

# **The Influence of Phonetic Training on Rhotic Production in Beginner L2 Spanish Learners with L1 Canadian English**

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# Introduction

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## Focus of this study:

- With phonetic training (perception and production training), do low-proficiency L2 Spanish learners with L1 Canadian English achieve more native-like production of the Spanish tap and trill?

# Spanish and English Rhotics

Table 1: Phonological Characteristics of Spanish and English Rhotics

Rhotic	Spanish Tap	Spanish Trill	English /ɹ/	English [r]
<b>Orthography</b>	r	rr (intervocally), r (other positions)	rr (intervocally), r (in all positions)	t, tt, d, dd
<b>Phonological Environments</b>	(1) Intervocally, (2) After a word-initial or word-medial tautosyllabic consonant (stop or /f/), (3) Word-finally, before a vowel, (4) Syllable-finally, word-medially, before a heterosyllabic consonant (most common), (5) Word-finally, before a consonant or pause (most common).	(1) Intervocally, (2) Word-initially, (3) Syllable-initially, word-medially, (4) Syllable-finally, word-medially, before a heterosyllabic consonant (for emphasis), (5) Word-finally, before a consonant or a pause (for emphasis).  Aerodynamically, the trill is very complicated to produce (Solé, 2002).	(1) Word-initial singleton onsets, (2) Word-initial clusters, (3) Intervocally, (4) Word-medial clusters, (5) Word-final clusters, (6) Word-final singleton codas.	Post-tonic, intervocalic position only (allophone of alveolar stops /t/ and /d/).

# Spanish and English Rhotics

Table 2: Phonetic Characteristics of Spanish and English Rhotics

Rhotic	Spanish Tap	Spanish Trill	English /ɹ/	English [r]
<b>Duration</b>	Mean 20 to 25 ms, Range 16 to 36 ms.	Mean 85 ms (3 closures, 15 ms/closure and 18 ms/vocalic element). Varies by position and following vowel.	Mean 90 to 148 ms (intervocalic ≈ word-initial singleton onsets < word-final singleton codas < word-initial clusters).	Range 23 to 36 ms.
<b>Formants</b>	N/A	F1: 500 Hz. F2: 1550 Hz. F3: 2500 Hz. Varies by following vowel.	F1: 380 Hz. F2: 1200 to 1310 Hz. F3: 1500 to 1660 Hz.	N/A
<b>Voicing</b>	Voiced.	Voiced.	Usually voiced, but devoiced when next to a voiceless obstruent.	Voiced (in general).

# Spanish and English Rhotics

Table 2: Phonetic Characteristics of Spanish and English Rhotics

Rhotic	Spanish Tap	Spanish Trill	English /ɹ/	English [r]
Place	Apico-alveolar.	Apico-alveolar.	Apico-alveolar or dorso-alveolar.	Apico-alveolar.
Manner	Tap (one brief closure).	Trill (most common realization). Two to six (mean of three) brief closures and vocalic elements in between.	Approximant (can be retroflexed or bunched, depending on speaker).	Flap (very similar, but not identical, to Spanish tap).
Example Words	<i>pero</i> (“but,”) <i>grande</i> (“large,”) <i>harto</i> (“full, a lot of, fed up,”) <i>hablar</i> (“to speak”)	<i>perro</i> (“dog,”) <i>regla</i> (“rule, ruler,”) <i>enredar</i> (“to tangle, to complicate”)	<i>road</i> , <i>trace</i> , <i>caring</i> , <i>afraid</i> , <i>fort</i> , <i>car</i>	<i>later</i> , <i>ladder</i>

# L2 Production of Spanish Rhotics

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- Both linguistic and learner variables influence rhotic production a great deal.

## Linguistic Variables:

- May be easier to produce taps than trills, since taps are easier to articulate than trills (Face, 2006; Johnson, 2008; Olsen, 2012, 2016; Weech, 2009; cf. Hurtado & Estrada, 2010).
  - May be easier to produce intervocalic rhotics than rhotics in other positions, due to airflow and articulatory movement constraints (Colantoni & Steele, 2008; Hurtado & Estrada, 2010; Johnson, 2008; Olsen, 2012, 2016).
  - Simultaneously acquiring the phonetic parameters of duration, voicing, and manner for Spanish rhotics in different phonological environments may be difficult for L2 learners.
- Order of acquisition of these parameters may vary based on phonological environment, and certain parameters may be acquired in some phonological environments before others (Colantoni & Steele, 2008).

# L2 Production of Spanish Rhotics

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## Linguistic Variables:

- L1 articulatory routines may influence L2 Spanish rhotic production at the beginning stages of L2 learning, but this influence may disappear with increased L2 proficiency (Olsen, 2012, 2016).
- Acquisition patterns for trills (categorical, gradient, or fossilized) may vary depending on aerodynamic measure (airflow, number of taps per trill, delay between taps, total tap duration, closure duration, time to vent pressure, open quotient) and phonological environment combined (Johnson, 2008).

# L2 Production of Spanish Rhotics

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## Learner Variables:

- Transfer errors may decrease and target-like rhotic productions may increase as L2 Spanish proficiency increases (Face, 2006; Johnson, 2008).
- With increased L2 proficiency, realizations for target trills may shift from L1 rhotics (transfer errors) to taps (developmental errors) to trills (target rhotics) (Face, 2006; Johnson, 2008; Weech, 2009).
- Formal pronunciation instruction (at home or abroad) may influence target-like rhotic production (Hurtado & Estrada, 2010; Weech, 2009).
- Living in a Spanish-speaking country for more than one year may be beneficial to rhotic production accuracy (Weech, 2009).

# L2 Perception of Spanish Rhotics

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- Previous research on perception of L2 Spanish rhotics is also important background for this study.
- Many L2 phonology models (ex. Best, 1995; Best & Tyler, 2007; Escudero, 2009; Escudero & Boersma, 2002, 2004; Flege, 1995; Major, 2001, 2008) postulate a perception-production link.
- Several theoretical models of perception and production hypothesize a link between the two modalities. (ex. Diehl & Kluender, 1989; Fowler, 1986; Liberman & Mattingly, 1985; Stevens & Blumstein, 1981)
- Also, many neuroscience studies posit a link between perception and production. (ex. Calvert et al., 1997; Fadiga, Craighero, Buccino, & Rizzolatti, 2002; Paus, Perry, Zatorre, Worsley, & Evans, 1996; Price, Crinion, & MacSweeney, 2011; Wilson, Saygin, Sereno, & Iacoboni, 2004)

# L2 Perception of Spanish Rhotics

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- L2 Spanish learners may discriminate the intervocalic tap and trill with high accuracy (Rose, 2010).
  - However, L2 learners may have difficulty lexically encoding the tap-trill contrast (listening to a word with the tap or trill and associating the correct rhotic with the correct word), which is associated with perceptual identification (Daidone & Darcy, 2014; Scarpance, 2014).
- Encoding the tap-trill contrast may be easier intervocalically (tap: *pero* “but” vs. trill: *perro* “dog”) than at word boundaries (tap: *pedir elotes* “to ask for corn” vs. trill: *pedí reloces* “I asked for clocks”) (Scarpance, 2014).

# Phonetic Training

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- Objectives: Improvements with training, transfer from one (trained) modality to the opposite (untrained) modality, generalization of learning to new speakers and new stimuli from training, long-term retention of learning from training.
- Duration: Long-term or short-term (long-term is much more common).
- Evaluation of training: Pre-test, Post-test design. Pre- and post-test are identical, and similar to training.
- Results most often measured through percentage of correct responses at pre- and post-test.
- Perception tasks: Discrimination, Identification.
- Production tasks: Elicited production/imitation, Reading passages, Picture description tasks.
- Feedback: Immediate (trial-by-trial) and cumulative (after each block of trials or after each session).

(Logan & Pruitt, 1995; see also Herd, Jongman, & Sereno, 2013; Sakai, 2016)

# Phonetic Training

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- Research has provided evidence for the effectiveness of phonetic training (perception and/or production training) in improving perception and production of a variety of L2 segments in many L1 groups, including L2 Spanish rhotics in L1 American English speakers.

(Herd et al., 2013; see also Bradlow, Akahane-Yamada, Pisoni, & Tohkura, 1999; Bradlow, Pisoni, Akahane-Yamada, & Tohkura, 1997; Kartushina, Hervais-Adelman, Frauenfelder, & Golestani, 2015; Sakai, 2016)

# Research Question

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- With phonetic training (perception and production training), do low-proficiency L2 Spanish learners with L1 Canadian English achieve more native-like production of the Spanish tap and trill?

# Hypotheses (Taps)

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- With phonetic training, low-proficiency L2 learners of Spanish with L1 Canadian English will produce intervocalic taps with more native-like duration and manner, but will improve less in voicing (Colantoni & Steele, 2008; Hurtado & Estrada, 2010).
- Improvement with training for taps in consonant clusters will be smaller than for intervocalic taps (Hurtado & Estrada, 2010).

# Hypotheses (Trills)

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- With phonetic training, low-proficiency L2 learners of Spanish with L1 Canadian English will produce intervocalic trills with more native-like duration, voicing and manner (Hurtado & Estrada, 2010).
- Improvement with training for word-initial trills and for syllable-initial, word-medial trills will be smaller than for intervocalic trills (Hurtado & Estrada, 2010).

# Hypotheses (Optional Taps/Trills)

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- With phonetic training, low-proficiency L2 learners of Spanish with L1 Canadian English will show less improvement for syllable-final, word-medial rhotics and word-final, pre-pausal rhotics (optional taps or trills) than for intervocalic taps and trills (Hurtado & Estrada, 2010).

# Participants

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- P003 (age 71, female).
- L1 Canadian English (from a small town in Ontario, near the Greater Toronto Area).
- Beginner L2 Spanish.
- Had no more than beginner proficiency in another L2.
- Had normal hearing and dentition.
- Served as an experimental participant for this pilot study.
- Control participant was recruited, but not available for testing.

# Rhotic Types/Positions Examined

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Intervocalic taps (ex. *pero* “but”)

Post-consonantal taps (ex. *grande* “large”)

Word-initial trills (ex. *regla* “ruler”)

Intervocalic trills (ex. *perro* “dog”)

Syllable-initial, word-medial trills (ex. *enredar* “to tangle, to complicate”)

Syllable-final, word-medial rhotics (ex. *harto* “full, a lot of, fed up”)

Word-final, pre-pausal rhotics (ex. *hablar* “to speak”)

# Pre- and Post-Test Task

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- Reading task (120 stimuli, in 4 blocks of 30).
- Completed twice (once before training and once after training).
- Carrier phrase: *Digo \_\_\_\_\_ otra vez. (I say \_\_\_\_\_ again.)*
- 70 target stimuli (10 for each combination of rhotic and position) and 50 distracters.
- 35 target stimuli with rhotic in a stressed syllable and the other 35 with rhotic in an unstressed syllable.
- Stimuli were real Spanish words, 2 or 3 syllables in length.
- Stimuli were primarily nouns, verbs, and adjectives, varying in frequency.

# Training Task: Phase 1 (Perception)

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- Perception task. P003 listened to 50 stimuli, with orthography presented on a computer screen.
- Produced by an adult male native Mexican Spanish speaker.
- 35 target stimuli (5 for each combination of rhotic and position) and 15 distracters.
- Each word repeated twice, with a 3 s ISI between auditory presentations.
- 16 target stimuli with rhotic in a stressed syllable and the other 19 with rhotic in an unstressed syllable.
- Stimuli were real Spanish words, 2 or 3 syllables in length.

# Training Task: Phase 2 (Production)

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- Production task. P003 listened to, twice, and then, repeated, once, 100 stimuli, with orthography presented on a computer screen.
- 75 produced by the same Mexican Spanish speaker as in Phase 1, 25 produced by an adult male native Peninsular Spanish speaker.
- 70 target stimuli (10 for each combination of rhotic and position, including the same 35 from Phase 1) and 30 distracters (including the same 15 from Phase 1).
- 3 s ISI between auditory presentations before stimuli were repeated out loud.
- 33 target stimuli with rhotic in a stressed syllable and the other 37 with rhotic in an unstressed syllable.
- Stimuli were real Spanish words, 2 or 3 syllables in length.
- Oral feedback provided: Positive reinforcement for target-like rhotic productions, encouragement to listen and repeat one more time if a rhotic production was not target-like.

# Distracter Task

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- Between Phases 1 and 2 of the training task, P003 answered 20 simple arithmetic problems (one operation only, with addition, subtraction, multiplication and division of positive integers up to 10) to erase stimuli in Phase 1 from short-term memory.
- Incorporating this task between the two training phases also reduced the influence of perception on production (see Sakai, 2016).
- This procedure was previously used in an L2 speech learning study by Trofimovich and Gatbonton (2006).

# Testing Protocol

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- The experiment was completed over one 50-minute session.

Table 3: Procedure for Experiment

<b>Task #</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>
<b>Task</b>	Consent form and questionnaire	Pre-test reading task	Training task, Phase 1	Distracter task	Training task, Phase 2	Post-test reading task
<b>Duration</b>	8 min	7 min	10 min	3 min	15 min	7 min

# Data Analysis

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Parameters measured for this study:  
(following Colantoni & Steele, 2008)

Duration (in milliseconds).

Voicing (in milliseconds, converted to a percentage).

Manner (qualitative description, based on waveforms and spectrograms).

Manner classified as approximants, taps, trills, or other.

# Results (Duration, Taps)

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- For intervocalic taps, mean duration showed very little change from pre- to post-test.

Pre: 89 ms.

Post: 89.9 ms.

SD: 6.27 ms.

SD: 11.01 ms.

- For post-consonantal taps, mean duration showed little change from pre- to post-test.

Pre: 90.9 ms.

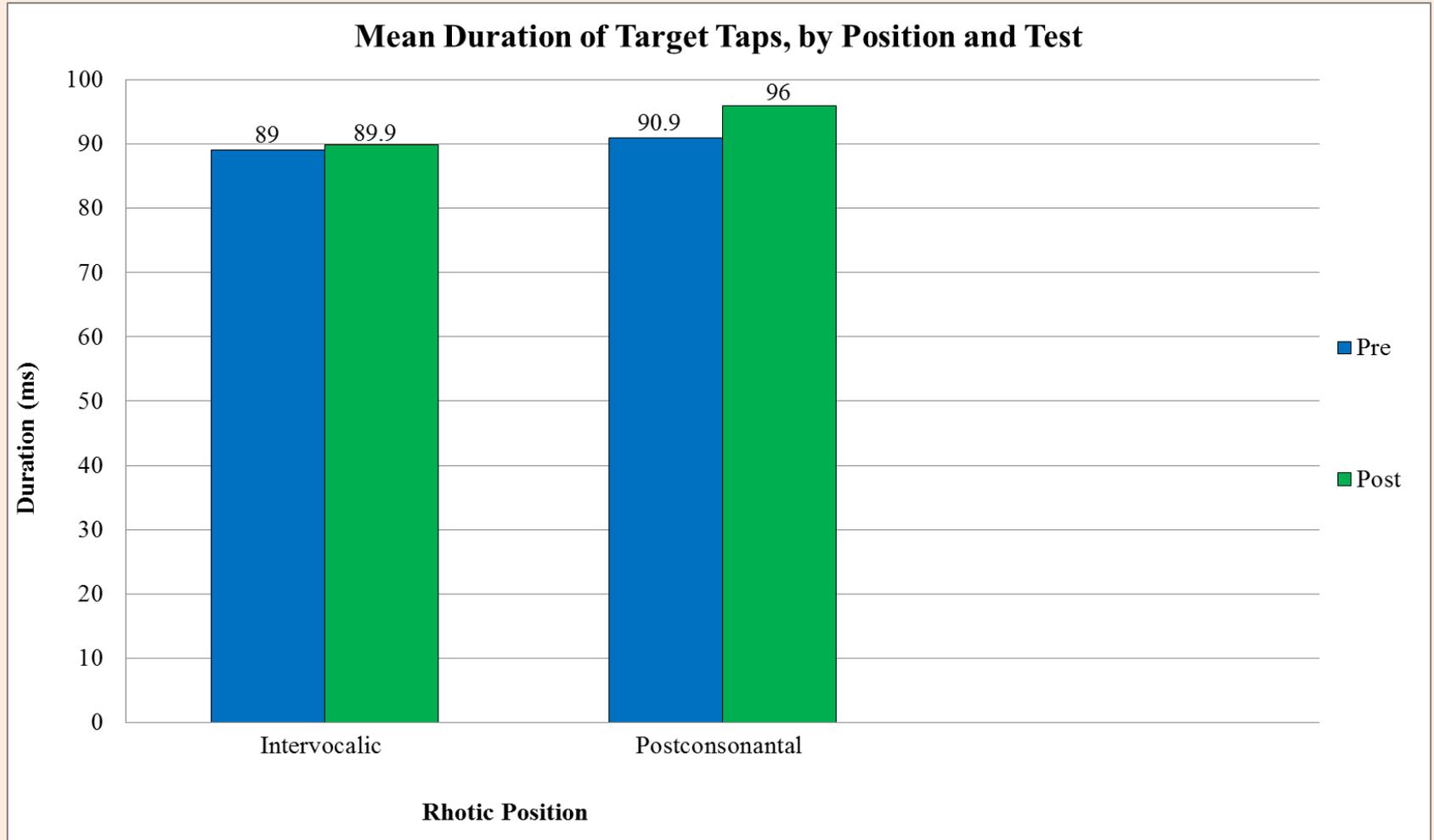
Post: 96 ms.

SD: 10.54 ms.

SD: 14.15 ms.

- No improvement toward target duration for taps in these phonological environments, which is typically 20-25 ms (Colantoni & Steele, 2005, 2008, 2011).

# Results (Duration, Taps)



# Results (Duration, Trills)

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- For word-initial trills, mean duration increased substantially from pre- to post-test.

Pre: 89.4 ms.

Post: 101.6 ms.

SD: 5.97 ms.

SD: 11.74 ms.

- For intervocalic trills, mean duration increased substantially from pre- to post-test.

Pre: 86.4 ms.

Post: 101.8 ms.

SD: 4.17 ms.

SD: 8.65 ms.

- For syllable-initial, word-medial trills, mean duration increased somewhat from pre- to post-test.

Pre: 87.9 ms.

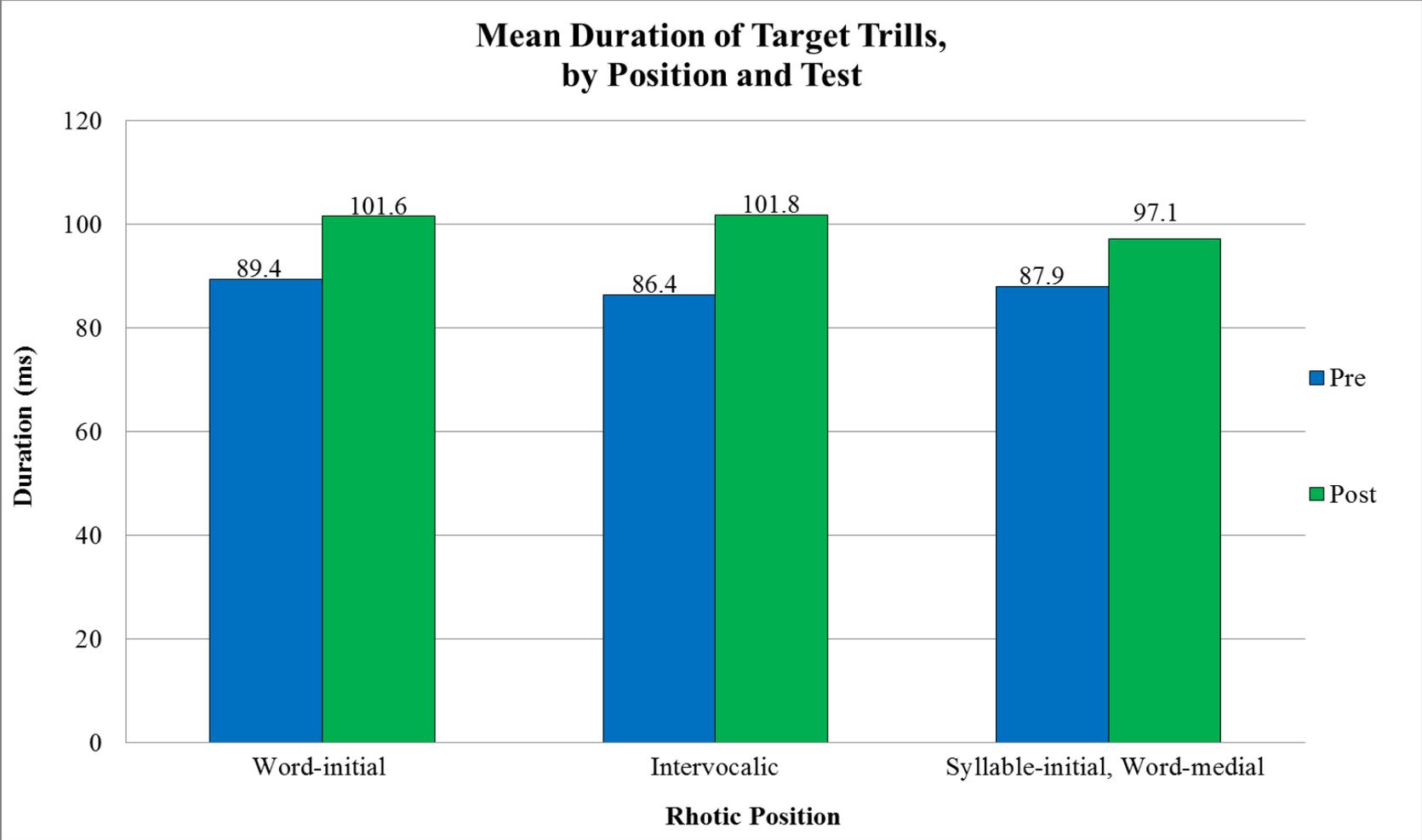
Post: 97.1 ms.

SD: 9.10 ms.

SD: 13.57 ms.

- Mean native speaker duration for trills (85 ms) already reached at pre-test. Lengthened at post-test, but still within the mean range for Romance trills, 75-130 ms (Colantoni, Steele, & Escudero, 2015).

# Results (Duration, Trills)



# Results (Duration, Optional Taps/Trills)

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- For syllable-final, word-medial rhotics, mean duration increased somewhat from pre- to post-test.

Pre: 84.3 ms.

Post: 91.9 ms.

SD: 4.35 ms.

SD: 7.19 ms.

- For syllable-final, word-final, pre-pausal rhotics, mean duration showed very little change from pre- to post-test.

Pre: 91.8 ms.

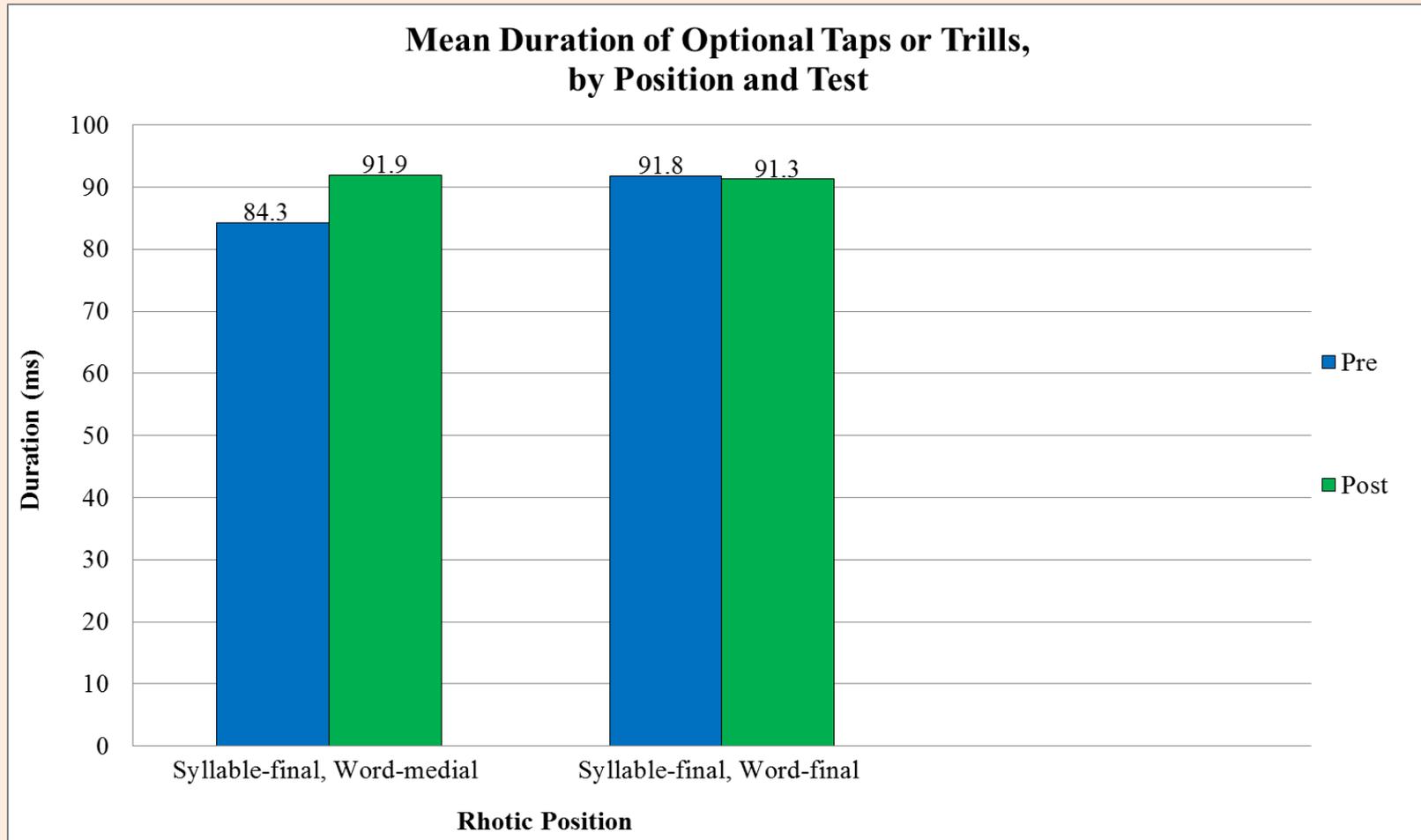
Post: 91.3 ms.

SD: 4.73 ms.

SD: 7.82 ms.

- No improvement toward the target duration for taps, which is the most common realization of rhotics in these environments (Colantoni & Steele, 2005, 2008).
- However, target-like duration for trills at pre- and post-test. Although rhotics in these phonological environments are most commonly produced as taps, native Spanish speakers sometimes produce the tap as a trill, and vice versa (Herd et al., 2013).

# Results (Duration, Optional Taps/Trills)



# Results (Voicing, Taps)

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- For intervocalic taps, mean voicing increased substantially from pre- to post-test.

Pre: 57.4 ms, 64.4%.

Post: 80.1 ms, 88.9%.

SD: 4.10 ms, 4.09%.

SD: 10.57 ms, 4.15%.

- For post-consonantal taps, mean voicing increased substantially from pre- to post-test.

Pre: 59.6 ms, 66%.

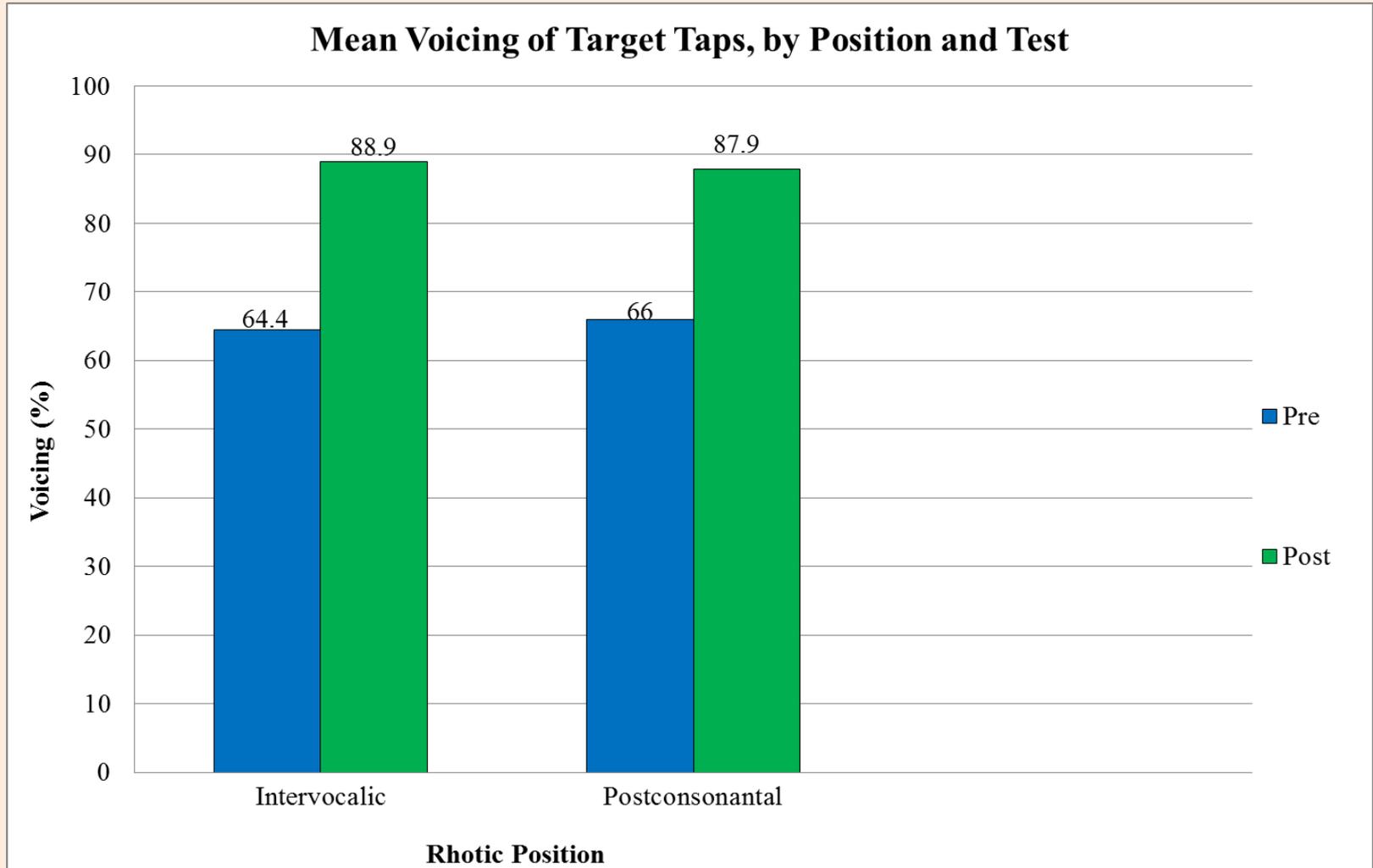
Post: 84.4 ms, 87.9%.

SD: 10.06 ms, 10.08%.

SD: 13.56 ms, 6.31%.

- Improvement toward target voicing for this segment, which is voiced (Quilis, 1999; Schwegler, Kempff, & Ameal-Guerra, 2010).

# Results (Voicing, Taps)



# Results (Voicing, Trills)

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- For word-initial trills, mean voicing increased substantially from pre- to post-test.

Pre: 57.3 ms, 64%.

Post: 90.7 ms, 88.9%.

SD: 5.46 ms, 2.98%.

SD: 11.42 ms, 2.42%.

- For intervocalic trills, mean voicing increased substantially from pre- to post-test.

Pre: 55.6 ms, 64.4%.

Post: 91.3 ms, 90%.

SD: 4.53 ms, 4.06%.

SD: 7.85 ms, 2.59%.

- For syllable-initial, word-medial trills, mean voicing increased substantially from pre- to post-test.

Pre: 54.4 ms, 61.9%.

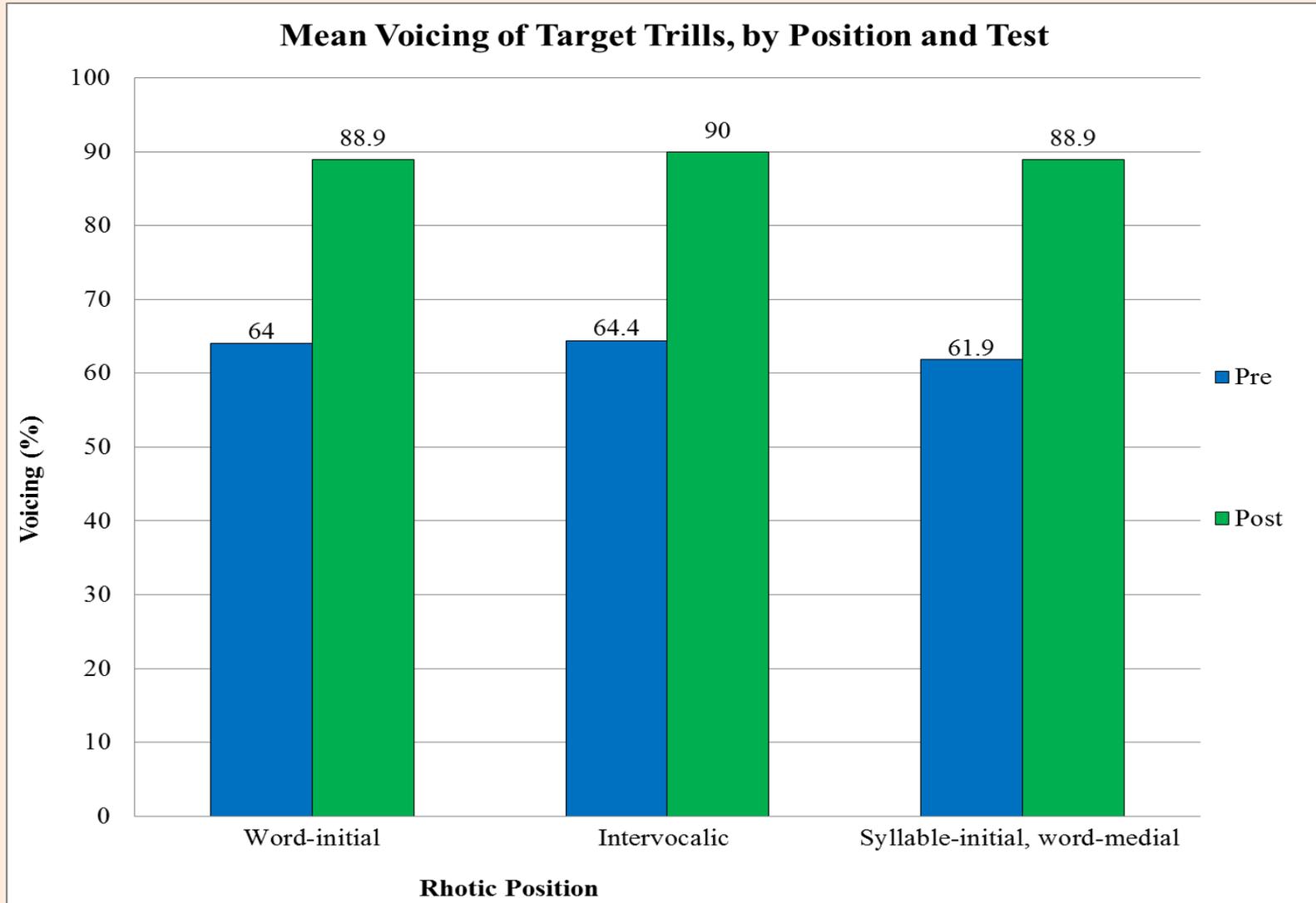
Post: 86.7 ms, 88.9%.

SD: 5.34 ms, 2.96%.

SD: 13.27 ms, 3.53%.

- Improvement toward target voicing for this segment, which is voiced (Quilis, 1999; Schwegler et al., 2010).

# Results (Voicing, Trills)



# Results (Voicing, Optional Taps/Trills)

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- For syllable-final, word-medial rhotics, mean voicing increased substantially from pre- to post-test.

Pre: 49.5 ms, 63.4%.

Post: 80.1 ms, 87.3%.

SD: 5.67 ms, 2.82%.

SD: 5.69 ms, 4.03%.

- For syllable-final, word-final, pre-pausal rhotics, mean voicing increased substantially from pre- to post-test.

Pre: 55.3 ms, 60.2%.

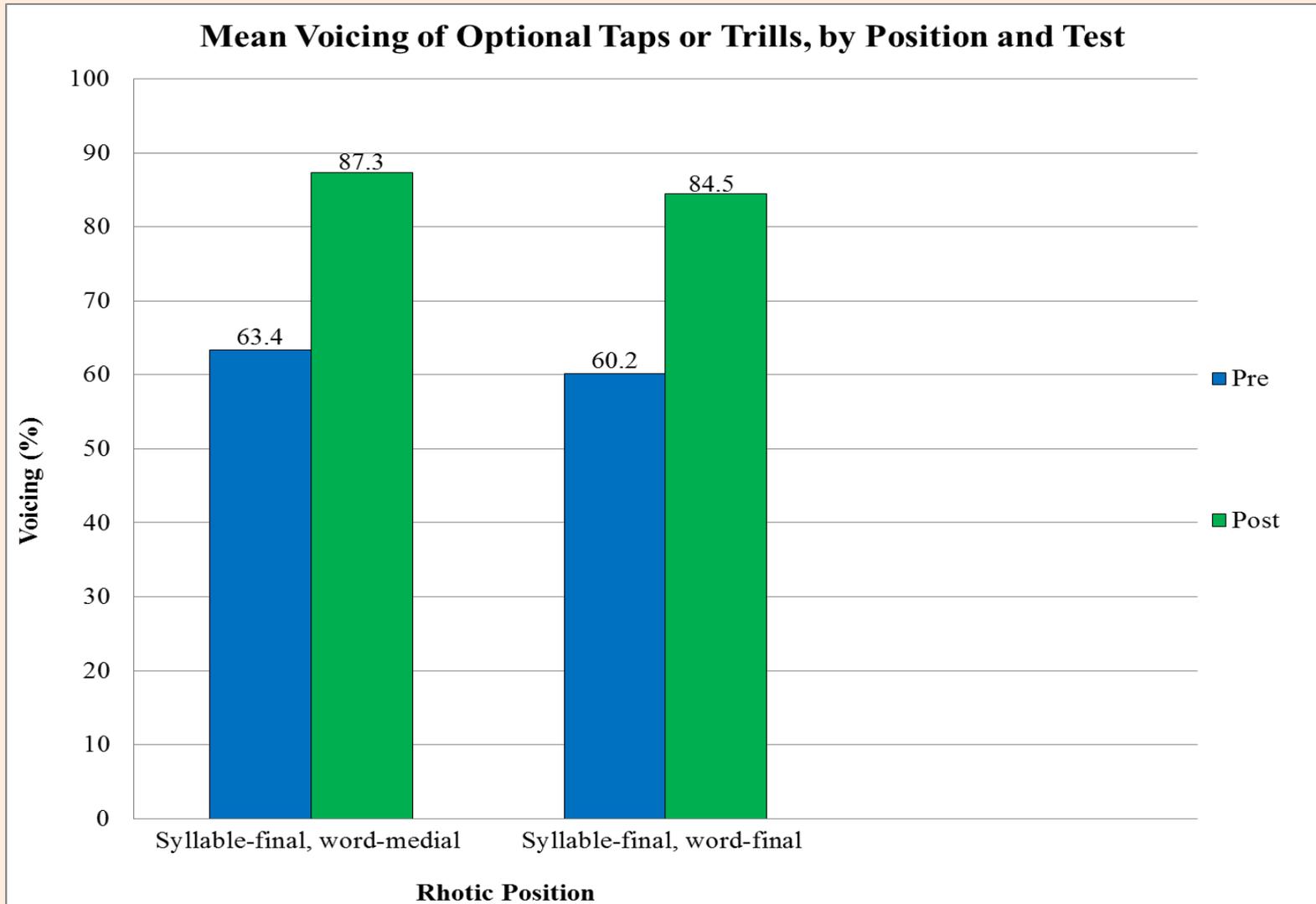
Post: 78 ms, 84.5%.

SD: 4.36 ms, 3.49%.

SD: 7.96 ms, 3.92%.

- Improvement toward target voicing for both taps and trills, which are voiced (Quilis, 1999; Schwegler et al., 2010).

# Results (Voicing, Optional Taps/Trills)



# Results (Manner, Taps)

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- For intervocalic taps, manner changed from approximants at pre-test to a mix of approximants and trills at post-test.

Pre: 10 approximants.  
100% approximants.

Post: 5 trills, 5 approximants.  
50% trills, 50% approximants.

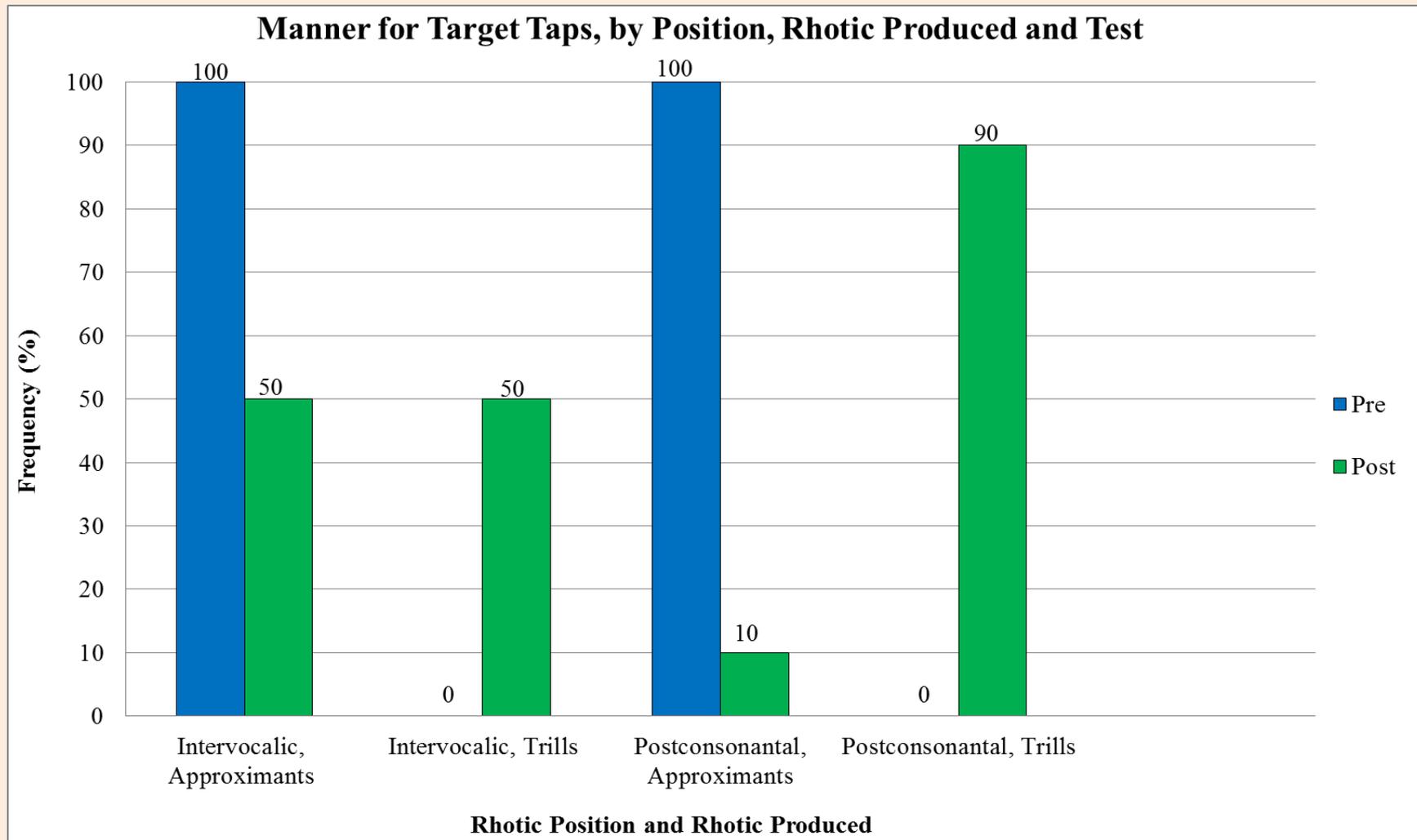
- For post-consonantal taps, manner changed from approximants at pre-test to predominantly trills at post-test.

Pre: 10 approximants.  
100% approximants.

Post: 9 trills, 1 approximant.  
90% trills, 10% approximants.

- Improvement toward near target-like productions, because L1 Spanish speakers sometimes produce the target tap as a trill (and vice versa). (Herd et al., 2013)

# Results (Manner, Taps)



# Results (Manner, Trills)

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- For word-initial trills, manner changed from approximants at pre-test to trills at post-test.

Pre: 10 approximants.

Post: 10 trills.

100% approximants.

100% trills.

- For intervocalic trills, manner changed from approximants at pre-test to trills at post-test.

Pre: 10 approximants.

Post: 10 trills.

100% approximants.

100% trills.

- For syllable-initial, word-medial trills, manner changed from approximants at pre-test to trills at post-test.

Pre: 10 approximants.

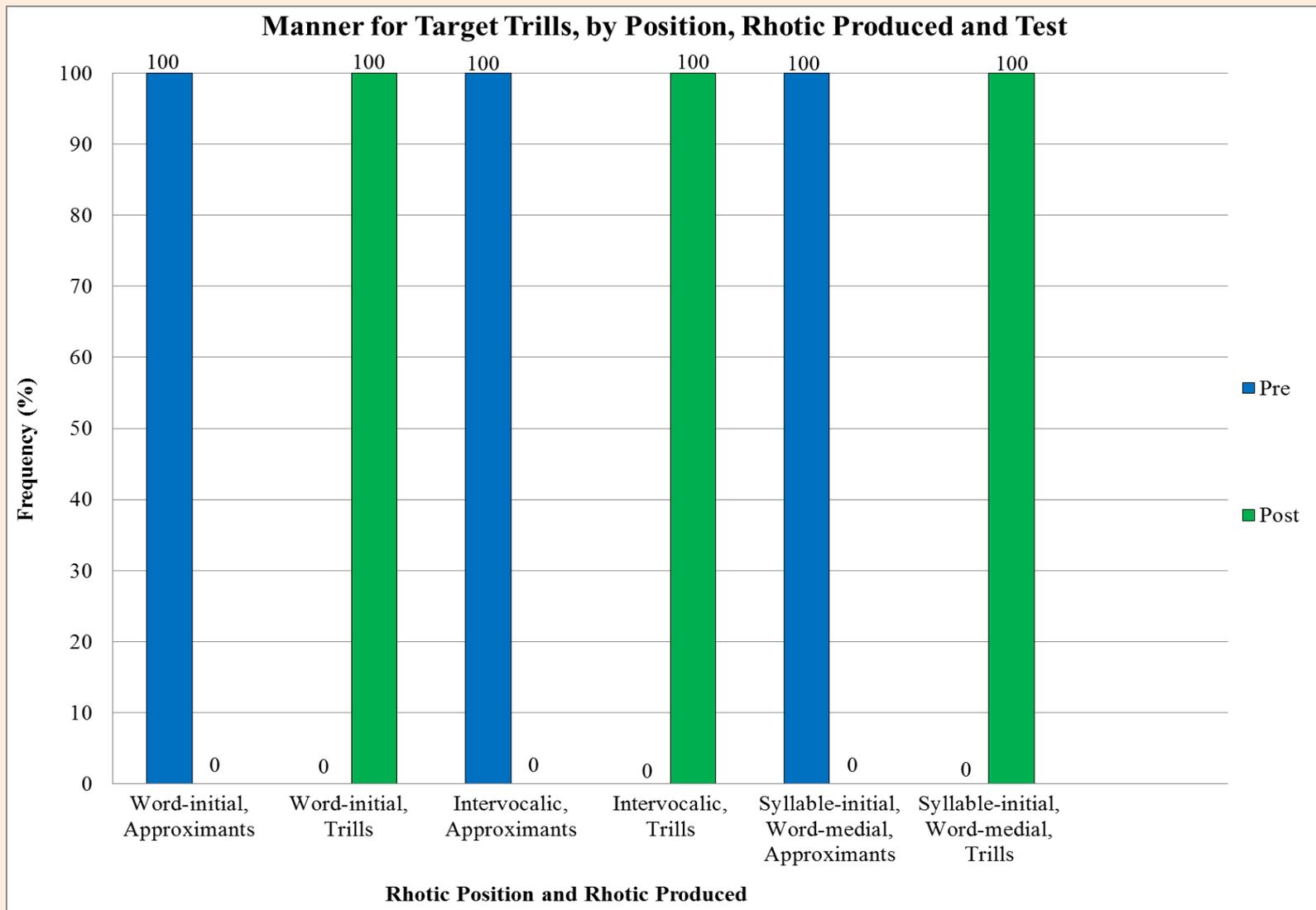
Post: 10 trills.

100% approximants.

100% trills.

- Improvement to target-like productions for this segment.

# Results (Manner, Trills)



# Results (Manner, Optional Taps/Trills)

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- For syllable-final, word-medial rhotics, manner changed from approximants at pre-test to a mix of approximants and trills at post-test.

Pre: 10 approximants.  
100% approximants.

Post: 6 approximants, 4 trills.  
60% approximants, 40% trills.

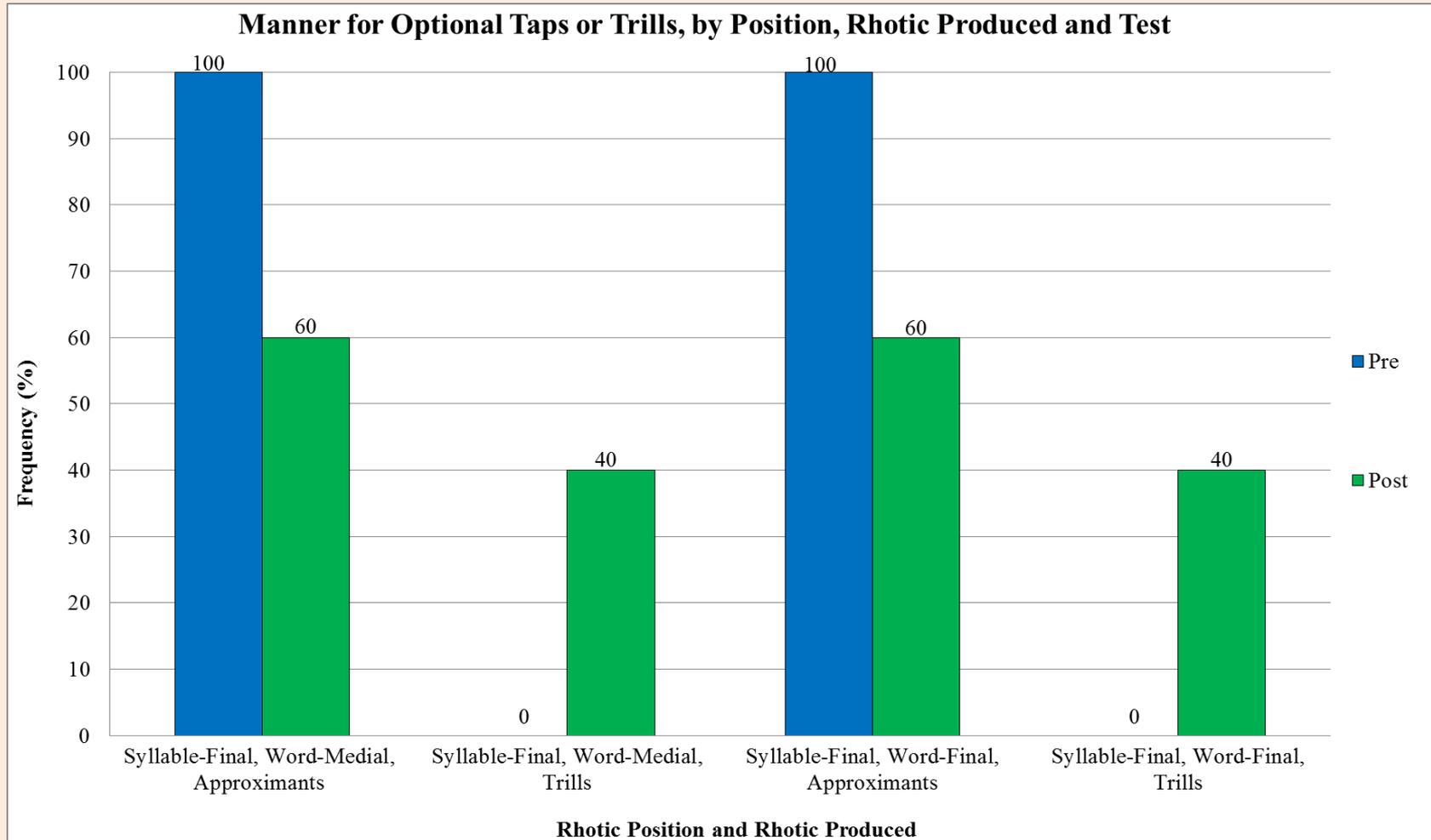
- For syllable-final, word-final rhotics, manner changed from approximants at pre-test to a mix of approximants and trills at post-test.

Pre: 10 approximants.  
100% approximants.

Post: 6 approximants, 4 trills.  
60% approximants, 40% trills.

- Some improvement toward target-like productions. Although rhotics in this phonological environment are most commonly produced as taps, native Spanish speakers sometimes produce the tap as a trill, and vice versa (Herd et al., 2013).

# Results (Manner, Optional Taps/Trills)



# Discussion

Table 4: Summary of Pre- to Post-Test Improvements

(= : parameter already target-like at pre-test, no change needed, ✓: improvement toward target-like productions, ≈: improvement toward near-target-like productions, ✗: no improvement from pre- to post-test)

Rhotic Type			
Parameter	Target Tap	Target Trill	Optional Tap/Trill
Duration	✗	=	=
Voicing	✓	✓	✓
Manner	≈ (Pre-Test: Approximants, Post-Test: Approximants or Trills)	✓	✓ (Pre-Test: Approximants, Post-Test: Approximants or Trills)

# Why the relative success for trills?

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- Likely because P003 may have perceived the Spanish trill to be a different segment from the English alveolar approximant or the English flap.
- The Spanish alveolar trill is not similar to any segment in Canadian English.
- Therefore, following Flege's Speech Learning Model (1995), the trill (a new category for P003) was easy to differentiate from the L1 Canadian English approximant and flap categories, and easy to produce in a native-like way.

# Why the relative difficulty for duration of taps?

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- The trill is perceptually the more different of the two rhotics from the English alveolar approximant (Hurtado & Estrada, 2010).
- Therefore, P003 may have perceived the Spanish tap as equivalent to the Spanish trill (a segment with longer duration than the tap).
- Consequently, P003 may have produced target taps with longer than target-like duration.

# Why were taps produced as trills at post-test?

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- The trill is perceptually the more different of the two rhotics from the English alveolar approximant (Hurtado & Estrada, 2010).
- Therefore, P003 may have perceived the tap as equivalent to the trill.
- Consequently, she may have produced target taps as trills.

# Future Work

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- Conduct this study on more L1 Canadian English participants, to generate a more robust statistical analysis of results.
- Also, conduct this study on participants from other L1 groups (Canadian/European French, European/Brazilian Portuguese, Catalan, etc.) to investigate if there are differences in rhotic improvement with training as a function of participants' L1.
- Investigate improvements in perception of rhotics with training. L2 Spanish learners may have difficulty acquiring Spanish rhotics in perception (ex. Daidone & Darcy, 2014) as well as production (ex. Face, 2006).

# Conclusion

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This study provides some evidence that:

- With a short amount of phonetic training, beginner L2 Spanish learners with L1 Canadian English may show some improvement in their productions of Spanish rhotics.
- These learners may show more production improvement for trills and optional taps/trills than for taps.

→ Trills are distinct (perceptually) from any Canadian English segment, while taps are more similar to the Canadian English flap than trills are.

- Order of acquisition of parameters may vary by rhotic type (see Colantoni & Steele, 2008).

For target taps (all phonological environments): Beginner L2 Spanish learners with L1 Canadian English may improve on voicing first, followed by manner, and then, duration.

For target trills and optional taps/trills (all phonological environments): These L2 learners may improve on duration before manner and voicing.

**Thank you!**  
**Merci!**  
**¡Gracias!**  
**Obrigado!**

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