Auditory Perception of Biological Movements: an evidence of cognitive specifities from sound synthesis

Thoret Etienne[1,3,4], Aramaki Mitsuko[1,3,4], Kronland-Martinet Richard[1,3,4], Velay Jean-Luc[2,3], Ystad Sølvi[1,3,4]

1. Laboratoire de Mécanique et d'Acoustique, CNRS, UPR7051, Marseille
2. Laboratoire de Neurosciences Cognitives, CNRS UMR7291, Marseille
3. Aix-Marseille Université, Marseille
4. Ecole Centrale Marseille

Background and aim of the study

The perception of movement induced by sound sources has been widely investigated in different contexts ranging from physics to neurosciences.

Surprisingly, **the auditory perception of biological movements,** like drawing movements, has never been formally studied.

The intrinsic characteristics of a sound could evoke a motion thanks to timbre variations (Merer et al., 2013)

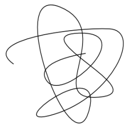
Moreover, such sounds can be described by subjects with drawings to translate the motion that they have perceived (Merer et al., 2013)

Here we focused on the perception of biological movements, which are naturally produced **when someone is drawing on a paper for example.**

Such movements **produced friction sounds which seemed to contain information about the ongoing movement** and the therefore about the geometric of the trajectory.

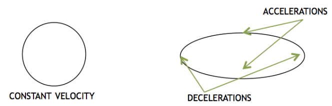
What do we hear in a friction sound? → **Characteristics of the underlying gesture ?** → **Can we imagine the shape which was drawn from the produced friction sound?**

Velocity ? Fluidity ? Jerkiness ?



How do we naturally draw?

When we are drawing, we **accelerate** in the flattest parts and we **slow down** in the most curved ones



The gesture is characterized by **a relation between the tangential velocity and the curvature,** the so-called 1/3 power law (Lacquaniti et al., 1983)

If the friction sounds reveal the kinematic properties, are we able to retrieve the 1/3-power law by listening to the produced friction sounds?

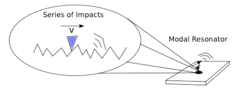
Experiment 1 – Auditory reenaction of biological movements

Subjects

20 subjects took part to the experiment

Stimuli

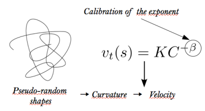
We can generate a synthetic friction sound solely from a given velocity profile with a simple phenomenological model of friction



Practically it consists in low pass filtering a noise with a cutoff frequency linked to the velocity profile (Van den Doel, 2001)

Task

Subjects had to calibrate the exponent of the power law to evoke the most natural gesture from the friction sound without seeing the shape nor the exponent



Results

The results revealed that subjects have calibrated the exponent close to 1/3:

Average exponent: $\bar{\beta}$= **0.361** (SD = .084)

Ascending threshold: $\bar{\beta}$= **0.39** (95% CI [.36 .43])

Decreasing threshold: $\bar{\beta}$= **0.31** (95% CI [.28 .34])

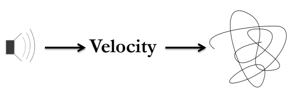
Conclusions

We are able to recognize biological motions only by listening to the corresponding friction sounds

Biological velocity profile is an acoustical *transformational invariant* enabling gesture recognition

Experiment 2 – Auditory discrimination of geometrical shapes

We are able to imagine a gesture from a friction sound, but, are we able to go further, **can we imagine a drawn shape from a friction sound?**

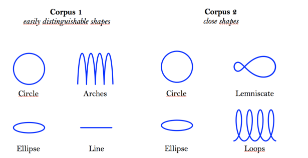


Task

To evaluate whether we are able to imagine a shape from a sound, we set up a discrimination task during which subjects had to associate friction sounds to visual shapes

Two corpuses of shapes were used:

shapes with cusp (easily distinguishable) and without (close shapes)

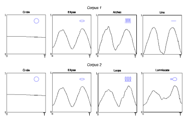


Auditory Stimuli

We recorded someone drawing those shapes on a graphic tablet

Friction sounds were recorded and velocity profiles were collected

Synthetic friction sounds were generated from the velocity profiles, this enable to precisely control which information is contained in the sound



Results & Conclusions

Sounds \ Shapes	Circle	Ellipse	Arches	Line
Circle	98.75	1.25	-	-
Ellipse	1.25	81.25	17.5	-
Arches	-	11.25	80	2.5
Line	-	-	2.5	97.5

Sounds \ Shapes	Circle	Ellipse	Lemniscate	Loops
Circle	100	-	-	-
Ellipse	-	50	4.17	45.83
Lemniscate	-	6.94	81.94	11.1
Loops	-	43.06	13.89	43.06

Confusion matrices for both synthesized and recorded sounds
(Green: well associated – Orange: confusions)

1) The **recorded** and **synthesized** sounds provide the same association rates:

→ **no significant differences were found between the confusions matrices obtained from recorded and synthesized sounds** (based on comparisons between cophenetic distances)

→ **the velocity profile** is a relevant information to evoke a shape

2) It's possible, **to a certain extent,** to discriminate shapes from friction sounds when the velocity profiles are sufficiently different

Further details are availabled *in Thoret et al. (2014) J. Exp. Psychol. Human* and *Thoret et al. (2013) From Sound to Music and Emotions - LNCS 7900*

Conclusions & Perspectives

What do we hear in a friction sound?

→ **the velocity,** and more, **the biological relation between velocity and curvature**

→ this biological relation enables **to discriminate geometrical shapes** from sounds, this result was not obvious even when the shapes were easily distinguishable

It's a new evidence of the close audio-motor relation between gestures and sounds which can be discussed according to different psychological frameworks:

- **ecological** and **ideomotor** (Gibson, 1966 / Hommel et al., 2001)
- **sensorimotor** (O'Regan et al., 2001)
- **enactive** (Varela et al., 1993)

Perspectives

1) to use other gestural information in the sound synthesis process to improve the discrimination between shapes (pressure)

2) to focus on idyosyncratic preferences: do subjects better associate sounds they produced rather than sounds produced by someone else?

3) it enables to imagine sonification processes of drawing, for blind people for instance, but also for the rehabilition of motor diseases

References

1. Merer, A et al. (2013). ACM TAP
2. Lacquaniti, F. et al. (1983). Acta Psychol.,
3. Van den Doel, K. et al. (2001). In Proc. of the 28th Conf. on CGIT ACM
4. Thoret, E. et al. (2014) J. Exp. Psychol. Human
5. Gibson (1966)
6. Hommel et al. (2001) Behav. Brain Sci.
7. O'Regan et al. (2001) Behav. Brain Sci.
8. Varela, F. et al. (1993)

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