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The Role of Nuclear Pitch Accents and Postnuclear Segments in the Perception of Nuclear Accent Placement in English by Spanish Speakers

El rol del acento tonal nuclear y el segmento postnuclear en la percepción del emplazamiento nuclear en inglés en hablantes de español

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Abstract

The nuclear accent in an intonation phrase highlights information focus, aiding information processing (Cruttenden, 2007). In English, its placement shifts to mark focus, while in Spanish, it is typically fixed on the final word, even when lacking semantic relevance. Spanish relies more on flexible syntax to indicate focus (Hualde, 2014). For Spanish speakers, perceiving nuclear accents in L2 English can be challenging; thus the need for tailored perceptual training. This study examines how nuclear pitch accent type (falling vs. rising) and postnuclear segment length influence nuclear accent perception. Two hypotheses were tested: (a) Longer postnuclear segments make nuclear word identification more difficult, increasing error rates; (b) Falling pitch accents are easier to perceive than rising ones, with higher scores expected for falling patterns. A perception test was conducted with River Plate Spanish-speaking students training to become teachers of English. Participants identified nuclear word locations in declarative sentences with falling and rising accents. Results showed that postnuclear segment length did not affect

perception accuracy in falling patterns whereas, in rising conditions, perception worsened with longer postnuclear segments, with participants often misidentifying postnuclear words as nuclear. A threshold effect emerged: postnuclear segments of four or more syllables significantly impacted rising pattern perception. These findings suggest that systematic, intensive training is crucial for learners, starting with falling accents and short postnuclear segments. Rising patterns should be introduced progressively, with longer segments attempted after mastering shorter ones. This approach may improve L2 perception of nuclear accent placement.

Keywords: intonation, nuclear accent, pitch accent, perception

Resumen

El acento nuclear en una frase entonativa realza el foco de información, facilitando su procesamiento (Cruttenden, 2007). En inglés, su posición cambia para marcar el foco, mientras que, en español, el núcleo tiende a recaer en la última palabra, incluso cuando ésta carece de carga semántica. El español se apoya más en una sintaxis flexible para indicar el foco (Hualde, 2014). Para los hispanohablantes, percibir los acentos nucleares en inglés como segunda lengua (L2) puede ser un desafío, lo que enfatiza la necesidad de un entrenamiento perceptivo adaptado. Este estudio examina cómo el tipo de acento tonal nuclear (descendente vs. ascendente) y la longitud del segmento posnuclear influyen en la percepción del acento nuclear. Se probaron dos hipótesis: (a) Los segmentos posnucleares más largos dificultan la identificación de la palabra nuclear, aumentando las tasas de error; (b) Los acentos tonales descendentes son más fáciles de percibir que los ascendentes, esperándose puntuaciones más altas para los patrones descendentes. Se llevó a cabo una tarea de percepción con estudiantes hablantes de español rioplatense que se estaban formando como profesores de inglés como L2. Los participantes identificaron las palabras nucleares en oraciones declarativas con acentos descendentes y ascendentes. Los resultados mostraron que la longitud del segmento posnuclear no afectó la precisión perceptiva en patrones descendentes, mientras que, en los patrones ascendentes, la percepción empeoró con segmentos posnucleares más largos, llevando a que los participantes identificaran erróneamente palabras posnucleares como nucleares. Surgió un efecto umbral: los segmentos posnucleares de cuatro o más sílabas impactaron significativamente en la percepción de los patrones ascendentes. Estos hallazgos sugieren que un entrenamiento sistemático e intensivo es crucial para los aprendices, comenzando con acentos descendentes y segmentos posnucleares cortos. Los patrones ascendentes deben introducirse de manera progresiva, intentando segmentos más largos una vez dominados los cortos. Este enfoque puede mejorar la percepción del acento nuclear en inglés como L2.

Palabras clave: entonación**,** acento nuclear, acento tonal, percepción

Introduction

In prosody, nuclear accent, also known as nucleus, nuclear stress or tonicity, is a central concept that plays a vital role in shaping the meaning and interpretation of spoken language. It refers to the most prominent stress or pitch accent within an intonational phrase, often located on the last lexical word of an intonation phrase (IP), though this placement can vary depending on discourse and context. The nuclear accent carries key information and often serves to highlight focus, contrast or other pragmatic functions within an utterance.

Ladd (2008) observes that there is a fairly sharp typological division between languages where nucleus is normally placed on the rightmost end of the IP and languages that allow the nuclear accent to be placed earlier. Vallduví (1991) uses the term *plasticity* to refer to the potential of a language to encode information structure by means of nuclear mobility. He correlates the parameter [+/- plastic] with syntax: languages with fixed word order are said to have plastic prosody, by which they allow nuclei to emerge in positions other than the default IP final. On the other hand, languages with free word order are said to be non-plastic, i.e. they are less likely to exhibit nuclear mobility. This plasticity has been formulated as a gradient variable rather than as a categorical parameter by Face & D'Imperio (2005), who suggest that both Spanish and Italian utilise a combination of word order and intonation to mark focus, indicating that the rigid typological division between these strategies is overly simplistic.

In English, the position of the nuclear accent can be moved to indicate focus on various constituents. In Spanish, on the other hand, the location of the nuclear accent tends to be fixed. Except in very special cases of narrow focus, the nuclear stress tends to fall on the last word, even if it carries no semantic load. Although in cases of contrast it is possible to place the nuclear stress on a non-final word, Spanish tends to exploit its more flexible syntax to indicate focus or pragmatic relevance (Hualde, 2014). The perception of nuclear accent in L2 English can be difficult for some non-

native hearers. In particular, Spanish-speaking learners may not accurately perceive the location of the nucleus in English (Ortiz Lira, 1995; García Lecumberri, 2001). This leads to the question of how to promote more accurate perception in learners through instruction, particularly through perceptual training based on materials specifically designed for this purpose. These materials should take into account the ways in which different acoustic cues are weighted in the perception process. This study addresses the issue of how the perception of English nuclear accent may be affected by two factors: nuclear pitch accent type (falling or rising) and postnuclear segment length (expressed as number of syllables). Possible accounts for these relationships are provided, based on the concepts of cross-linguistic influence and intralingual processes.

Theoretical framework

The nucleus is the obligatory constituent within an intonation phrase (IP), where there may also be optional elements, prenuclear and postnuclear. The prenuclear segment may consist of several unstressed and stressed non nuclear syllables. When the IP contains more than one stressed syllable, the first syllable is often referred to as the *onset* syllable (Brazil, 1997), the element that can establish a change in pitch height or a static pitch within the prenuclear segment. The onset accent can also be described as the secondary pitch accent in the IP, second in importance to the nuclear pitch accent. Like the nucleus, the onset accent marks information as new to the listener.

The onset and the nucleus delimit the *scope of focus*, i.e. the stretch of linguistic material the speaker wants the hearer to pay attention to. The postnuclear segment can contain both function words and lexical items. This segment lies outside the focal range, i.e. it does not contain new information and is therefore not relevant to the message to be conveyed. Since lexical items have potential for accent, those items that lie outside the scope of focus are said to be deaccented, reflecting its predictability or givenness within the context of situation in which they are uttered. Accurate nucleus perception is therefore important for comprehension,

since information focus promotes effective psycholinguistic processing by the hearer (Cruttenden, 2007).

The newness signalled by the nucleus means that nucleus placement is crucial in determining the meaning of an utterance. A shift in nuclear accent placement can entirely change the focus or intended message of a sentence. Understanding and producing appropriate nuclear accent placement is essential for effective communication. This aspect of intonation can be particularly challenging for learners of English as a second language, particularly for those whose native language exploits syntax rather than prosody to construe certain pragmatic or attitudinal meanings.

1. Nucleus placement in English

In English, speakers assign accents to words that contribute *new information*, that part of the IP which the speaker presents as unavailable to the listener (Halliday, 1970). If a lexical word does not contribute new information, it is said to be *old* or given. This term refers to lexical items already in play in the interaction; the speaker presents the information as already known or assumed by the listener. When there is old information in the IP, the focus is said to be narrow. Ladd (1980, p. 84) introduces the idea that, in English, all lexical words are accented by default, and defines de-accentuation as the loss of prominence on a word that would normally be accented. Cruttenden (2007, p. 81) classifies known information into four types: *verbatim* or literal repetition (because it has been mentioned before in exactly the same words), paraphrastic (the information is expressed in other words), implicit (the information is derived from information already introduced) and physical evidence (it refers to an object visible to the participants in the interaction).

Brazil (1997) views verbal interaction as the outcome of speaker decisions, influenced by their evaluation of the degree of shared understanding or common ground where the perspectives of both speaker and listener overlap. As the interaction unfolds, this shared space expands with the exchange of new information. This additional information influences the

speaker's choice of specific words to highlight as candidates for prominence in the discourse.

Brazil characterises the placement of the nucleus, and accentuation more broadly, as a process of selecting meaning. He suggests that when a speaker highlights a particular word, they are indicating that this word represents a selection from a set of options or paradigm. This paradigm emerges from the intersection of two factors: a general paradigm, defined by the grammatical structures of the language, and an existential paradigm, shaped by the interactional and situational context. If the context limits the options within the existential paradigm to just one, no process of meaning selection occurs, and thus, the word will not receive accentuation. Examples (1), (2) and (3) show cases of narrow focus where the final lexical words are deaccented because their senses have already been introduced (capitals show the location of nuclear accent).

1) We set up camp in the Himalayas, WAY up high.
2) The result nil-nil against Brazil is not a BAD result.
3) Arsenal two, Aston VILLA two.

In English, broad focus IPs have a nucleus placed on the last lexical item, whereas in cases of narrow focus, the nucleus will often be found on non-final lexical words[1]. However, certain new lexical items, i.e. elements that do not fit into any of the old information categories proposed by Cruttenden (2007), are nonetheless deaccented, even when they are part of the focal range. These elements have not been mentioned before in the discourse in any way, nor have they been introduced implicitly. They are the so-called exceptions to the broad focus rule (Ortiz Lira, 1995; Wells, 2006). Example (4) shows the nuclear accent on a non-final word, even when the last lexical word contributes new information.

[1] Narrow focus may also involve IPs where the focus is at the rightmost end of the IP, while the material preceding the nucleus may be out of focus. Therefore, tonicity on the last lexical item does not necessarily entail broad focus.

4) The KETTLE's boiling.

The fact that the nuclear accent is often found early in the IP may lead learners to overgeneralise this tendency to early nucleus. This may have an influence both on L2 English production and perception.

2. Nucleus placement in Spanish

In Spanish, the nuclear accent tends to be less mobile than in English. When the IP is in broad focus, the nuclear accent tends to fall on the last word, even if it carries no semantic load, as shown in examples (5) and (6).

5) Tengo sed. Necesito tomar ALGO. (Cf. I need to DRINK something)
6) No me siento BIEN (Cf. I don't FEEL well[2]).

Ortiz Lira (1995, p.2.) notes that "given information in Spanish can be, and in fact normally is, accented, as simple observation of facts attests". He goes on to mention Kingdon's (1958) observation that "Spanish speakers tend to place pitch accents on a word that has already been accented in the same utterance, a practice that is relatively rare in English" (op. cit., p. 245-6). This is shown in example (7).

7) Trabaja de noche en el CINE, y hoy no hay CINE.

This late assignment of the nucleus also takes place on words that are retrievable, as in examples (8), (9) and (10).

8) El resultado cero a cero con Brasil no es un mal RESULTADO. (Ortiz Lira, 1995).
9) Hicimos campamento en los Himalayas, un lugar bien ALTO[3].
10) Arsenal dos, Aston Villa DOS.

[2] *Adverbs of proper functioning* are highly predictable and therefore have the value of a functional word (Gussenhoven, 1984, p. 38)

[3] Although the nucleus on *bien* is also possible, this does not invalidate the acceptability of the nucleus on *alto*.

It is often claimed that Spanish tends to exploit its more flexible syntax to indicate focus or pragmatic relevance (Hualde, 2014). Indeed, this is the case in example (11), where the syntactic subject is placed at the end of the IP so that it can receive the nuclear accent.

11) Está hirviendo la PAVA.

However, the tendency to re-accent words that do not need highlighting suggests that the pursuit of pragmatic focus is not always the reason why Spanish-speaking users of English produce nuclei on old or given information. It might well be that Spanish speakers are less sensitive to the informational status of lexical words than they are to syntax, although this cognitive aspect needs to be researched. The fact that the nuclear accent in Spanish is often found late in the IP may lead learners to transfer this L1 tendency to late nucleus onto the L2. This can have an influence both on L2 English production and perception.

3. Acoustic cues that have an influence on nucleus placement perception

The perception of nuclear prominence involves the psycholinguistic processing of a number of prosodic articulatory features. It is now widely accepted that perception of accent is mediated by the perception of pitch and stress as the main factors (Fry, 2001; Cruttenden, 2007, 2014, among others). Studies have shown that the primary indicator of prominence is pitch, the perceptual correlate of fundamental frequency or F0 resulting from the vibration of vocal folds (Bolinger, 1958; Pierrehumbert, 1980; Ladd, 2008, among many others). Pitch may be static, i.e. remain constant through the syllable, or may be dynamic. Nuclear accent tends to be signalled by a change in pitch.

A second prosodic cue is given by the intensity in the accented syllable. The speaker employs articulatory effort, or stress (Laver, 1994), which is perceived as loudness by the hearer. The duration of the prominent syllable also impinges on perception (Fry, 2001; Lehiste, 1970). The combination of F0, stress and duration render accent, understood as an

articulatory and acoustic entity, whereas the combination of percepts associated to these dimensions constitute prominence. The perception of nuclearity, therefore, depends on the perception of the prosodic features associated with the nuclear syllable.

Since English relies heavily on prosody to signal focus, learners who miss the subtle cues of nuclear accent placement may miss out on critical information. This could lead to confusion or misinterpretation, particularly in contexts that require the recognition of contrasts or corrections. Many learners' difficulties in perceiving and producing nuclear accent stem from prosodic transfer, where the intonational patterns of the learner's first language (L1) influence their use of stress and accent in English as a second language (L2). Spanish speakers often misperceive the location of nuclear accents, possibly due to transfer of L1 prosody. In particular, learners tend to be rather insensitive to the absence of accent in given (old) lexical items and thus to their informational status. This affects the *weighting*[4] of more relevant items against those that may be retrieved from previous discourse or situational context.

Previous studies in the perception of L2 English nuclear accent placement

Many studies in L2 tonicity have addressed the issue of native language influence on the perception of nucleus in L2 English. Research by Ladd (2008) and Beckman and Pierrehumbert (1986) has shown that native English speakers exhibit a heightened sensitivity to the informational status of words, distinguishing between given (already known) and new

[4] The term *cue weighting* refers to the process by which individuals assign varying levels of importance to different sensory cues when interpreting complex stimuli. This concept is particularly significant in speech perception, where listeners rely on multiple acoustic signals to discern phonetic elements. The weighting of these cues indicates their relative influence on perceptual decisions. The term "weighting" is preferred over "weighing" in this context because it denotes the assignment of importance or value, rather than the physical act of measurement. "Weighting" implies a proportional influence that each cue exerts on perception, aligning with its usage in statistical and psychological literature.

information through specific prosodic configurations. This sensitivity is evident in their use of pitch accents and de-accentuation to signal the status of information within discourse. Non native speakers, however, do not consistently use accenting and deaccenting to differentiate between given and new information.

Ortiz Lira (1995) explored how Spanish speakers place the nucleus when speaking English and whether they transfer patterns from Spanish. He examined the similarities and differences in nucleus placement rules between the two languages, focusing on cases where interference might cause misinterpretations or nucleus misplacement in English. His findings suggest that Spanish speakers sometimes transfer their native accentual patterns into English, which can lead to non-native prosodic patterns and may affect listeners' comprehension. This emphasises the importance of teaching intonation to help Spanish-speaking learners of English.

García Lecumberri (2001) examined how native language background affects learners' ability to perceive and assess focus in English. Her study explores whether and how learners transfer aspects of their native language intonation patterns when assessing the placement of the nucleus in English IPs. Her findings suggest that cross-linguistic influence is an important factor in nucleus placement perception. This can lead to challenges in accurately identifying and assessing the intended focus in English speech. The author highlights the need for targeted teaching approaches that address focus and nuclear accent perception, especially for learners whose native languages differ significantly from English in intonational patterns.

Traoré Reig (2014) investigated whether Catalan learners of English who fail to perceive English tonicity patterns struggle to understand the intended meaning and attitudinal nuances of speech. Her study also explored the influence of first language (L1) prosodic transfer. The results indicated that while the learners had difficulty interpreting meaning conveyed by contrastive or corrective tonicity patterns, they were generally able to discriminate and identify pitch differences. The study

suggests that positive prosodic transfer can occur between Catalan and English, as Catalan speakers utilize focus in their L1, aiding their perception of pitch in English. The author concludes that a Catalan learner of English can discriminate different pitch accents independently from their meaning and placement while they may be able to identify the tonic syllable in an utterance independently from the meaning of the pitch accent.

An examination of the literature does not show many studies that specifically address the role of acoustic cues in nuclear placement perception. One such study is that by Hua, Li & Wayland (2019), who compared native and non-native (Chinese) English speakers' assessments of nuclear accent placement produced by Chinese learners of English. Besides examining differences in how native and non-native English speakers perceive nuclear accents, they also set out to determine which acoustic cues (duration, pitch, intensity) influence listeners' judgments of nucleus placement. As stimuli, they employed speech samples produced by Chinese learners of English. These included sentences with nuclear accent placed on specific words. Participants listened to the speech samples and identified where they perceived the nucleus to be. Their judgments were compared against the intended nuclear accent placement. It was found that native English speakers primarily relied on word duration as the main cue for perceiving nuclear accent. Longer duration of the nuclearised word was a strong indicator of prominence. On the other hand, non-native listeners used a combination of duration and intensity to identify nuclear stress. They placed more weight on changes in loudness than native speakers. This suggests that prosodic cue weighting, and possibly, temporal resolution of changes in prosodic cues, may be language specific and shaped by L1 experience. Moreover, native listeners showed greater consistency in identifying nuclear accent placement, reflecting their stronger attunement to the prosodic patterns of English, while non-native listeners demonstrated more variability in their responses, likely influenced by their reliance on multiple, less reliable acoustic cues. The findings suggest that teaching English prosody to non-native speakers should emphasize duration as a critical cue for nuclear accent placement.

The authors claim that instruction could focus on producing longer stressed syllables and appropriately reducing the duration of unstressed syllables.

Aims of this study

This study aimed at analysing the influence of two different factors on the perception of nucleus placement: a) nuclear accent type and b) postnuclear segment length. Two hypotheses were posited:

Hypothesis 1: The number of postnuclear syllables influences the perception (and therefore, identification) of the location of the nuclear word. Longer postnuclear segments, containing a larger number of syllables, lead to more difficult perception, i.e., larger error rates.

Hypothesis 2: Successful identification of the nuclear word poses a lower degree of difficulty in falling than in rising tonal configurations. It was predicted that perception test scores for falling pitch accent patterns would be higher than scores for rising patterns.

Method

A quasi experimental[5] design was used to test the hypotheses. There were two independent variables or factors: nuclear pitch accent type, with two levels, accent type 1 (falling intonation) and type 2 (rising intonation); and number of postnuclear syllables, with four levels (0, 2, 4, 6). The dependent variable was the perception score, i.e. the number of successful identifications of the nuclear word. It was assumed that correct identification stemmed from accurate perception.

1. Participants

Participants (N=53) were students at a Teacher Education Programme in the city of Buenos Aires. They were training to become teachers of English (age mean: 24.2 years old, SD: 5; AOA (age of acquisition) mean: 10.75 years, SD: 3.66). As part of their training, they were attending courses

[5] There was no random selection of experimental subjects.

in English intonation four hours a week. They all belonged to the same course group. At the time of testing, they had had eight weeks of instruction in theoretical aspects and approximately eight hours of intonation imitation practice, but had no experience of perceptual training nor had they taken any nucleus placement identification tests.

2. Stimuli

The participants listened to a total of 80 utterances, produced by the same speaker, using four types of nuclear pitch accents: fall, rise, fall-rise and rise-fall. Two of these configurations (falling and rising) were the target forms, while the other two tonal patterns acted as fillers.

The target stimuli set comprised a total of twenty falling accents (accent type 1) and twenty had low rising accents (type 2)[6]. Both falls and rises occurred in sentences with different postnuclear segment lengths, measure by the number of postnuclear syllables present: zero (no post tonic segment), two, four and six syllables[7]. Postnuclear segments with two, four and six syllables all had iambic metrical feet. Each set of twenty sentences was made up of the same syntactic forms and lexis from the first word to the nuclear word, as shown in examples (12. a-d). Capital letters indicate the nuclear word.

Example (12)

a) She flatly refused to eat the MEAT.
b) She flatly refused to eat the MEAT he bought.
c) She flatly refused to eat the MEAT a week ago.
d) She flatly refused to eat the MEAT he bought a week ago.

[6] The patterns employed were similar to O'Connor & Arnold's (1973) *high drop* and *low bounce.*

[7] The post nuclear segment lengths were similar to those encountered by the students in their oral practice texts.

All nuclear words were monosyllabic. Pre nuclear segments contained high static accents, although with some degree of declination[8] and were identical in each four-sentence set. Both the structure of pre and postnuclear segments were designed to control for any extraneous variables that might have had an impact on the perception of nuclearity. **Figures 1 and 2** show falling and rising intonation contours for some of the stimuli. Due to space constraints, only two different postnuclear conditions are shown.

Fig. 1. Pitch contours of falling nuclear pitch accents in IPs with two different postnuclear segment conditions (zero and two syllables). Capital letters signal the nucleus.

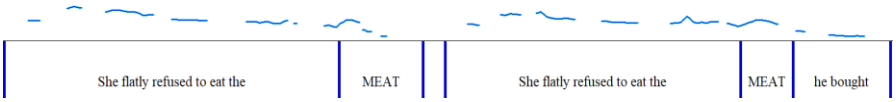
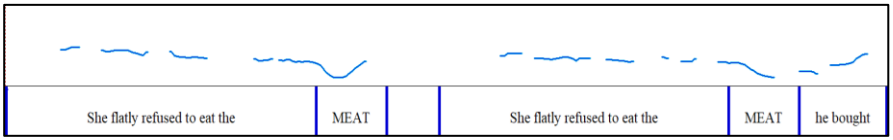


Fig 2. Pitch contours of rising nuclear pitch accents in IPs with two different postnuclear segment conditions (zero and two syllables). Capital letters signal the nucleus.



The sentence tokens were read aloud and recorded by an expert English-speaking phonetician. They were then checked for consistency, both auditorily by another expert phonetician and instrumentally, using Praat v. 6.4.13 (Boersma & Weenink, 2024). The contours were examined for any significant F0 variations across nuclear words in different tokens. Following Niebuhr, Reetz, Barnes & Yu (2021), any nuclear F0 excursions greater than 1.5 semitones were corrected by means of the manipulation editor in Praat. Nuclear F0 values in falling accents averaged 116.5 Hz across the

[8] Declination is the tendency for F0 to decline gradually during the course of utterances (Ladd, 2008)

nuclear vowel duration; in rising accents, the mean value for F0 was 74 Hz; onsets averaged 126.5 Hz. Intensity was normalized across tokens.

3. Task

Participants were asked to listen and identify the nuclear word in each sentence. The test was administered in a quiet room, a language laboratory where participants usually had their lessons. The audio tracks were played back over headphones. The participants were divided into two groups and the stimuli were arranged in two blocks, A and B. The first group of participants was first exposed to block A and then to block B, while the second group of participants took the test in reverse order. This was done to reduce carryover effects. All subjects listened to all sentences in all conditions. For each postnuclear level (0, 2, 4, 6) there were five sentences, totalling 185 stimuli for each level. For each nuclear pitch accent type, there were 740 stimuli. Each participant was exposed to 20 falls and 20 rises (targets) and 40 distractors. The stimuli were randomised. Prior to the task, the participants took a pilot test to make sure they understood the task.

In each stimulus, a 1.5 second-long beep followed by a 1.5 second-long silent gap was inserted before the start of each utterance. This was to allow listeners to prepare for the upcoming stimulus. 1.5 seconds after the end of the utterance, there was a second beep that prompted participants to record their responses by circling the perceived nuclear word. This limitation to their decision time aimed at avoiding overthinking: a less speculative and more spontaneous response was sought, in an attempt to elicit the response that more closely represented internal processes rather than self-monitoring and self-correction.

Results

The results were tabulated in terms of *hits* and *fails*. The term *hit* is used here in a narrow sense. It does not refer to correct identification by random

guessing[9]; rather, a hit is regarded as a reflection of accurate nucleus perception. Likewise, the term *fail* is used to refer to an error, a misidentification of the nucleus, i.e. a participant circled a word that was non nuclear. Every time participants identified the nuclear word correctly, they got a point. Otherwise, no point was awarded. Each subject got a perception score for stimuli with falling pitch patterns and another score for stimuli with rising patterns, which were added up for group scores.

Within each pitch accent type category, there were partial scores for each level of the postnuclear factor. The crossing of factor levels produced eight conditions: F0, F2, F4, F6 and R0, R2, R4 and R6. F0 refers to IPs bearing falling nuclear pitch accents and no postnuclear syllable; F2 refers to stimuli with falling accents and two postnuclear syllables; F4 refers to stimuli containing falling accents and four syllables after the nucleus, and F6 refers to falling stimuli with a postnuclear segment six syllables long. Likewise, IPs with rising accents included instances with no postnuclear syllables (R0) as well as postnuclear segments with two, four and six postnuclear syllables (R2, R4 and R6, respectively).

The effect of postnuclear segment length, i.e. the number of postnuclear syllables, was tested for each accent type. The overall score was 967 hits, or nuclear placements accurately identified (i.e., perceived) out of 1480 utterances heard. Out of 740 falling accents, participants correctly perceived 504 nuclei (68.4% hits), whereas out of 740 rising stimuli, 461 nuclei (62.3% hits) were accurately perceived. Although these figures do not seem to differ greatly, the differences become apparent when the results are disaggregated according to the different conditions tested. The bar graph in **Figure 3** shows the distribution of data values across accent types and postnuclear segment lengths. The pie charts in **Figures 4 and 5** show relative distribution of hits for each accent type condition, out of 504 falling and 461 rising hits, respectively.

[9] The test methodology was designed to reduce the impact of random variability, employing strategies such as randomisation and counterbalancing. This approach ensures that any residual variability can be quantified and incorporated into the analysis as a calculated error rate, in line with standard statistical practices.

Fig. 3. Overview of perception hits for all conditions

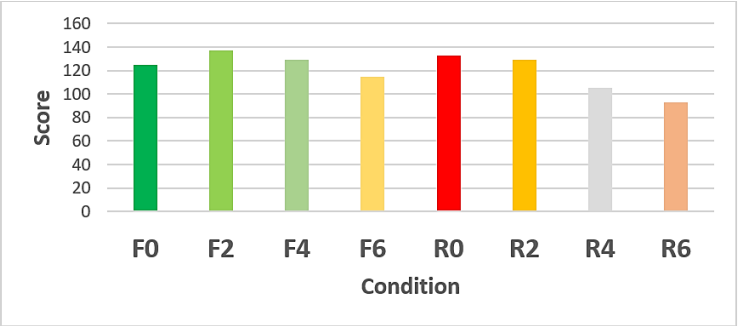


Fig. 4. Relative perception hits for IPs bearing falling nuclear pitch accents

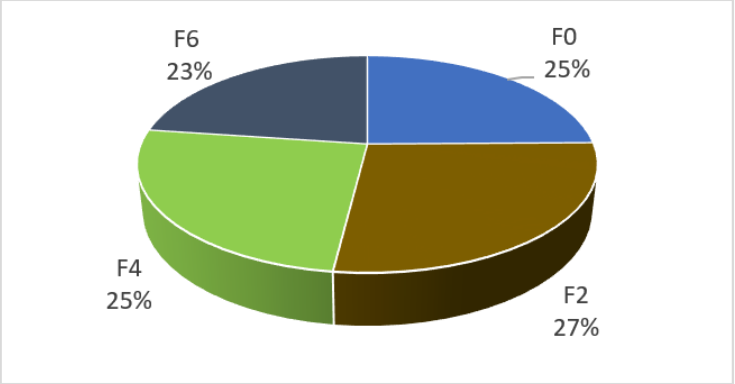
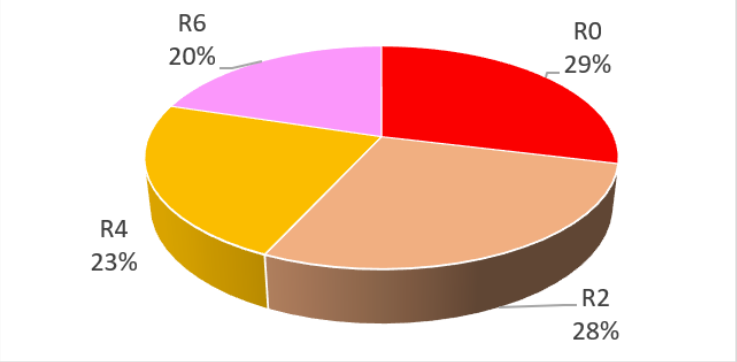


Fig. 5. Relative perception hits for IPs bearing rising nuclear pitch accents



Analysis

1. Statistical analysis

1.1. Effect of postnuclear segment length for each nuclear accent type (hypothesis 1)

In order to examine the effect of postnuclear syllable length for IPs with falling and rising nuclear accents separately, two Cochran's Q tests[10] (Siegel & Castellan, 1988) were run[11]. For stimuli with falling nuclear accents, p= 0.044; for stimuli with rising nuclear accents, p< 0.001. This means that, although both p values were smaller than 0.05, only the rising condition showed a significantly greater difference across different postnuclear segment lengths. In order to establish where the most significant differences lay, a post hoc McNemar test[12] (McNemar, 1947; Siegel & Castellan, 1988) was run for the rising pairwise comparisons. The p values obtained showed that only the pairs R0-R6, R0-R4 and R2-R4 exhibited the most significant differences. **Table 1** shows the p values for post hoc pairwise comparisons for rising conditions.

Table 1. McNemar post hoc pairwise comparisons for rising conditions

	R0 - R2	R0 - R4	R0 - R6	R2 - R4	R4 - R6
N	185	185	185	185	185
χ^2	,225	10,125	20,253	9,132	2,824
p	,635	,001	,000	,003	,093

[10] The Cochran's *Q* test shows whether the means of three or more dependent samples are different. This test is suitable for binary data (hit=1 and fail=0 response type), as used in this study (Siegel & Castellan, 1988).

[11] All results were tested at an alpha level of 0.05.

[12] A McNemar test shows whether the means of two dependent samples are different. This test is suitable for binary data.

However, these pairs exhibited different effect sizes. For the R0-R6 comparison, a Cohen's *g*[13] value of 0.22 suggests a moderate effect size, indicating that there is a difference between conditions R0 and R6 in terms of correct identification rates (Cohen, 1988). For the R0-R4 comparison, Cohen's *g* of 0.15 suggests a small size effect, smaller than the other conditions. For the R2-R4 comparison, Cohen's *g* of approximately 0.24 suggests a medium-sized effect, indicating that there is a difference (the largest one in this group) between conditions R2 and R4 in terms of correct nucleus perception rates, with the pattern of hits and fails differing between the two conditions.

1.2. Effect of nuclear accent type for each postnuclear segment length (hypothesis 2)

In order to assess the effect of nuclear accent type, postnuclear segment length was controlled for. In this case, the comparison involved the number of times the participants correctly perceived the nucleus in IPs bearing falling and rising nuclear accents, keeping the number of postnuclear syllables constant. Therefore, the pairwise comparisons were set up as F0-R0 (falling and rising stimuli with no postnuclear segments), F2-R2, F4-R4 and F6 and R6.

A McNemar test was carried out to assess whether there were any differences in the falling and rising oppositions, i.e., how correct identifications of nuclear words in falling patterns compared to those in rising patterns for the same postnuclear length. As shown in **Table 2**, the test revealed no significant differences between the F0-R0 and the F2-R2 conditions ($p>0.05$ in both cases).

[13] An effect size shows the degree to which two means are different. Cohen's *g* indicates effect size thus: for *g* values smaller than 0.05, effect size is negligible; between 0.05 and 0.15, there is a small effect; between 0.15 and 0.25, the effect is medium-sized, showing a medium-sized difference between falling and rising patterns.

Table 2. McNemar post hoc pairwise comparisons for rising vs. falling accents, for each postnuclear segment condition

	F0 - R0	F2 - R2	F4 - R4	F6 - R6
N	185	185	185	185
χ2	1,085	,817	8,491	6,891
p	,298	,366	,004	,009

The tendency, however, changes when the length of the postnuclear segment increases to four and six syllables ($p<0.05$ in both cases). It is clear that perception scores in the four and six-syllable segments differ depending on the type of nuclear accent involved. As for effect sizes, these are relatively small: for F4-R4, Cohen's *g*= 0.124 and for F6-R6, *g*= 0.119. Although modest, these values are greater than those for F0-R0 and F2-R2 (0.049 and 0.043, respectively), i.e. there is a greater postnuclear segment effect on perception when the nuclear pitch accent is a rising one.

2. Overall analysis and discussion

The *p* values show that the differences between the falling accent scores (hits) are not significant, and therefore, for IPs bearing falling nuclear accents, the number of postnuclear syllables does not have an influence on the perception and identification of the nuclear word. Therefore, hypothesis 1 is not corroborated for IPs with falling accents. However, the hypothesis is supported for rising accents. Except for the comparison R0 with R2, the rest of the pairwise comparisons show that the differences between mean scores are significant. This suggests that, for the tonal sequences with rising accents, postnuclear segment length has an impact on the scores of correct identifications of the nuclear word. Furthermore, except for R4-R6, the *p* values show that the differences become more significant as the number of postnuclear syllables increases, with the R0-R6 and R2-R6 differences being the largest in magnitude.

The *p* value= 0.796 suggests that, when the nucleus is two syllables away from the final syllable (R0-R2 comparison), the presence of postnuclear

material has no significant impact on the correct identification of the nuclear location. That is, the way in which the nuclear pitch accent is phonetically implemented—either as an intra-syllabic F0 glide or as a stepped-up difference (as in R2, R3 and R4)—does not appear to affect the dependent variable. This might indicate that, in order to find appreciable differences between perception score values, it is necessary that at least four syllables should mediate between the nuclear syllable and the last postnuclear syllable.

Hypothesis 2 is also corroborated. The length of the postnuclear segment seems to have a greater influence when the nuclear accent rises in pitch, whereas, in the case of patterns with falling nuclear accents, the number of postnuclear syllables has virtually no impact on nuclear word identification scores. This pattern suggests a possible interaction between nuclear pitch accent type and postnuclear segment length, although the present analysis did not test this relationship directly.

To corroborate whether the type of nuclear pitch accent has an effect on the perception of nucleus location, scores were compared holding the number of postnuclear syllables constant. Further McNemar tests were performed to compare the means of the pairs F0-R0, F2-R2, F4-R4 and F6-R6. The McNemar *p* values show that only the pairs F4-R4 and F6-R6 show significant differences. When the number of postnuclear syllables is smaller than four, nuclear accent type does not seem to have an impact on the responses. That is, only when the postnuclear segment has a length equal to or greater than four syllables, an effect on the dependent variable can be found. In the corpus, this segment length seems to be the threshold value at which the presence of postnuclear syllables begins to play an important role in the perception of nuclear location.

The errors found can shed light on the cognitive processes involved in the participants' perception. A preference for late nuclei could result from L1 transfer (Selinker, 1974) or cross-linguistic influence (Kellerman and Sharwood Smith, 1986). Late nucleus assignment would be motivated by L1 experience, i.e. the tendency of nuclei to fall on the last word in Spanish.

On the other hand, the assignment of nuclear status to the onset syllable would reflect an intralingual process, namely overgeneralisation, of the frequent occurrence of early nuclei in English. In other words, some learners may interpret early nuclearity as a marker of 'Englishness' and therefore tend to process the prosodic cues afforded by the onset accent (pitch height and stress) and give them nuclear status. This, coupled with the high perceptual salience of the onset accent (an F0 value slightly higher than the mean F0 in the nucleus, although perceptually very close to the nuclear pitch), makes the onset syllable a highly likely candidate for its categorisation as a nucleus. It is interesting to note, however, that an interpretation of the error from the point of view of memory and processing capacity would mean that an earlier pitch event overrode a later one. This goes against the expectation that the last pitch event would be stored and retrieved more readily than the first. This underscores the idea that intralingual mechanisms such as overgeneralisation can be deeply rooted in the L1-L2 interface, and may win over the 'last heard, first remembered' tendency.

Turning to the issue of errors in IPs with rising nuclear pitch accents, it is probable that at least some participants perceived the nucleus to be on the word immediately preceding the nuclear word due to an incorrect weighting of the F0 step-down difference between the last pre nuclear syllable and the nuclear syllable. This difference in pitch may have caused the perception of falling nuclear pitch, and therefore motivated participants to interpret that this drop in pitch was a manifestation of the nucleus. Once again, the familiarity with falling pitch as opposed to the relative newness of the low rising contour may have played a role in this type of processing.

Conclusions and limitations

This study shows that nuclear accent type and postnuclear segment length can affect the perception of nucleus placement in English by speakers of River Plate Spanish. The findings suggest that both factors interact in complex ways that influence the perceptual identification of the nuclear

word. Longer postnuclear segments can pose a greater level of difficulty – expressed as cognitive load- in rising intonation patterns. These results indicate the existence of a perceptual threshold beyond which Spanish-speaking learners find it increasingly difficult to track how nuclear pitch develops in rising, post nuclear movement.

From a theoretical standpoint, the study contributes to the understanding of cross-linguistic influence in L2 prosodic perception. Most of the nucleus placement errors found tend to fall into one of two main categories: either the nucleus was erroneously assigned to the last lexical item in the IP or it was misperceived as being placed in an earlier position than it actually was. The first error type points to cross-linguistic influence or L1 transfer, while the second error type can be attributed to intralingual processes.

These two complementary tendencies can be interpreted in light of L2 speech models, such as the Speech Learning Model (Flege, 1995; Flege & Bohn, 2021), according to which L2 listeners re-weight the acoustic cues of the target language using categories shaped by their L1 experience. It seems that speakers of River Plate Spanish are less sensitive to the acoustic cues associated with nuclear accent or, more probably, they employ a cue weighting mechanism that does not compute the different cues in a native-like fashion. They may assign excessive weight to positional information while underweighting pitch dynamics and duration cues associated with English nuclear accent. They may also resort to non acoustic parameters, such as position in the IP or overgeneralisation of early nuclearity.

Although individual factors such as memory, aptitude or cognitive style were not controlled for in this study, they certainly play an important role in perception, and could be a source of error in at least some of the participants' responses. Indeed, the two predictors tested in this study could be related to cognitive load and the degree of difficulty involved.

Besides individual factors, this study did not investigate in detail responses where participants placed the nuclear word to the left of the actual nucleus, nor did it analyse cases where, in rising intonation patterns, participants placed the nucleus on the second, fourth or sixth postnuclear

syllable. Therefore, it did not quantitatively assess whether there is a correlation between the presence of postnuclear syllables and the identification of a certain position within the postnuclear segment as predominant in the responses (e.g. whether in rising pitch IPs, those participants who marked the nucleus incorrectly tended to favour the sixth (last) syllable of the postnuclear segment, as opposed to other non nuclear syllables). A detailed analysis of the errors (i.e., the locations where the participants perceived the nuclei incorrectly) and their possible predictor variables fall outside the scope of this study. The complexity and variety found in the participants' performances warrant a study of their own. This will be fully addressed in further research.

Taken together, the findings support the view that successful acquisition of English nuclear pitch accent perception involves a gradual restructuring of perceptual strategies and cue hierarchies. Understanding how learners reorganise these perceptual processes provides a foundation for the pedagogical applications discussed in the following section.

Pedagogical implications and training applications

The outcomes of this study have direct implications for the design of intonation instruction and perceptual training programs aimed at Spanish-speaking learners of English[14]. Given that perception constitutes the foundation of accurate production (Flege, 1995; Flege & Bohn, 2021; Best & Tyler, 2007; Escudero, 2005), developing learners' ability to perceive the nucleus within the intonation phrase should be an explicit pedagogical goal in L2 intonation teaching. This gives rise to the question of how learners could be trained so that they reorganise their cue weighting process in such a way that accurate perception will occur.

[14] Speakers of other Romance languages might also profit, since the tendency to late nucleus and flexible syntax have also been described for other Romance languages, especially Spanish, Italian and Catalan (Face & D'Imperio, 2005; Feldhausen & Vanrell, 2014). The replication of this study with speakers of other Romance languages could show whether the hypotheses presented are corroborated or refuted.

In early stages of tonicity learning, it may be desirable to use acoustic stimuli with only falling pitch accents as a starting point. Then, the next step in the training would include falling IPs with increasingly longer postnuclear segments. Once perceptual stability is achieved, rising accents would be introduced. Initially, they should be presented in tokens with no postnuclear segments, as the presence of postnuclear syllables may cause listeners to misidentify the nucleus and place it in a late position. Postnuclear segment length would be gradually increased as learners make progress though the training programme, and learn to integrate duration and intensity with F0 in the overall determination of nuclearity. This scaffolding approach would allow learners to consolidate perception before moving to more challenging stimuli.

Given that the misinterpretation of postnuclear syllables as nuclear is a major source of difficulty for Spanish speakers, learners should also be trained to recognise acoustic deaccentuation, not only in terms of pitch change but also of reduced intensity following the nuclear syllable. Classroom practice would include guided listening tasks in which learners compare contextualised utterances differing only in postnuclear length, marking the syllable where the main pitch event occurs. These activities can raise awareness of word informational status, i.e. whether a lexical word is uttered as new, unpredictable[15] information or as retrievable information. This could promote more native-like cue weighting. Teachers could reinforce these distinctions by providing contrastive feedback.

Technological tools could enhance prosody teaching. Software such as Praat (Boersma & Weenink, 2024), WASP (Huckvale, 2000) or WinPitch (Martin, 2011) allow learners to visualise pitch contours in real time. The inclusion of visual feedback of F0 trajectories has been shown to increase accuracy in both perception and production of prosodic patterns (De Bot,

[15] A model of nuclear accent placement prediction, based on contextually and cognitively-driven predictability, can be found in [Author] (2024, 2025). This framework could help learners anticipate the most likely location of the nucleus, thus orienting selective attention towards nuclear acoustic correlates.

1980, 1983; Hardison, 2004). For the present training context, tasks might involve learners identifying the nuclear syllable on a displayed intonation contour[16], then producing the visualised pattern orally while monitoring the match between their own and the model's F0 track. Such visual/oral/aural perception–production loops could promote the internalisation of nuclear accent cues.

Although visual display tools offer immediate and intuitive feedback**,** their pedagogical value should be approached with caution**,** as learners may rely on visual cues at the expense of auditory sensitivity. Indeed, some studies have shown that the addition of visual cues to perception training tasks can be as effective as using auditory cues alone, rather than enhance performance in dual (auditory+visual) tasks. For example, McCrocklin (2016) investigated the use of audio and video input in L2 vowel perception training. She found that, in contrast to previous research (Hardison, 2004; Hardison, 2005), the introduction of video versus audio made little difference in perception rates, although her participants were more engaged in the dual task. In other words, her findings do not support the Dual Coding Theory (Paivio, 1986) nor the Cognitive Theory of Multimedia Learning (Mayer, 2001), which claim that audio plus video would allow for dual coding and thus better storing and accessing of new information. Therefore, while visual feedback has been shown to aid prosody training, its specific effects on the perception of nuclear placement remain under-researched and warrant further empirical investigation.

The presence of cross-linguistic and intralingual errors in this study point to the need to organise perception training into stages, prior to the training sessions proper. Before any training begins, there should be an assessment of the type of misplacements; in some individuals, L1 transfer may predominate, while intralingual errors might predominate in others. This

[16] For an untrained beginner, identifying the nucleus in an unmarked, un-segmented intonation contour may pose a difficult task. The nuclear pitch event might be confused with other, non nuclear, events. Therefore, for initial training purposes, the location of the nucleus should be marked beforehand and provided in a text grid, below the segmented contour.

means that different learner profiles would have different needs and should therefore receive exposure to tokens especially designed to tackle learners' idiosyncratic difficulties. Such action would provide a more personalised experience and would address more specific aspects of the training process.

Future directions

Future research should pursue three main lines of inquiry. First, longitudinal studies could examine whether systematic perceptual training leads to measurable improvement in both perception and production of nucleus placement. Such work would bridge the gap between experimental and pedagogical phonetics and contribute to the growing literature on perceptual learning in L2 prosody (Hardison, 2004; Levis & Suvorov, 2018).

It would also be valuable to test the robustness of the threshold effect found here. i.e. whether the four-syllable limit generalises across other nuclear pitch accents, such as fall-rises and rise-falls. The present analyses were designed to address the two hypotheses originally proposed. Future studies could extend this line of inquiry by examining directly the apparent interaction between nuclear pitch accents type and postnuclear segment length, by means of factorial statistical models[17].

The inclusion of spontaneous or semi-spontaneous speech materials could help clarify whether similar cognitive constraints operate outside controlled laboratory conditions. Future studies might incorporate cognitive measures, such as reaction times, to investigate real-time processing of nuclearity. Such multimodal approaches could reveal how attention and working memory interact with cue weighting during the perception of nuclear accents.

As mentioned in the conclusions and limitations section, this study did not quantitatively evaluate the likely relationship between the presence of

[17] A factorial analysis examines the effects of two or more independent variables simultaneously and can determine whether the effect of one variable changes according to the level of another variable, that is, whether there is an interaction effect (Field, 2018).

postnuclear syllables and the identification of a certain position within the postnuclear segment as predominant in the responses. Further studies should address nuclear pitch accent type as a predictor of nuclear placement on a specific pre or postnuclear syllable. If a correlation were to exist, this could be taken as an indicator of a cue-weighting strategy where nuclear pitch accent type wins over lower level prosodic features, such as duration or intensity.

Furthermore, the potential contribution of two psychological factors could be investigated: echoic memory and working memory. Echoic memory (Atkinson & Schiffrin, 1968) is the starting point in the processing of speech auditory cues, the first stage in the memory process before information moves to short-term and working memory if consciously attended to. Working memory, on the other hand, is the processing system that manipulates information stored in echoic memory (Baddeley & Hitch, 1974; Baddeley, 2000) and could be the seat of the cue-weighting process. Research is needed to ascertain whether these factors correlate with success at nucleus placement identification.

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