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Acoustics of Speech and Environmental Sounds

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Introduction

- **This study presents a preliminary acoustic analysis of environmental sound stimuli.**
- **The environmental sounds are present in everyday life.**
- **Onomatopoeic representations are frequently used to describe such sounds: speech sounds report environmental sounds.**

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Literature Review

- **Environmental sound research has practical applications in various areas (Gygi and Shaphiro 2006):**
  - medicine
    - habilitation/rehabilitation of hearing impaired and development of diagnostic methods
  - artificial inteligence
    - relationship between semantic and physical parameters of environmental sounds
  - noise control
    - annoyance in specific environments
  - design of virtual auditory environments
    - develop a conceptual framework for designing soundscapes

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Literature Review

- **Musical listening vs Everyday listening (Gaver, 2003)**

we analyse features of the sound itself, (Gaver, 2003)	we listen to events and not sounds, we pay attention to what is generating the sound and not the emotional sensations or acoustic features conveyed by the sound (Gaver, 2003)

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Literature Review

- **Research methods should consider (Gaver, 2003)**
  - materials involved
    - Solids
    - Liquids
    - Gases
  - type of interaction
    - Solids

      impacts - scrapping - rolling - deformation
    - Liquids

      drip - pour – splash - ripple
    - Gases

      explosion – gusts – wind

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Literature Review

- **Takada, Tanaka and Iwamiya (2006) analyzed onomatopoeic representations of environmental sounds for a set of commercially available stimuli.**
- **The subjects described the sounds according to quality rating scales and using onomatopoeic representations.**
- **Results showed similar acoustic properties in the stimuli expressed by onomatopoeic representations classified into the same clusters.**

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Environmental Sounds Stimuli

- **26 stimuli from audio recordings used in clinical practice by Portuguese speech and language therapists**
  - Sample: total of 42 environmental sounds
    - animal vocalizations
    - sounds produced by the human body
    - sounds of nature
    - sounds of objects
    - sounds of means transportation

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Environmental Sounds Stimuli

- **Stimuli were classified according to the type of interaction between materials (Gaver 1993)**
  - Most of the sounds : a single event, i.e., involved only one type of interaction between materials,
  - Some stimuli that involve two types of interaction.

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Environmental Sounds Stimuli

Material	Solids						Liquids						Gases					
Type of Interaction	Impact		Deformation		Scrapping		Drip		Splash		Ripple		Explosion		Gust		Wind	
Stimuli	1	bell	3	claps	2	closing door	5	rain	5	rain	19	river	8	thunder	12	filling up a tire	4	whistle
	2	closing door	6	walking down a staircase	9	digging with a shovle	11	filling a glass of water	14	see			16	boiling water	24	plain	10	wind
	3	claps	7	to snap one's fingers	20	rubbing the hands	25	shower	22	waterfall								
	6	walking down a staircase	18	drum	23	saw			25	shower								
	9	digging with a shovle			26	sweep												
	13	walking																
	15	cover and plate																
	17	axe																
	18	drum																
	21	hammering																

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Method *Experiment 1*

- **We analysed all stimuli:**
  - Time waveforms
  - Spectrograms
  - Acoustic measures:
    - duration
    - F0, F1, F2 and F3 for periodic signals
- **Most of the sounds had a spectrogram similar to noise signals, so**
  - multitaper spectra (PSD Thomson estimates) were calculated with 11 ms windows left aligned to the start of the samples
  - peaks and broad peaks in the spectra were analysed

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Method *Experiment 2*

- **Subjects: 10 (5 male and 5 female) with normal hearing abilities**
- **Were asked to describe the stimuli using an onomatopoeic representation.**
- **The stimuli were presented in the randomized order**
- **Subjects were able to listen (headphones) to the sound stimuli for as many times as they felt necessary**
- **Onomatopoeic representations produced by the subjects were recorded (microphone and PC)**

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Method *Experiment 2*

- **Onomatopoeic representations were coded using 15 phonetic parameters**

– 5 Places of Articulation

bilabial, labio-dental, alveolar, palatal and velar

6 Manners of Articulation

plosive, fricative, liquid and nasal + voiced or voiceless

– 3 Vowel features

group 1 – /æ, a, ɛ, e/

group 2 - /i/

group 3 – /u, o, ɔ/

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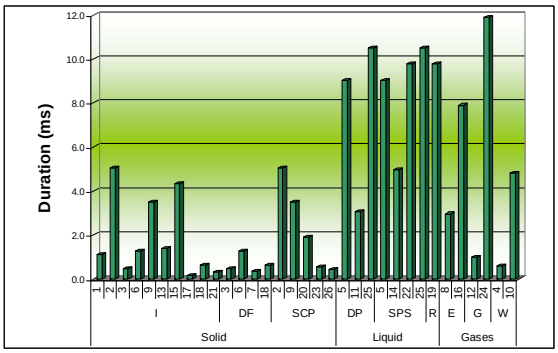
Results *Experiment 1*

- **Shorter Durations**
  - Solids specially deformations
  - In speech: stop consonants
- **Longer Durations**
  - Liquids and gases (generate more continuous sounds)
  - In speech, fricatives and vowels



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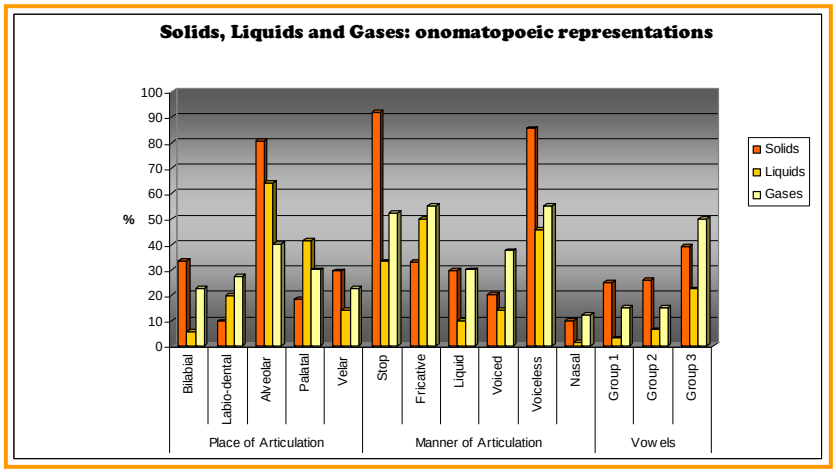
Results *Experiment 2*



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Results *Experiment 2*

- **Solids**
  - Place of articulation
    - **alveolar**
  - Manner of articulation
    - **voiceless stops**
  - Vowels
    - **group 3 /u, o, ɔ /**
  - Use of consonants vs use of vowels
    - **Consonants are used more often**
  - Example of an onomatopoeic representation used by the subjects
    - **/tɔk tɔk/, /tũ tũ/**
  - Type of interaction **Impacts**
    - **acoustic aperiodic signal with high average amplitude that decayed over time**
    - **frequency caracteristics of a noise signal**

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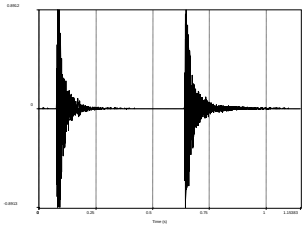
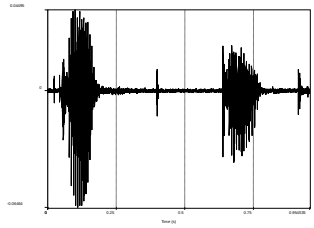
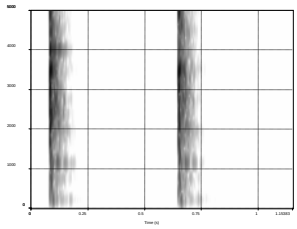
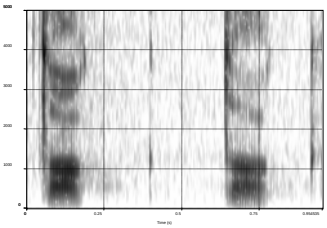
Results *Experiment 2*

- **Solids**

	Environmental sound "hammering"	Onomatopoeic representation /tɔk tɔk/
waveform		
spectrogram		

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Results *Experiment 2*

- **Liquids**
  - Place of articulation
    - **alveolar** and **palatal**
  - Manner of articulation
    - **devoiced fricatives**
  - Vowels
    - **group 3 /u, o, ɔ/**
  - Use of consonants vs use of vowels
    - **Consonants are used more often**
  - Example of an onomatopoeic representation used by the subjects
    - **/ʧ:/, /ʃ:vũ:/**
  - The frequency components of most of this noise signals
    - **above 1 kHz**

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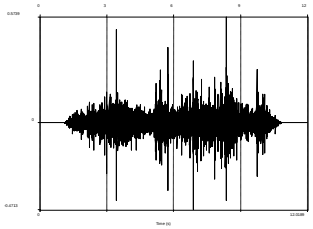
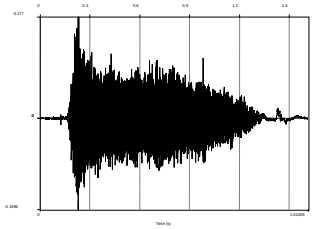
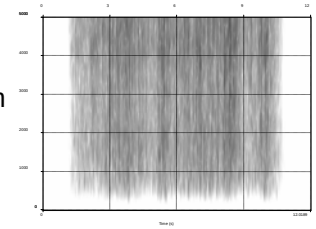
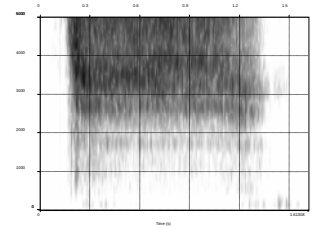
Results *Experiment 2*

- **Liquids**

	Environmental sound river	Onomatopoeic representation /ʧ:/
waveform		
spectrogram		

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Results *Experiment 2*

- **Gases**
  - Place of articulation
    - **alveolar** and **palatal**
  - Manner of articulation
    - **devoiced stops, nasals (mostly used)** and also used **fricatives**
  - Vowels
    - **group 3 /u, o, ɔ/**
  - Use of consonants vs use of vowels
    - **Consonants are used more often**
  - Example of an onomatopoeic representation used by the subjects
    - **/fuː/, /fjw/, /uːûː/**
  - Most frequency characteristics of these noise signals
    - **below 1 kHz**

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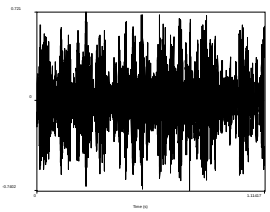
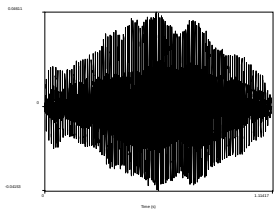
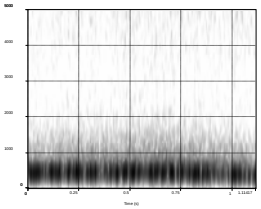
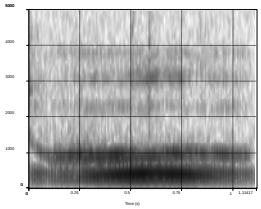
Results *Experiment 2*

- **Gases**

	Environmental sound wind	Onomatopoeic representation /uː/
waveform		
spectrogram		

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Conclusions

- **Sounds produced by basic level events generated by similar materials or interactions**
  - Seem to share some acoustic properties:
    - Duration
    - Amplitude
    - Frequency
  - Are described with speech by onomatopoeic representations with similar phonetic features

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Future Work

- **Develop two complementary experiment in which**
  1. Noise
     - Different amplitude
       - white noise, 355-710 Hz, 410-1400 Hz, 1400-2800Hz and 2800-5600 Hz
     - Different S/N
       - +5 dB, 0 dB, -5 dB, -10 dB and -15 dB
  2. Filter the stimuli in the same 4 frequency ranges

↓

Test the subjects signal perception and relate the results with the materials and interactions involved in sound production

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Future Work

- Use the stimuli for the audio-verbal rehabilitation of hearing-impaired
- Develop a test of environmental sounds for children (3 to 10 years)

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References

• Gaver, W. 1993. What in the world do we hear?: an ecological approach to auditory event perception. Ecological Pschology 5(1), 1-29.

• Gygi, B., G. Kidd, C. Watson 2004. Spectral-temporal factors in the identification of environmental sounds. Journal of the Acoustic Society of America, 115 (3), 1252-1265.

• Takada, M., K. Tanaka, S. Iwamiya 2006. Relationships between auditory impressions and onomatopoeic features for environmental sounds. Acoustic Science Technology 27(2), 67-79.

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