**BACKGROUND**

1. **VOT distributions and mastery of voiced stops:**
   - Cross-language differences in the age of children's mastery of adult-like voiced stops typically are explained in terms of the relative difficulty of the gestural organization for the language-specific VOT distributions.
   - Early mastery of English voiced stops:
     - Short lag VOT allowed, requires little precision in the laryngeal gestures
   - Late mastery of French/Spanish voiced stops:
     - VOT required, has the greatest motoric/aerodynamic demands

2. **Puzzling mastery patterns for voiced stops in ...**
   - **Japanese**: there is a short-lag VOT allophone (as in English).
   - **Greek**: lead VOT is the norm (as in French).
   - **Japanese**: but two-year-old Greek children produce them with adult-like lead VOT values.
   - **Greek**: lead VOTs are mastered later than voiceless stops (Yasuda, 1970).

3. **Can language-specific phonetic details explain both puzzles?**
   - **Japanese**: overlapping VOT values between voiced and voiceless stops.
   - **Greek**: only 29.3% (22/210) of girls' voiced stops and 43.8% (92/210) of boys' voiced stops were prevoiced.

**METHODS**

I. **Database**

**Materials and participants:**
- word-initial stops and nasals elicited in familiar words
- Japanese: 93 child (aged 2 through 3 years) and 20 adult (18 – 30) speakers of Japanese, Greek, or English.
- recordings made in their home countries in the Tokyo area, Japan; Thessaloniki area, Greece; central Ohio, USA.

**Tasks:**
- picture-named word-repetition task (Japanese and English) and picture-naming task (Greek and Japanese children)

II. **Measurements and analysis**

**Japanese and English**

- **a. Accuracy judgment measures:**
  - native speaker transcriptions of 'correct' or 'incorrect' for all children's stop productions (errors also transcribed phonetically)
- **b. Acoustic measures:**
  - VOT, f0, and H1-H2 measured in all adult productions and in all child productions that were transcribed as correct or as plosive substitutions.
- **c. Statistical analysis:**
  - three types of mixed effects logistic regression model with target context (adult) or transcribed context (for child productions) as dependent variable and various sets of acoustic measures as independent variables

**Greek and Japanese**

- **a. Duration**
  - of voicing lead (i.e., VOT) in the voiced stops and nasal murmur in nasals.
- **b. Amplitude trajectory**
  - during the voicing bar and nasal murmur:
    - the first peak amplitude in the FFT spectrum made from a 6 ms Hamming window centered at each glottal pulse starting at the burst,
    - normalized by the amplitude of the following vowel (Burton, Blumstein & Stevens, 1992)
- **c. Statistical analysis**
  - mixed effects model with normalized amplitude as dependent variable and time as independent variable.

**RESULTS**

I. **JAPANESE & ENGLISH**

**a. Transcription accuracy**

**b. VOT characteristics**

**c. Testing VOT cue sufficiency: Log-Likelihood Ratio Test**

Three mixed effects logistic regression models:
- **Dependent variable:** odds ratio of transcribed (for children) or target (for adults) /
- **Predictors:** (1) VOT-only model (base model), (2) VOT & f0 model, (3) VOT & H1-H2 model

Log-likelihood ratio test showed that:
- **ADULTS’ STOPS:**
  - Adding either f0 or H1-H2 to VOT did not improve the model fit in English.
  - Adding either f0 or H1-H2 to VOT improved the model fit in Japanese.

**CHILDERN’S STOPS:**
- Adding H1-H2 (but not f0) to VOT improved the model fit in English.
- Adding either f0 or H1-H2 to VOT improved the model fit in Japanese.

**Parameter estimation**

In Japanese children’s productions, other parameters such as f0 and H1-H2 played a relatively large role in differentiating stops transcribed as voiceless from stops transcribed as voiced.

**RESULTS II. GREEK & JAPANESE**

**a. VOT overlap**

**b. VOT overlap**

**c. VOT overlap**

**d. VOT overlap**

**e. VOT overlap**

**f. VOT overlap**

**ADULTS’ STOPS:**
- VOT overlap between short-lag VOT for /d/ and intermediate - lag VOTs for /t/ in Greek.
- VOT overlap between short-lag VOT for /d/ and intermediate - lag VOTs for /t/ in Japanese.

**CHILDERN’S STOPS:**
- Japanese children produced adult-like VOT overlap.

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* Paidologos Project webpage: [http://www.ing.ohio-state.edu/~edwards/](http://www.ing.ohio-state.edu/~edwards/)

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**DISCUSSION & CONCLUSION**

**Japanese voiced stops ...**
- can have short-lag VOT values, similar to English voiced stops. However, ...
- the voiceless stops have intermediate VOT values, so that VOT is not a sufficient acoustic cue for differentiating voiced from voiceless stops in Japanese.

**Greek voiced stops ...**
- contrast robustly with voiceless stops in always having lead VOT values. However, ...
- this lead can be produced with minimal venting, because voiced stops can be prenasalized.

**Japanese voiced stops ...**
- early mastery of Greek-speaking children, as compared to English-speaking children.
- At 42 months, Japanese-speaking children are only at 75% for /d/.

**Greek voiced stops ...**
- lead VOT required, has the greatest motoric/aerodynamic demands
- children were taking advantage of nasal venting to lower the supraglottal pressure in order to maintain vocal fold vibration
- Taken together, these results suggest VOT, in and of itself, cannot explain the mastery of voicing and aspiration categories across all languages.
- If the mastery pattern in a language contradicts predictions based on VOT alone, then the language-specific phonetics of the voicing contrast may provide an explanation.