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.
• 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 intelligence  
  • 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

• **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)
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

• 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.
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

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.
### Environmental Sounds Stimuli

<table>
<thead>
<tr>
<th>Material</th>
<th>Solids</th>
<th>Liquids</th>
<th>Gases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Interaction</td>
<td>Impact</td>
<td>Deformation</td>
<td>Scrapping</td>
</tr>
<tr>
<td>Stimuli</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 bell</td>
<td>5 claps</td>
<td>2 closing door</td>
<td>3 rain</td>
</tr>
<tr>
<td>2 closing door</td>
<td>walking down a staircase</td>
<td>9 digging with a shovel</td>
<td>15 filling a glass of water</td>
</tr>
<tr>
<td>3 claps</td>
<td>to snap one's fingers</td>
<td>20 rubbing the hands</td>
<td>25 shower</td>
</tr>
<tr>
<td>6 walking down a staircase</td>
<td>18 drum</td>
<td>23 saw</td>
<td>25 shower</td>
</tr>
<tr>
<td>9 digging with a shovel</td>
<td>26 sweep</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13 walking</td>
<td>10 cover and plate</td>
<td>17 see</td>
<td>19 dust</td>
</tr>
<tr>
<td>21 hammering</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 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
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)

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 – /e, a, ɛ, e/
    group 2 - /i/
    group 3 – /u, o, ɔ/
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

Results Experiment 2

Solids, Liquids and Gases: onomatopoeic representations
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/, /kɔtɔtɔ/
- Type of interaction Impacts
  - acoustic aperiodic signal with high average amplitude
    that decayed over time
  - frequency characteristics of a noise signal

Results Experiment 2

**Solids**

Environmental sound
“hammering”

Onomatopoeic representation
/tɔk tɔk/

waveform

spectrogram
Results Experiment 2

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

Results Experiment 2

• Liquids
  – Environmental sound
    • river
  – Onomatopoeic representation
    • /ʃʃ/
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/, /fjʊ/, /uːtuː/
  - Most frequency characteristics of these noise signals
    - below 1 kHz

<table>
<thead>
<tr>
<th>Environmental sound</th>
<th>Onomatopoeic representation</th>
</tr>
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<tbody>
<tr>
<td>wind</td>
<td>/u/</td>
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- **Results Experiment 2**

  - **Gases**
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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

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
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)

References

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