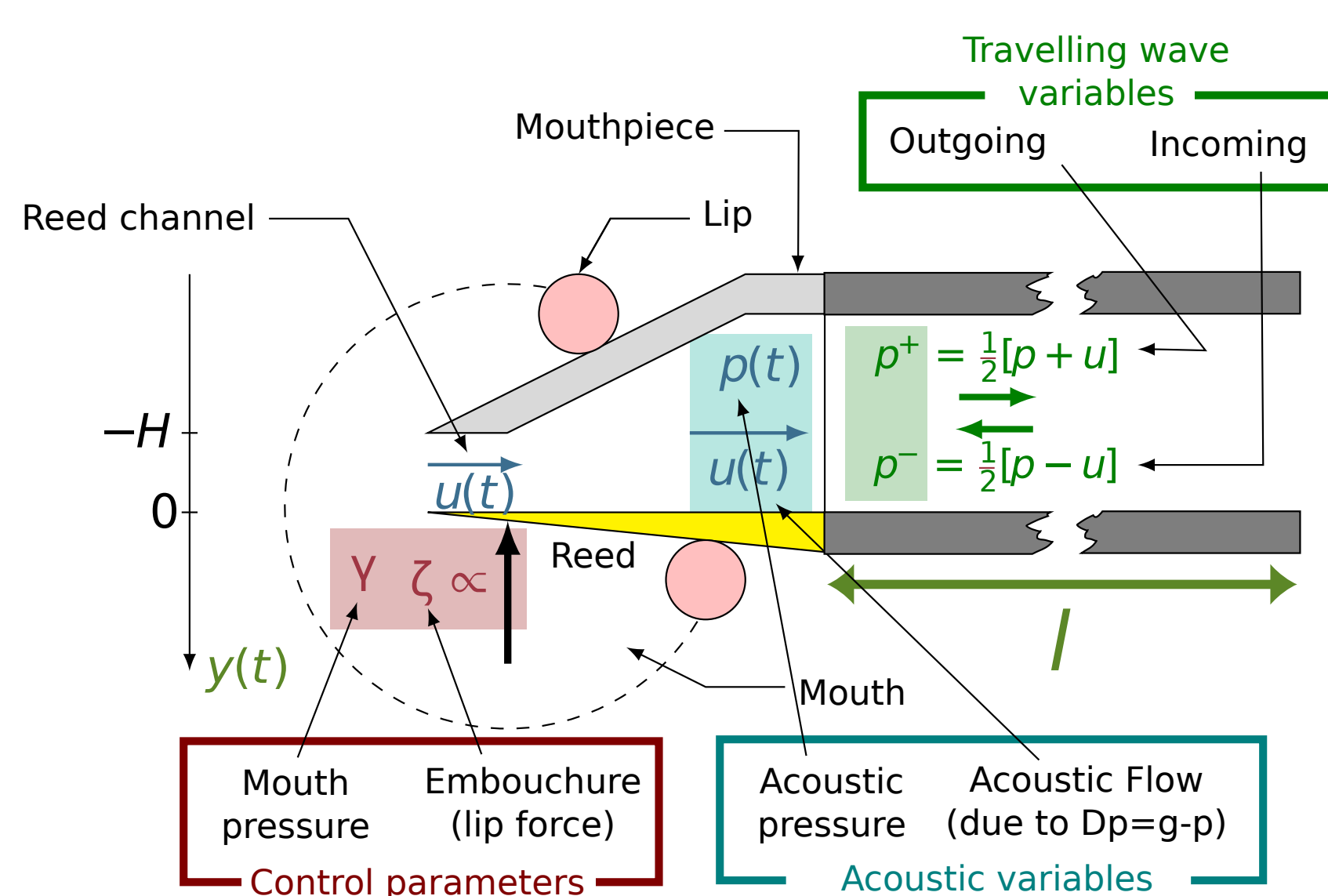
**Means used:**

- Simplified clarinet model (iterated map)

\* **Dynamic oscillations threshold:** value of the time-varying mouth pressure at which the onset of oscillations occurs.

## State of the art

### Iterated map for clarinet-like systems



#### Assumptions:

- The reed is assumed to behave as an ideal massless and undamped spring
- Plane wave ( $p^+$  and  $p^-$ ) propagation cylindrical resonator is without losses or dispersion

**Iterated map:**  $p_n^+ = G(p_{n-1}^+, \gamma)$

The time step  $n$  corresponds to the round trip time  $\tau = 2l/c$  of the wave with velocity  $c$  along the resonator of length  $l$ .

### Dynamic oscillations threshold for linearly varying mouth pressure

When the mouth pressure increases linearly, the clarinet model is written as follows:

$$\begin{cases} p_n^+ = G(p_{n-1}^+, \gamma_n) \\ \gamma_n = \epsilon n \end{cases}$$

Based on a general method given by Baesens [1], Bergeot *et al.* [2, 3] provide a numerical and analytical investigation of the dynamic oscillation threshold of this clarinet model.

#### Major conclusions of [2, 3]:

- **Two operative regimes:**
  - The **Deterministic Regime:** In this case, the noise does not affect the bifurcation delay which does not depend on the slope  $\epsilon$  of the blowing pressure.
  - The **Sweep-Dominant Regime:** In this case, the bifurcation delay is affected by the noise, becoming larger as the blowing pressure  $\gamma$  is increased quicker.
- Good agreement between analytical prediction of the dynamic oscillation threshold and numerical simulation for both operative regimes
- Suddenly interrupting a steady pressure increase can trigger earlier oscillations ([4]), even before the dynamic threshold

#### Open questions:

- Is it possible to trigger oscillations at lower pressures with a non-linear increase of mouth-pressure rather than a linear one?
- Can a profile that stabilises without discontinuity of derivative delay the oscillations compared to a sudden interruption?

## Results

### Prediction of dynamic oscillation threshold with exponential variation of $\gamma$

System with exponential time-varying parameter ( $\gamma$ )

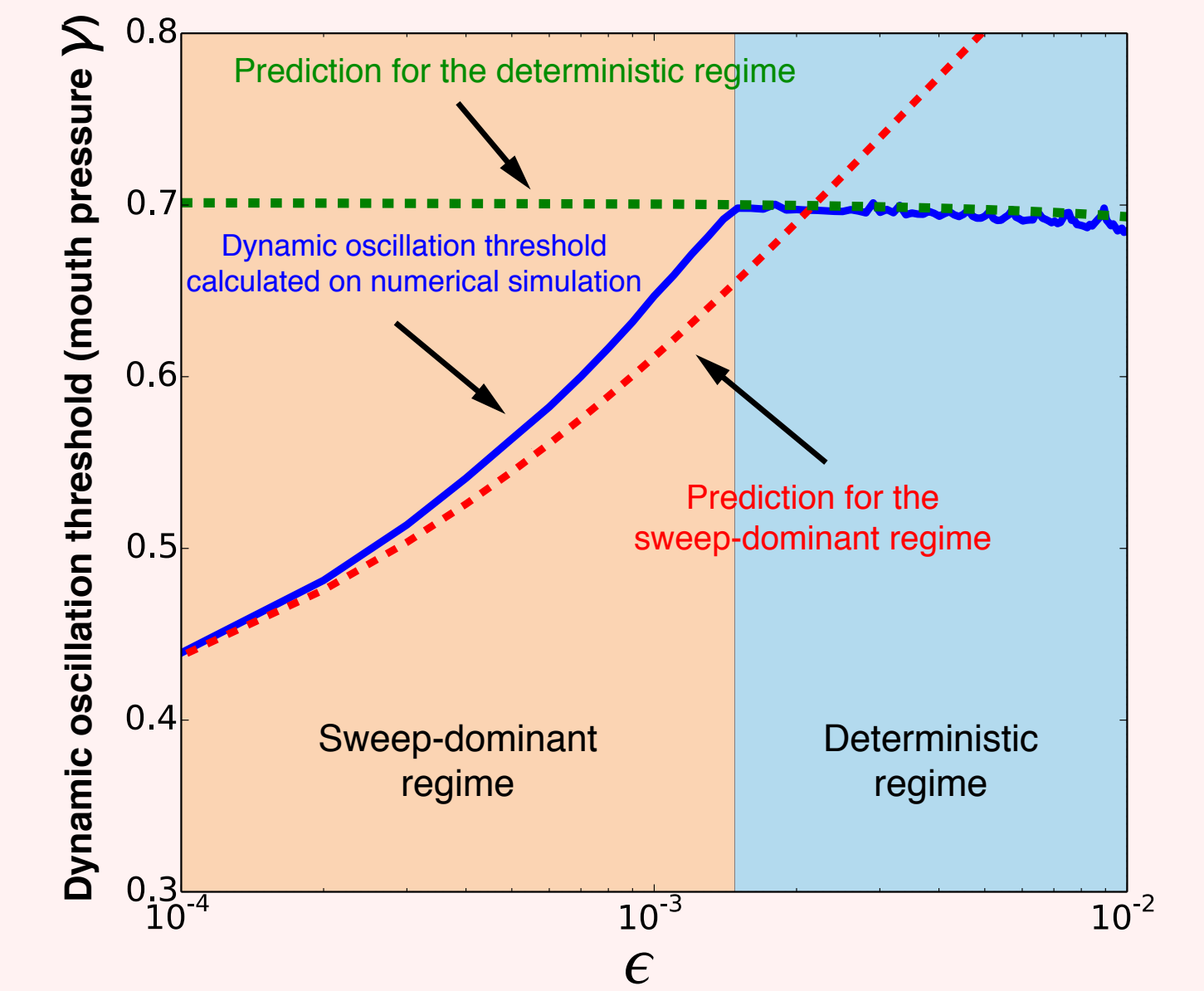
$$\begin{cases} p_n^+ = G(p_{n-1}^+, \gamma_n) \\ \gamma_n = \gamma_M (1 - e^{-n\epsilon}) \end{cases}$$

Change of variable  
 $\eta_n = \ln(\gamma_M / (\gamma_M - \gamma_n))$

System with linear time-varying parameter ( $\eta$ )

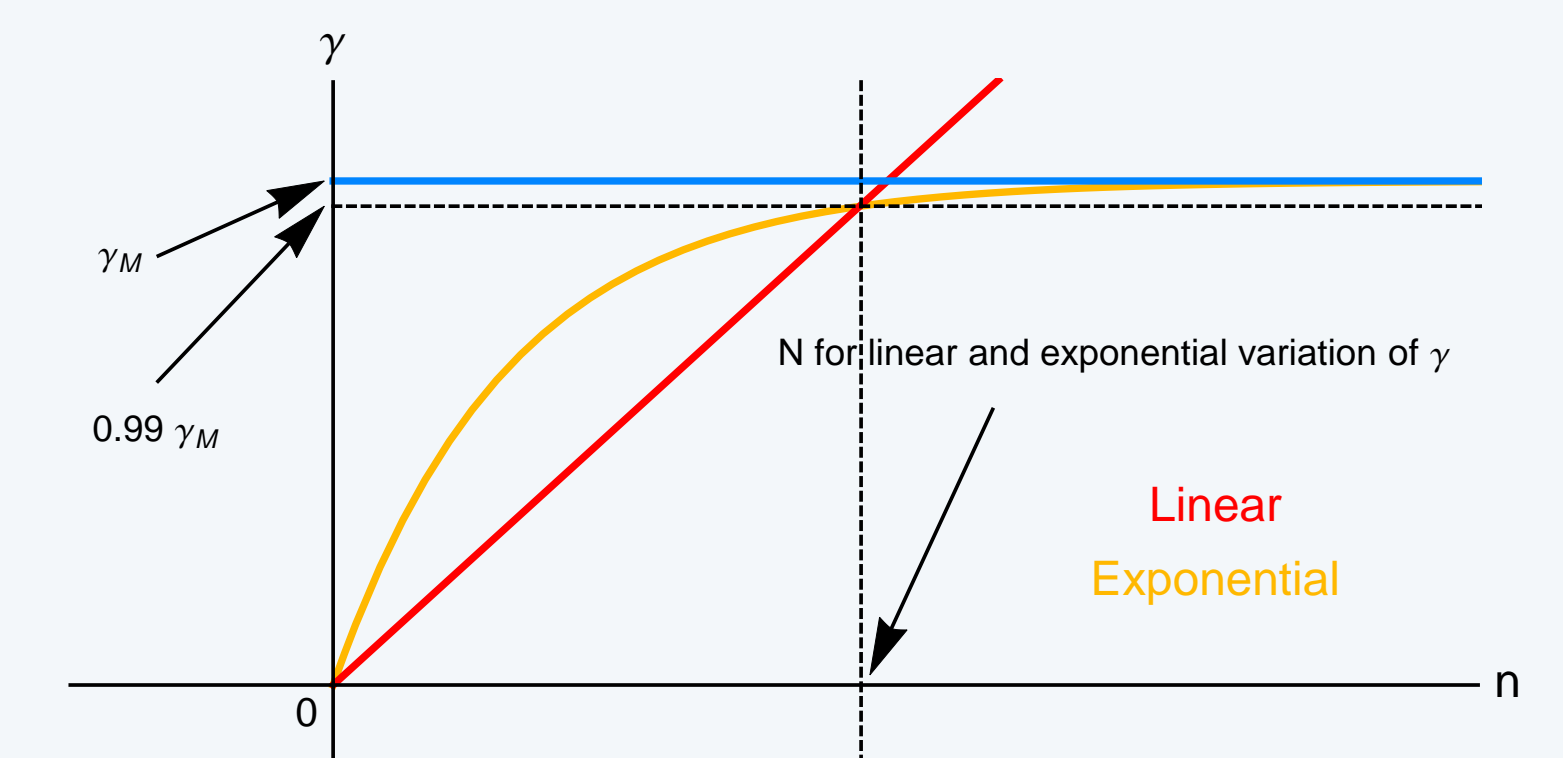
$$\begin{cases} p_n^+ = H(p_{n-1}^+, \eta_n) \\ \eta_n = \epsilon n \end{cases}$$

System with linear time-varying parameter  
↓  
Results obtained for linear variation of the mouth pressure can be used  
↓



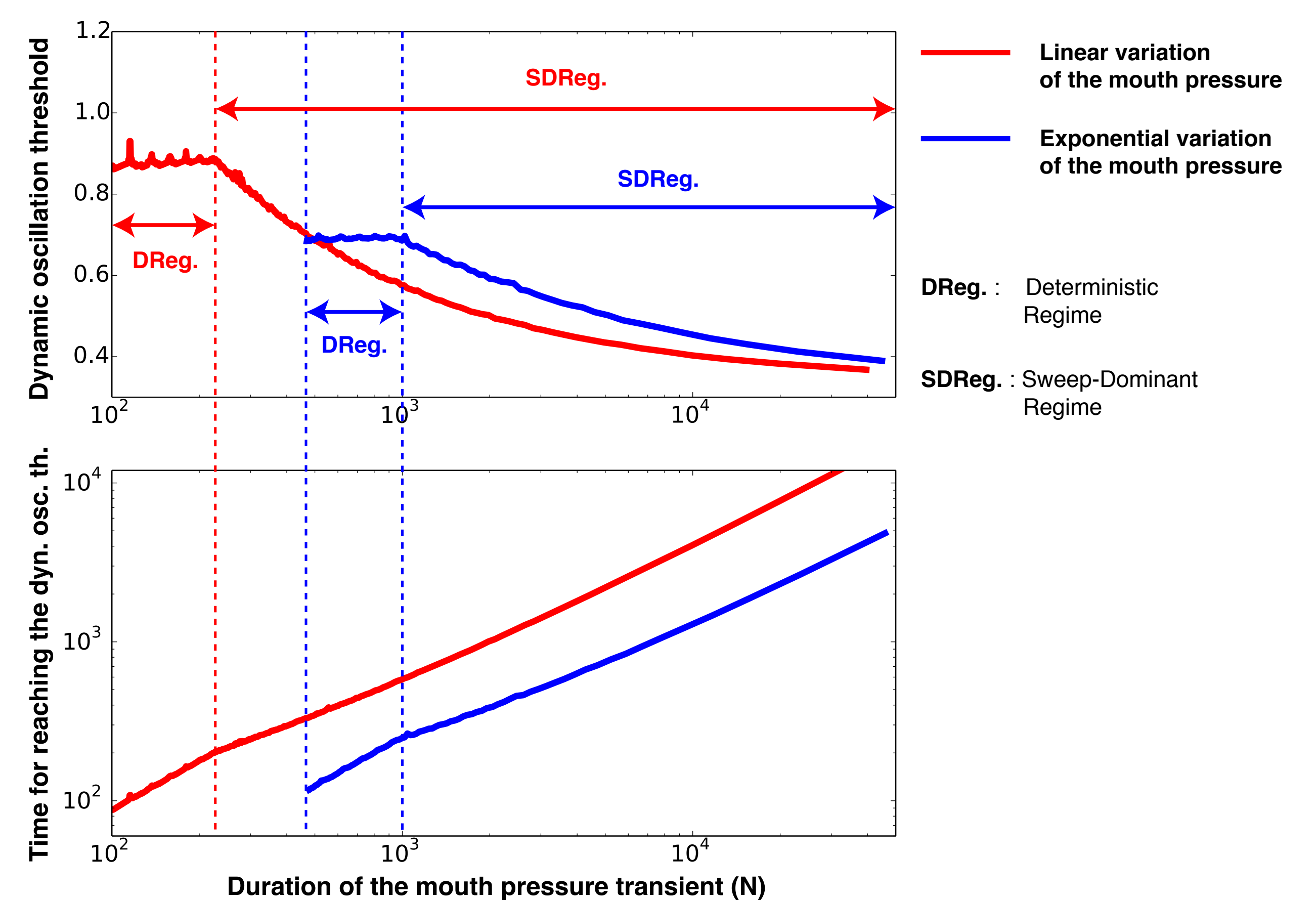
### Linear vs. exponential variation of the mouth pressure

Dynamic oscillation thresholds are compared between linear and exponential time profiles reaching 99% of the target value  $\gamma_M$  at the same time  $N$ .



### Results

- **Dynamic oscillation threshold:**
  - DReg.: larger for linear variation of the mouth pressure
  - SDRReg.: larger for exponential variation of the mouth pressure
- **Time for reaching dynamic oscillation threshold:**
  - Always larger for linear variation of the mouth pressure



### Conclusion

- Prediction of the dynamic oscillation threshold of a clarinet model for exponential variation of the mouth pressure
- Preliminary investigation of the effect of the shape of mouth pressure variation on clarinet attack transient

According to this ideal model, an exponential increase of the mouth pressure is best suited to trigger sooner the attack transient

### References

- [1] C. Baesens. Slow sweep through a period-doubling cascade: Delayed bifurcations and renormalisation. *Physica D*, 53:319–375, 1991.
- [2] B. Bergeot, A. Almeida, C. Vergez, and B. Gazengel. Prediction of the dynamic oscillation threshold in a clarinet model with a linearly increasing blowing pressure. *Nonlinear Dynam.*, 73(1-2):521–534, 2013.
- [3] B. Bergeot, A. Almeida, C. Vergez, and B. Gazengel. Prediction of the dynamic oscillation threshold in a clarinet model with a linearly increasing blowing pressure: Influence of noise. *Nonlinear Dynam.*, 74(3):591–605, 2013.
- [4] Baptiste Bergeot. *Naissance des oscillations dans les instruments de type clarinette à paramètre de contrôle variable*. PhD thesis, Université du Maine, 2013.