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
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# Acoustic characteristics of vowel reduction in advanced Spanish-English bilinguals

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## BACKGROUND

- Phonological acquisition in a second language (L2) is well-known to be a challenging task, particularly for adolescent and adult learners (see, e.g., Piske, MacKay, & Flege, 2001).
- Transferring first language (L1) phonological knowledge onto the L2 leads to a foreign accent.
- The transfer of phonological categories from the L1 to the L2 has received particular attention, especially as regards stops (Flege, Frieda, Walley, & Randazza, 1998; Baker, 2010) and vowels (Bohn & Flege, 1992; Major, 1987; Flege, Bohn, & Jang, 1997).
- Less is known about the transfer of phonological processes from the L1 to the L2.
- Reduction of unstressed vowels is a well-known phonological property of American English (Chomsky & Halle, 1968).
  - Spanish and English pose an interesting language pairing with regard to vowel reduction because Spanish does not demonstrate vowel reduction, while English does (Flege & Bohn, 1989).
  - Successful production of English reduced vowels, like /ə/, requires learners not simply to acquire a new category, but also to implement a novel phonological process.
  - Previous research on Spanish-English bilinguals' acquisition of English vowel reduction has shown that learners must first acquire the ability to unstress vowels before acquiring reduction (Flege & Bohn, 1989).
  - Past research has also shown that Spanish-English bilinguals are more successful at producing reduced vowels with native-like duration than native-like formants (Byers & Yavas, 2017).
- The goal of this study is to investigate the acoustic production of English unstressed vowels by advanced Spanish-English bilinguals and English monolinguals.
  - Temporal and spectral properties of unstressed vowels are analyzed.
  - Extra-linguistic factors such as language dominance, age of acquisition, length of exposure to L2, and linguistic attitudes are examined in relation to acoustic properties of vowel reduction.

## METHODS

### Participants

- 10 monolingual English speakers (2 M, 8 F; 19 - 26 years, M=20.9) from the U.S. Midwest.
- 10 Spanish-English bilinguals raised in Colombia currently residing in Indiana (3 M, 7 F; 19 - 30 years, M=23.1).

### Stimuli

- Paired words containing vowels /a, æ, ε, i, ʌ/ in identical consonantal environments in stressed and unstressed position.
  - Examples: <rabbit, bit; contest, test>.
  - Six stressed and six unstressed target words per vowel; 60 target words total.
- Target words embedded in a customized carrier phrase beginning with "The word X means..."
  - Example: "The word *topic* means the theme of discussion."
  - Carrier phrases matched as closely as possible for length and rhythm.

### Procedure

- Participants completed repetition task in sound-insulated booth.
  - All target sentences recorded by a native speaker of Midwestern American English
  - Participants heard recording of target sentence and had five seconds to repeat.
  - Randomized order.
  - All target sentences appeared twice per participant.

### Acoustic Measures

- Duration, F1, and F2 measured in Praat (Boersma & Weenink, 2020) for all target vowels.
- Duration ratio calculated as unstressed vowel / stressed vowel.
  - A higher duration ratio indicates less reduction (less differentiation between stressed and unstressed vowels).
  - Repetitions paired randomly.
- Formants normalized using log-additive regression normalization (Barreda & Nearey, 2018).
- Euclidean distance between stressed and unstressed vowels calculated.
  - Greater Euclidean distance indicates greater differentiation between stressed and unstressed vowels.

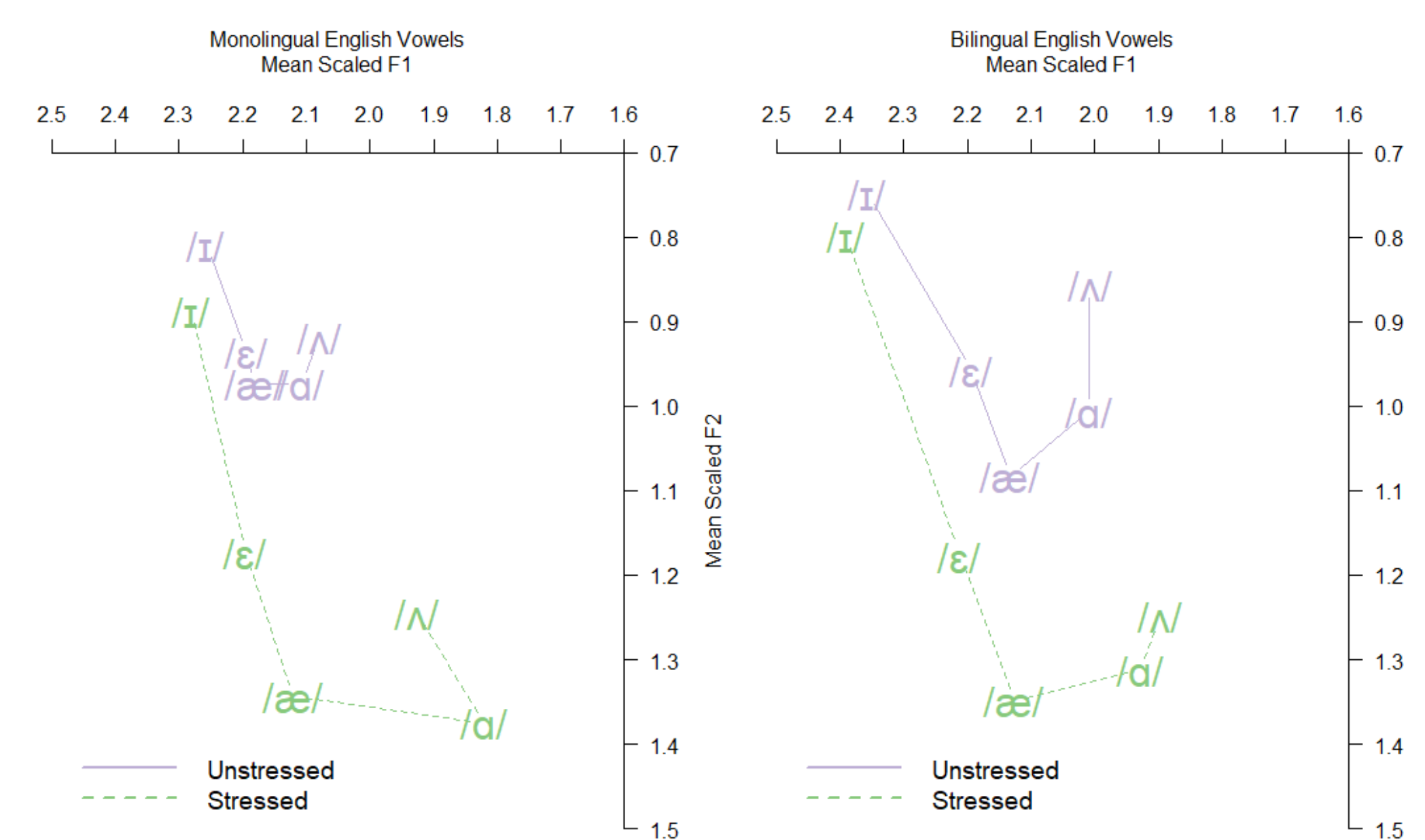
## RESULTS BY GROUP

### Research Question 1

How do highly proficient Spanish-English bilinguals differ from English monolinguals in their production of English reduced vowels?

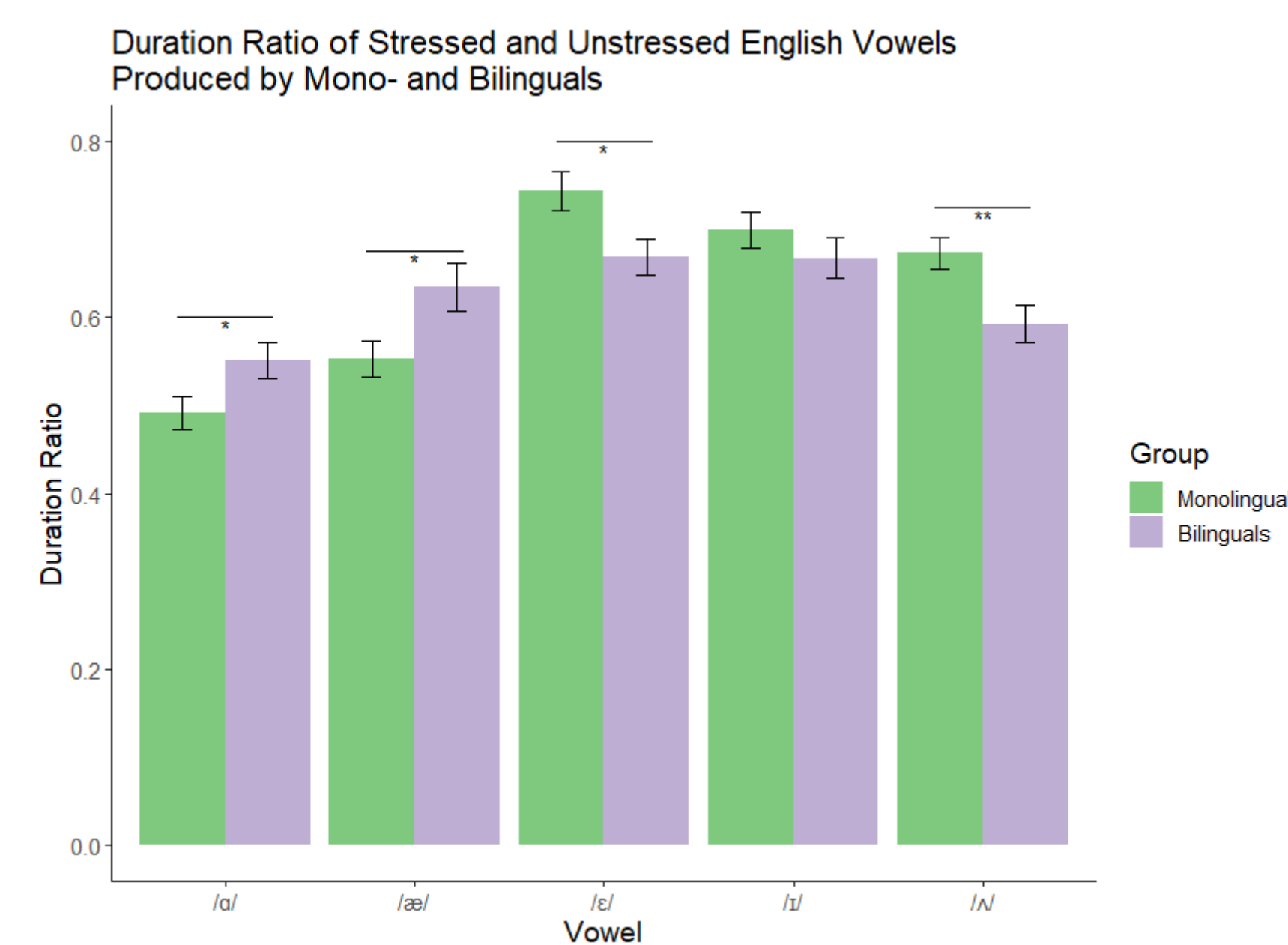
### Formant Values

- Bilinguals produced visibly less centralized reduced vowels than monolinguals, as shown below.
- Bilinguals produced very similar /ʌ/ and /ɑ/ in stressed position, but raised /ʌ/ visibly more than /ɑ/ in unstressed position.
- Monolinguals reduced mid and low vowels very similarly in unstressed position, while bilinguals' reduced vowels were more distinct from one another.



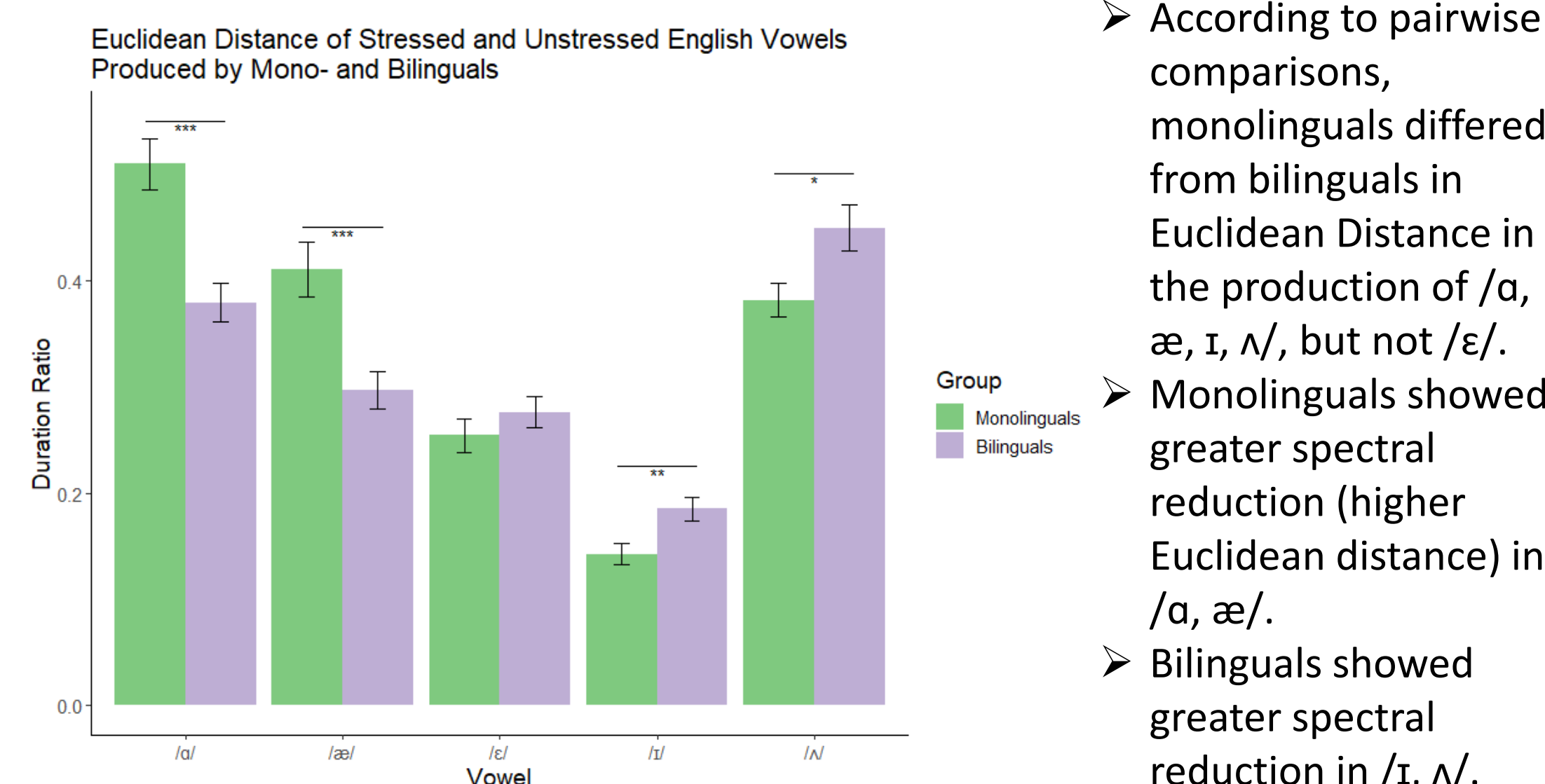
### Duration Ratio

- Significant effects of Group ( $\beta = .306$ , SE = .130,  $p < .05$ ), Vowel ( $\beta = .089$ , SE = .038,  $p < .05$ ), and Group by Vowel ( $\beta = -.040$ , SE = .016,  $p < .05$ ) on Duration Ratio.
- According to pairwise comparisons, monolinguals differed from bilinguals in Duration Ratio in the production of /a, æ, ε, ʌ/, but not /i/.
- Monolinguals showed greater temporal reduction (lower duration ratio) in /a, æ/.



### Euclidean Distance

- Significant effects of Group ( $\beta = -.452$ , SE = .053,  $p < .001$ ), Vowel ( $\beta = -.107$ , SE = .023,  $p < .001$ ), and Group by Vowel ( $\beta = .054$ , SE = .006,  $p < .001$ ) on Euclidean Distance.



- According to pairwise comparisons, monolinguals differed from bilinguals in Euclidean Distance in the production of /a, æ, i, ʌ/, but not /ɛ/.
- Monolinguals showed greater spectral reduction (higher Euclidean distance) in /a, æ/.
- Bilinguals showed greater spectral reduction in /i, ʌ/.

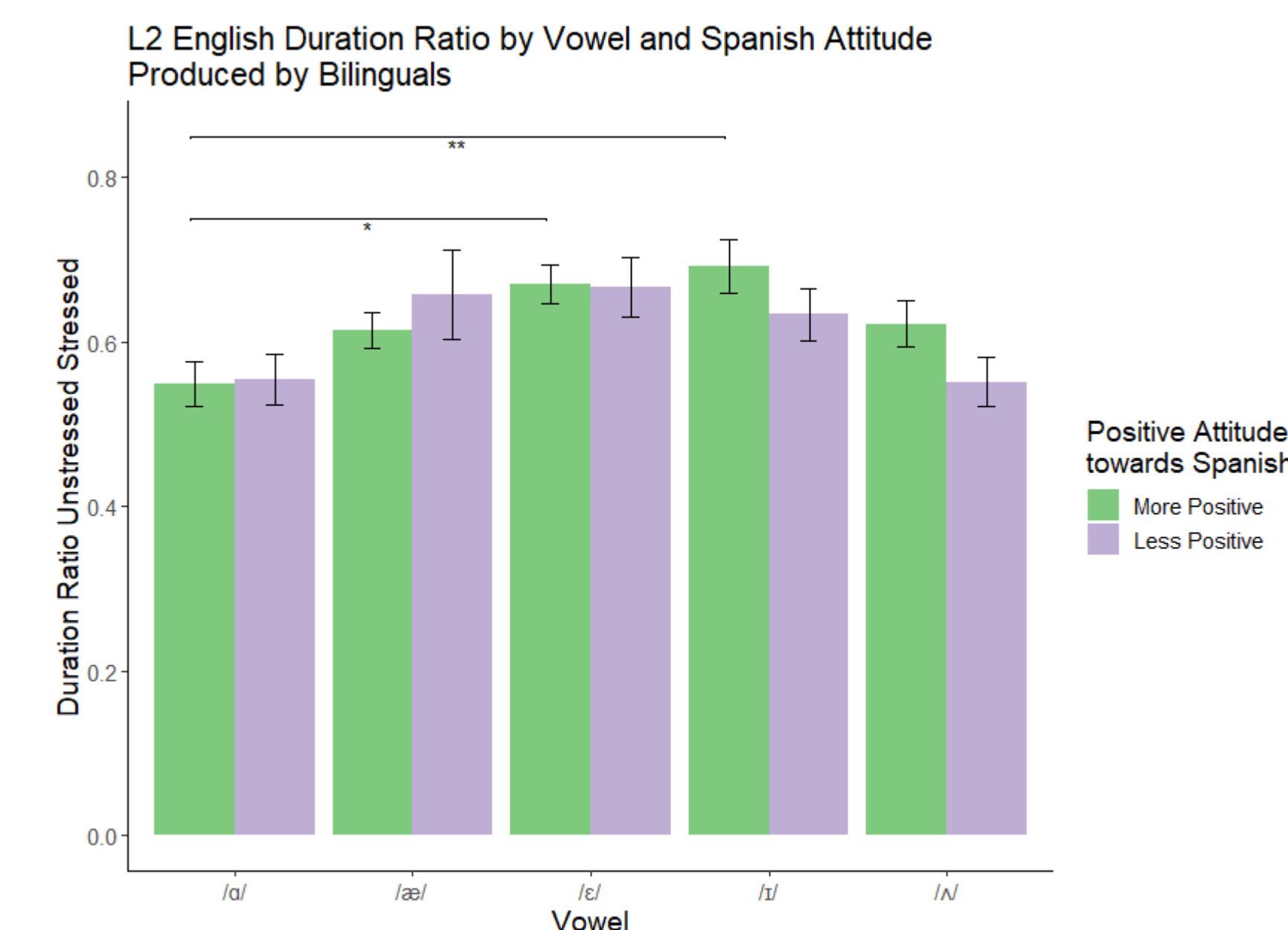
## RESULTS – EXTRA-LINGUISTIC FACTORS

### Research Question 2

How effectively do language dominance, attitudes toward Spanish and English, age of onset of acquisition, and L2 exposure predict the degree of vowel reduction in English produced by highly proficient Spanish-English bilinguals?

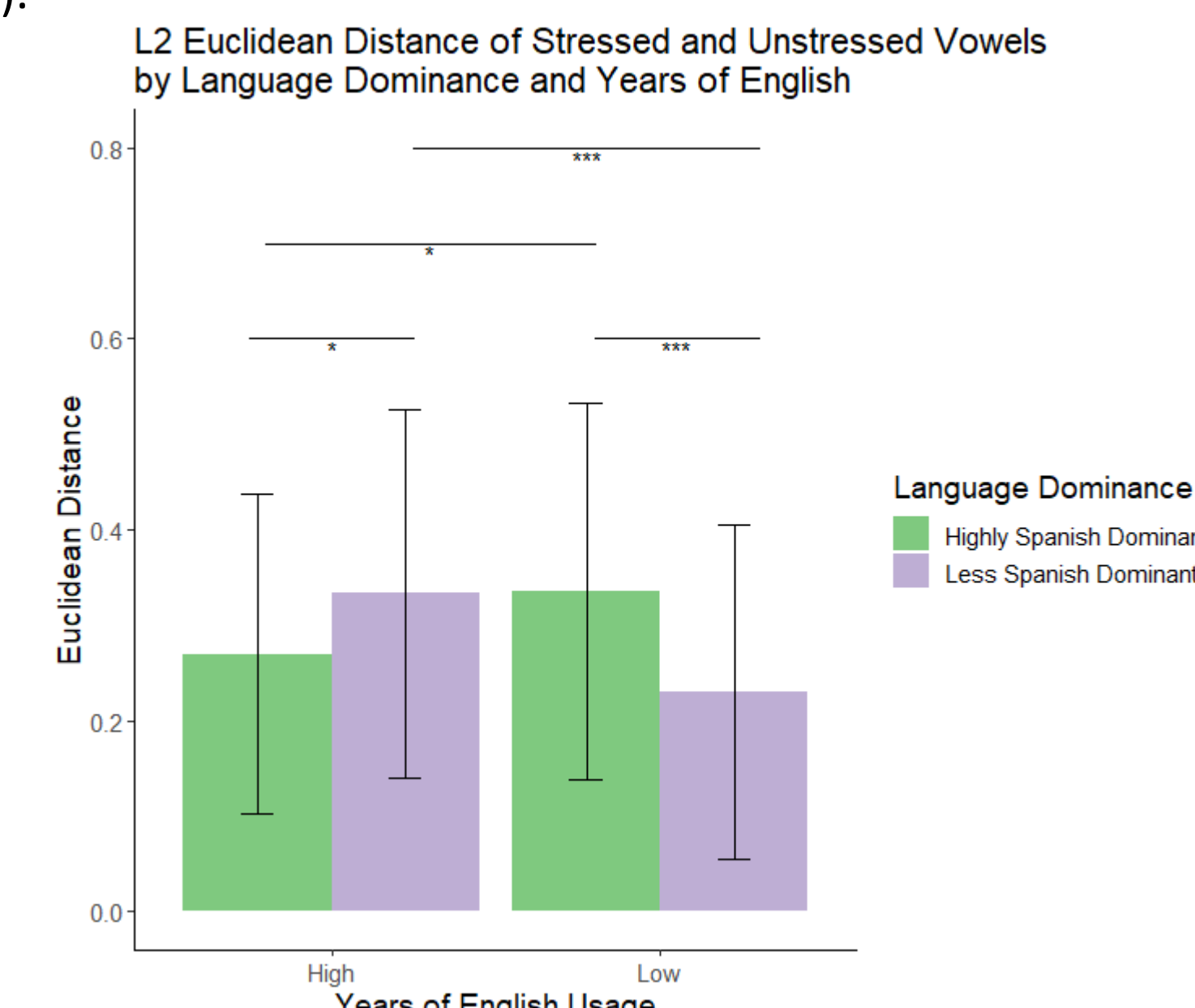
### Duration Ratio

- Language dominance, years spent using English, age of onset of L2 acquisition, and attitude toward English had no effect on duration ratio.
- Spanish attitude had a significant effect on duration ratio ( $\beta = -.0298$ , SE = .0135,  $p < .05$ ): more positive attitudes led to a lower duration ratio (more reduction) (M=0.633, SD=0.209) than less positive attitudes (M=0.617, SD=0.257).



### Euclidean Distance

- Years of English had a significant effect on Euclidean distance between stressed and unstressed vowels ( $\beta = .290$ , SE = .143,  $p < .05$ ).
- More years spent learning and using English led to a greater differentiation between stressed and unstressed vowels (M=0.322, SD=0.189). Fewer years led to less differentiation – i.e., less reduction (M=0.310, SD=0.197).
- Language dominance and years spent using English were useful in predicting Euclidean distance between stressed and unstressed vowels (significant interaction:  $\beta = -.047$ , SE = .0194,  $p < .05$ ).



## DISCUSSION - L1 VS. L2 REDUCTION

- LMMs revealed significant differences between monolinguals and bilinguals across vowels.
- Monolinguals reduced /a, æ/ significantly more than bilinguals according to both temporal and spectral measures, according to pairwise comparisons.
- Bilinguals reduced /ε, i, ʌ/ significantly more or indistinguishably from monolinguals, as shown above.
  - The greater Euclidean distance of bilinguals' /ʌ/ can be attributed to the merger of stressed /ʌ/ and /ɑ/.
  - /ʌ/ has to shift further in bilingual speech when reduced than do other vowels, suggesting that bilinguals' reduction is target-based rather than source-based.

	Greater Temporal Reduction	Greater Spectral Reduction
/a/	Monolinguals	Monolinguals
/æ/	Monolinguals	Monolinguals
/ε/	Bilinguals	No significant difference
/i/	No significant difference	Bilinguals
/ʌ/	Bilinguals	Bilinguals

Table 1 - Significantly greater reduction by group, vowel, and acoustic measure

## DISCUSSION – EXTRA-LINGUISTIC FACTORS

- Participants with more positive attitudes towards Spanish evinced more reduction in English than those with less positive attitudes.
- It is unexpected that speakers with more positive attitudes would demonstrate more reduction, if more reduction is assumed to correspond to a more native-like accent.
  - Under this interpretation, more positive attitudes toward Spanish would lead speakers to embrace a stronger L1 accent in order to signal their affiliation with their native language, leading to less reduction.
  - One possible reason for the actual finding to diverge from this theory could be in the formulation of the survey assessing language attitudes.
  - This metric focused on general attitudes toward Spanish, of which issues of identity formed only a small part.
- Language dominance and years since age of onset of acquisition had a statistically significant impact on spectral reduction, but not in a clearly linear fashion.
  - It is unclear why dominance and years of English use would interact with regard to spectral reduction as they do.

### Future Research

- Future work will investigate how the degree of temporal or spectral reduction in reduced vowels impacts the perception of accentedness in Spanish-accented English.
- Additional work on production will examine the acoustic qualities of stressed and unstressed vowels in Spanish produced by Spanish-English bilinguals and Spanish monolinguals to determine whether English bilingualism impacts L1 productions in the area of vowel reduction.

## ACKNOWLEDGEMENTS

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