ICA 2013 Montreal
Montreal, Canada
2 - 7 June 2013

Education in Acoustics
Session 2aED: Tools for Teaching Advanced Acoustics

2aED8. Spectrogram puzzles: A tool for teaching acoustic phonetics
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One of the most useful tools for the acoustic analysis of speech is the spectrogram. A spectrogram is a visual representation of speech, which includes time, frequency, and amplitude information. To conduct appropriate and accurate acoustic-phonetic analyses, students must learn to identify important features of vowels and consonants on spectrograms. To help students learn to identify these features, the spectrogram puzzle exercise was developed. In this exercise, spectrograms of sentences are printed using a large-format printer and cut into phoneme sections. Students then arrange the segments into the appropriate order based on a provided sentence. Depending on students’ level of knowledge and experience, task difficulty can be increased or decreased by: (1) providing phonetic transcription versus orthography, (2) including more or less easily identifiable consonants, (3) including citation-style speech versus conversational or disordered speech, and (4) having teams versus individual students complete the exercise. Through these modifications, this activity can be used with a wide range of students from beginning undergraduate to advanced graduate students. For all students, spectrogram puzzles provide a hands-on, interactive learning experience that can facilitate critical thinking, collaborative learning, and acquisition of knowledge about the representation of speech sounds on spectrograms.

Published by the Acoustical Society of America through the American Institute of Physics
INTRODUCTION

One of the most useful tools for the acoustic analysis of speech is the spectrogram. A spectrogram is a visual representation of sound. Spectrograms include time information on the x-axis, frequency information on the y-axis, and amplitude information, which is indicated by gray scale. To conduct appropriate and accurate acoustic-phonetic analyses, students must learn to identify important features of phonemes (i.e., vowels and consonants) on spectrograms. To help students learn to identify these features, the spectrogram puzzle exercise was developed.

SPECTROGRAM PUZZLES

In the spectrogram puzzle exercise, spectrograms of words, phrases, or sentences are created in a program such as Praat (Boersma and Weenink, 2012) and then printed using a large-format printer and cut into phoneme sections. The phoneme-sized sections of the spectrogram are given to students in random order (Figure 1a). Students are then required to arrange the segments into the appropriate order based on a provided word, phrase, or sentence (Figure 1b). Depending on students’ level of knowledge and experience, task difficulty can be increased or decreased through several means described below. The factors described below also could be employed to change the difficulty of other spectrogram interpretation exercises – such as “mystery spectrogram” reading or spectrogram segmentation.

![FIGURE 1](image)

Students can be provided with two types of information as they arrange the elements of the spectrogram: transcription or orthography. The transcription may be a broad transcription (i.e., phonemic transcription), in which only phonemes are given but not additional detail, or a narrow transcription, in which both phonemic transcription and diacritics (i.e., additional markings which indicate specific phonetic properties of the phoneme instantiations) are provided. If students are only provided with orthography – the conventional writing system – they will have to determine the transcription, which will add an additional challenge. Providing a narrow transcription will result in an easier task because at least some of the production idiosyncrasies will be indicated. Thus, the students will have more information to help them arrange the sections of the spectrogram in the appropriate order based on the provided transcription. For example, the spectrogram in Figure 2 shows the sentence “This is his”. Students could be provided with the orthography (e.g., “This is his”), a broad transcription (e.g., /ðɪsɪzɪz/), or a narrow transcription (e.g., [ðɪsɪzɪz]). In this particular example, the narrow transcription would alert the students to the fact that both /z/ phonemes in this particular production were partially devoiced as indicated by the devoicing diacritic (i.e., the small circle below the /z/).
The difficulty level of the spectrogram puzzle exercise can be changed through the inclusion of consonants that are more or less easily identifiable. For example, composing a puzzle with consonants that are easily confused with vowels would be more difficult than a puzzle with consonants that have distinct acoustic features compared to vowels. Two word-length examples that demonstrate this difference are provided in Figure 3. The word “lean” shown in Figure 3a has consonants (i.e., /l/ and /n/) that have acoustic properties similar to vowels. That is, both consonants are voiced sounds with clear formant structure. The students would need to attend to the specific formant values and overall amplitude to arrange the elements of the puzzle correctly. A puzzle composed of words with these classes of sounds would be quite difficult. In contrast, a puzzle made of consonants with easily identifiable acoustic properties – such as words with fricatives (e.g., /s/ or /ʃ/) and stop consonants (e.g., /b/ or /k/) – would be less challenging. A set of sentences primarily composed of easily identifiable consonants that are controlled for syllable count can be found in McGarr (1981). An example of a word with more easily identifiable consonants is shown in Figure 3b. The word displayed, “ship”, has consonants with acoustic properties that are distinct from one another and from the vowel.

Citation vs. Conversational Style Speech

The speaking style used for the utterances shown on the spectrogram can modulate the difficulty level of the puzzle. A sentence produced in a citation or clear speaking style (Smiljanic and Bradlow, 2009) will have more distinct patterns. The productions of sounds in this style are likely to be similar to the examples that are typically presented to students initially. In contrast, a sentence produced in a conversational style is more likely to have shorter, less acoustically distinct speech sounds as well as segment deletions and other changes that make the
spectrogram less easy to segment and arrange. An example of the phrase – “butter and jam” – in the two speech styles is shown in Figure 4. Note the difference in overall duration, the changes in specific phonemes (e.g., an aspirated /t/ in the clear production of “butter” but a flap in the conversational version), and elision of phonemes (e.g., the full production of “and” /ænd/ in the clear version versus a syllabic nasal /n/ in the conversational version).

FIGURE 4. Examples of the phrase “butter and jam” produced in a clear speaking style (a) and a conversational speaking style (b). A spectrogram puzzle constructed from the conversational-style phrase, [bʌtʰəndʒæm], would be more challenging for students than the clearly produced phrase, [bʌtˈəndʒæm].

CONCLUSION

For all students, spectrogram puzzles provide a hands-on, interactive learning experience that can facilitate critical thinking, collaborative learning, and acquisition of knowledge about the representation of speech sounds on spectrograms. Through the modifications described above, this activity can be used with a wide range of students from beginning undergraduate to advanced graduate students.

ACKNOWLEDGMENTS

We would like to thank Kelly Bailey, Nancy Eastman, and the students in our fall 2012 section of Phonetics for Speech and Hearing Sciences for their helpful feedback on the first implementation of the spectrogram puzzle activity.

REFERENCES

