A Cross-linguistic Developmental Study of Vowel Spectral Movement Patterns

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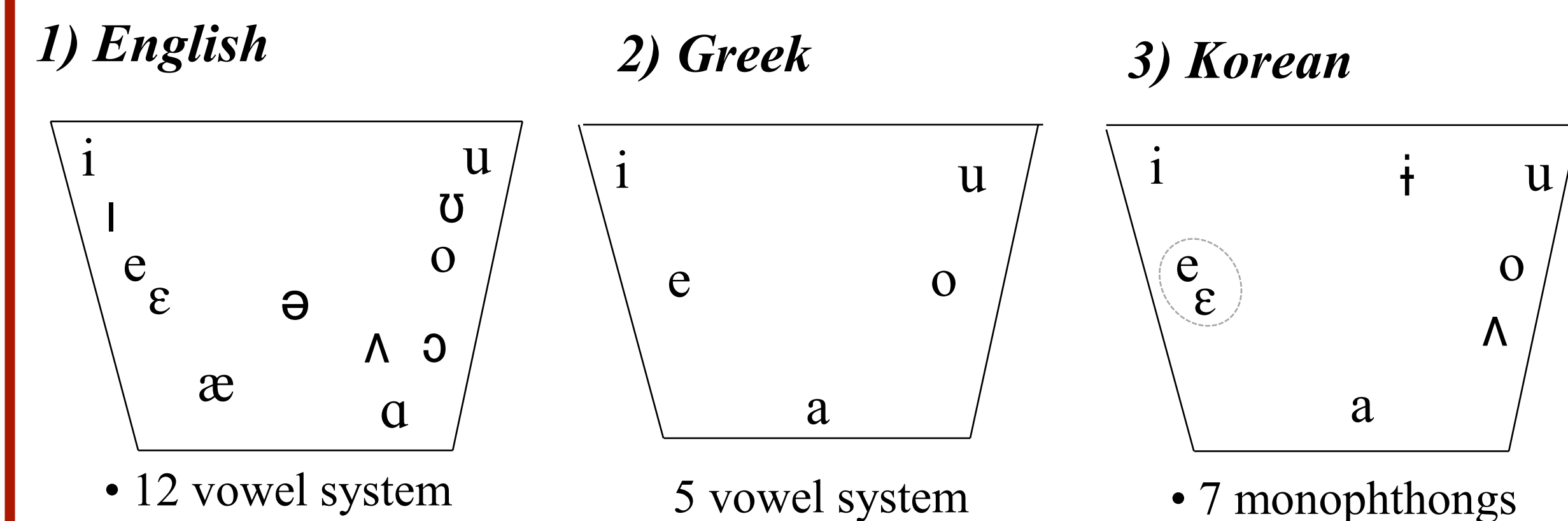
INTRODUCTION

• Traditionally, vowels have been characterized acoustically by formant frequencies measured at or near the vowel midpoint (e.g., Hillenbrand, Getty, Clark, & Wheeler, 1995; Peterson & Barney, 1952).

• However, vowel perception studies (e.g., Nearey & Assmann, 1986; Strange *et al.*, 1976) have shown the important role of vowel spectral movement patterns in identifying and characterizing vowels.

• Chung, Kong, & Weismer (2010) showed systematic cross-linguistic differences in spectral movement patterns of American English and Korean vowels produced by adults; English vowels had more movements and had consistent direction of movements, while Korean vowels showed less and inconsistent patterns of spectral movements.

PURPOSE OF THE STUDY

• This study examines cross-linguistic spectral movement patterns of five shared vowels (/a, i, u, e, o/) produced by monolingual adults, 5-year-olds, and 2-year-olds of American English, Greek, and Korean.

• Two questions were addressed:
  • Do native-speaking adults from different languages produce shared vowels with similar or language-specific spectral movement patterns?
  • If there is systematic cross-linguistic differences in vowel spectral movement patterns, to what the extent are these differences in spectral movement patterns realized in children's speech?

VOWEL SYSTEM OF EACH LANGUAGE

1) English

• 12 vowel system

2) Greek

5 vowel system

3) Korean

• 7 monophthongs

METHODS

The data used in this study is part of a larger study, *παιδολογος* project (Edwards & Beckman, 2008; Edwards & Beckman, 2009).

a. Participants
• Ten speakers in each of three age groups (2-, 5-year-olds, & adults) for each language.
• Native speakers of American English (Columbus, Ohio), Greek (Thessaloniki), and Korean (Seoul).
• All child participants passed a hearing screening and had age-appropriate oromotor skills.
• All adult participants had no history of speech, language, or hearing problems.

b. Stimuli
• /a/, /e/, /i/, /o/ and /u/ vowels in CVC contexts
• The word initial consonants were alveolar /s/ and post-alveolar /ʃ/ for American English, alveolar /s/ for Greek, and denti-alveolar /s/ for Korean. Coda environment varied for each stimulus item.

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c. Procedure
• Speech samples were collected using a word repetition task.
• Productions were digitally recorded and a trained native phonetician of each language transcribed the target vowels as correct or incorrect. Only the vowels that were judged as 'correct' were used.

d. Acoustic Analysis
• F1 & F2 were extracted from the vowel onset to offset, with a step size of 6ms, using *Praat* (Boersma & Weenink, 2006).

e. Statistical Analysis
• A time-series data analysis of mixed effects regression (Barr, 2008; Mirman, Dixon & Magunuson, 2008; Singer & Willett, 2003) was employed for each vowel type, language, and age group
• The dependent variables were log-transformed F1 or F2 values; the independent variables were three orders of orthogonal polynomial parameters (linear slope, quadratic, and cubic).
• Time was normalized to seven different time points.
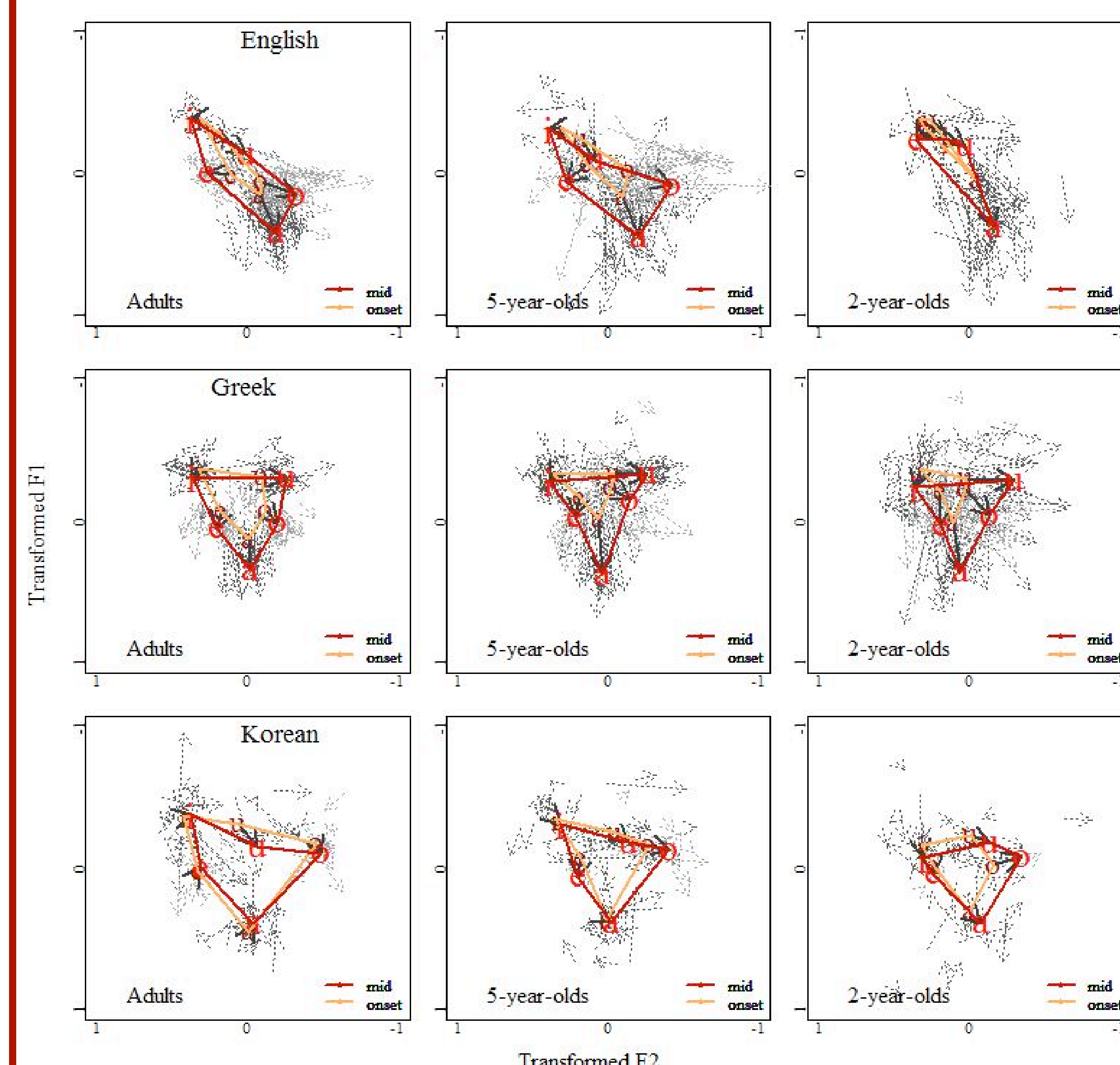
RESULTS

A. Vowel space analysis

FIGURE 1. F1 plotted against F2 from vowel onset to midpoint for five vowels of English, Greek, and Korean for three age-groups

• **Cross-linguistic Differences (Adults' productions):**
  • F1 and F2 trajectories of English and Greek vowels had more movement than Korean vowels, and had more consistent direction of movements: movements were generally toward the periphery of the vowel acoustic space.
  • F1 and F2 trajectories of Korean vowels showed little movement and inconsistent direction of movements across vowel types, except for /u/.
  • Minimal movement in F1 and F2 trajectories was observed for /i/ of all languages.

• **Developmental Patterns**:
  • Like adult vowels, F1 and F2 values of vowels produced by English- and Greek-speaking children moved towards the periphery of the vowel acoustic space.
  • F1 and F2 of vowels produced by Korean-speaking children showed inconsistent direction of movement.

B. F1 & F2 trajectory analysis

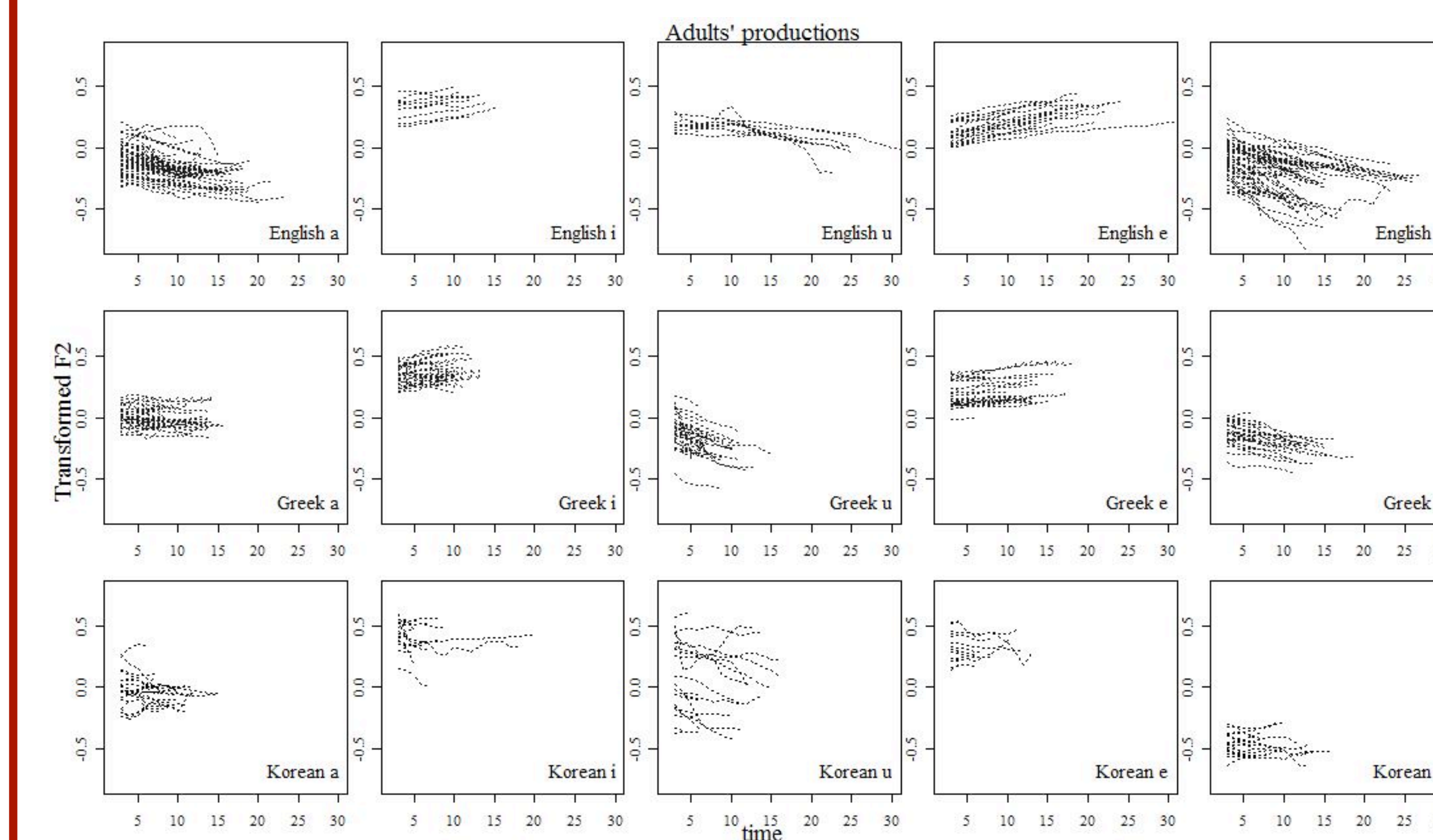#### a. Cross-linguistic differences in adults

FIGURE 2. F2 trajectories of five vowels produced by adult speakers
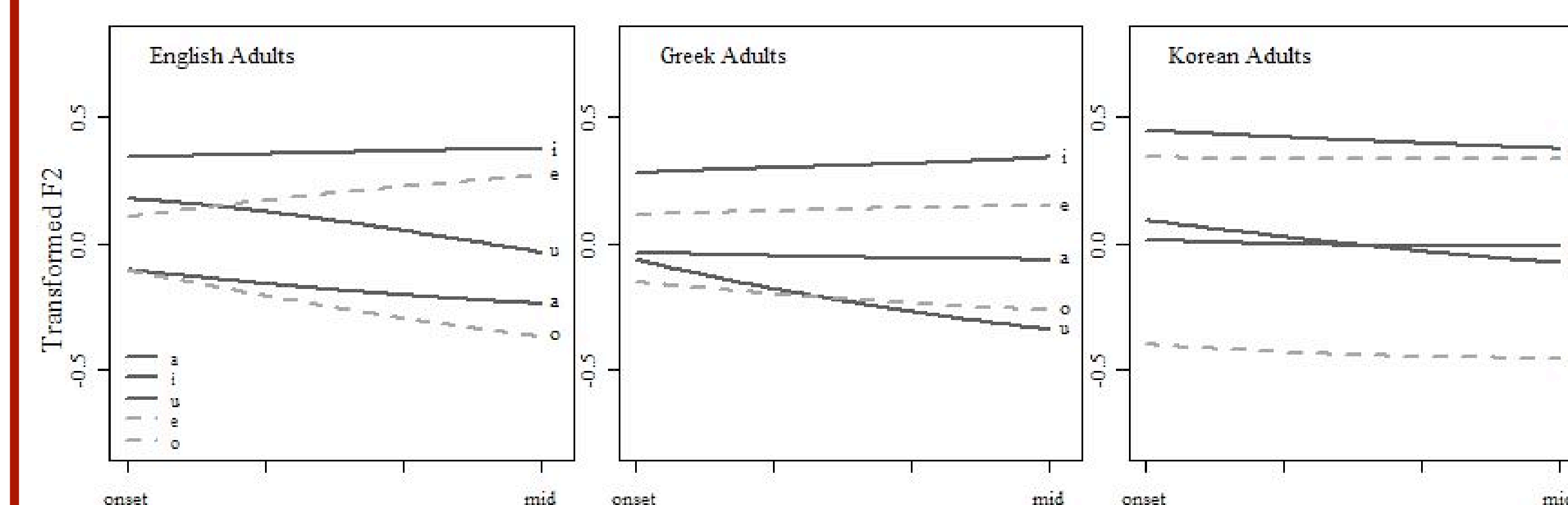

FIGURE 3. Fitted regression curves for F2 trajectories of adult vowels

• English:
  • A significant linear downward movement of F2 trajectories for back vowels was observed, indicating movement towards more posterior part of the vowel acoustic space.
  • For front vowels, an upward (but not significant) movement of F2 trajectories was observed, indicating movement toward more front part of the vowel acoustic space.
  • A significant downward movement was observed for low back vowel /a/, indicating movement towards more posterior part of the vowel acoustic space.
• Greek:
  • Similar to English for back vowels, F2 trajectories of /a/ were flatter than English /a/.
  • Significant upward linear movement for /e/ was observed.
• Korean: minimal spectral movement (F2) was observed for all vowel categories.
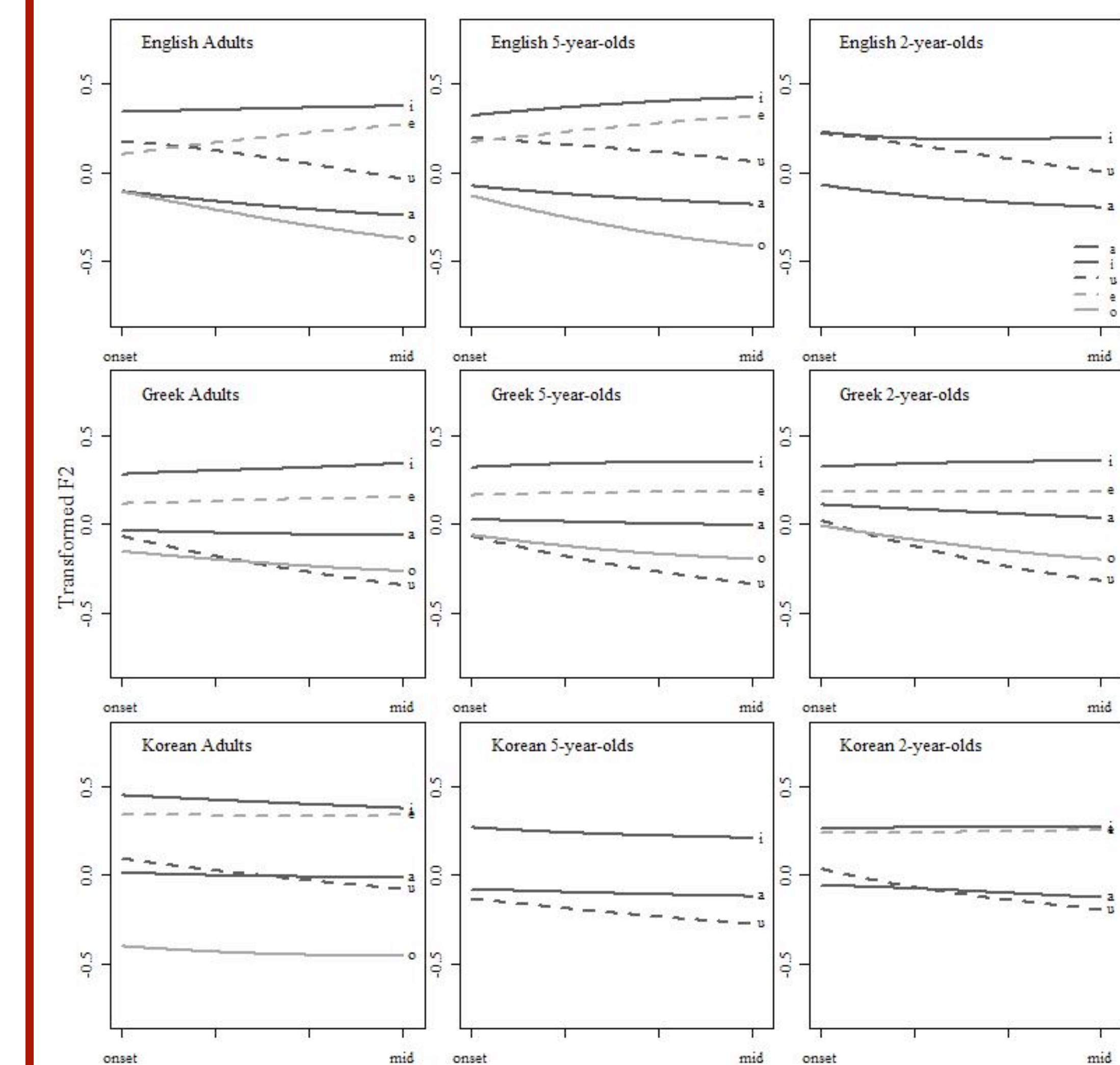
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b. Developmental patterns

FIGURE 4. Fitted regression curves for F2 trajectories of adults and children

• F2 trajectories of the 5-year-olds and 2-year-olds were remarkably similar to those of adults of their native languages.

DISCUSSION

• Cross-linguistic differences in vowel spectral movement patterns were found; English & Greek vowels showed more movement than Korean vowels.
• F1 and F2 trajectory patterns of children were very similar to those of adults, indicating children as young as 2 years of age are capable of producing vowels in a language-specific manner.
• Vowel spectral movements were vowel-specific, minimal movement was observed for /i/, while greater movement was observed for /u/ (F2) across languages.
• Durational differences: minimal spectral movements in Korean vowels than English & Greek vowels might be due to significantly shorter duration of Korean vowels than Greek & English vowels.
• Similar F1 or F2 trajectory patterns of children and adults could also indicate children's ability to produce adult-like degrees of coarticulation (e.g., Katz, Kripke, & Tallal, 1991)

ACKNOWLEDGEMENTS