“¿Es una Pregunta?”: An ERP Study on the Perception of Early Intonational Cues in Spanish Learners

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# Abstract

Accurately parsing intonation is crucial for a language like Spanish, where declaratives and absolute interrogatives are syntactically and lexically, and only differ in intonation. Although the final pitch movement is the main cue for determining sentence modality in Spanish, the first pitch peak of the utterance acts as a secondary cue (Face, 2007). This study uses EEG to investigate the sensitivity to early pitch accents for identifying sentence modality in L1 English L2 Spanish individuals of varying proficiency levels. Participants completed a two-alternative forced choice task, in which they were tasked with identifying an utterance was question or not. In the target items, participants were exposed to utterances in which the first pitch accent peak was manipulated to be higher (for base-declarative utterances) or lower (for base-interrogative utterances). Under the Associative Learning hypothesis (Kamin, 1969), it would be expected that the initial learners of Spanish pay attention only to the final pitch movement to determine sentence modality, which is the most salient cue and, in most varieties of Spanish, follows universal language tendencies. Due to this, the manipulated stimuli would elicit no N400, which has been seen to be elicited by anomalous pitch accents. Advanced learners, on the other hand, would be sensitive to other intonational cues, such as the peak height of the first pitch accent, and the anomalous pitch accent would thus elicit an N400.

*Keywords:* ERP, EEG, prosody, intonation, suprasegmental, interrogatives

*Word count:* WORD\_COUNT

# 1. “¿Es una Pregunta?”: An ERP Study on the Perception of Early Intonational Cues in Spanish Learners

# 2. Introduction

Native speakers integrate intonational cues in the speech stream temporally early in on-line speech processing (Li, 2018), but do learners make use of the same cues? In Spanish, declaratives and absolute interrogatives are syntactically and lexically ambiguous [Table 1](#tbl-eg-sentences); they are only disambiguated at the intonational level through modulation of fundamental frequency (F0), the rate of vocal fold vibration perceived as pitch. Traditional analysis of Spanish prosody typically points to the final F0 movement of an utterance in determining if an utterance is a declarative or interrogative (Tomás Navarro, 1944), but recent research by Face (2007) has determined in a gating experiment that native Spanish speakers can distinguish between a declarative and absolute interrogative as early as the first stressed syllable of the sentence. Do learners of Spanish make use of the same intonational cues to predict sentence modality?

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 1: Spanish declarative and absolute interrogative.   | Sentence Type | Spanish | English | | --- | --- | --- | | declarative | Mariano habla del tiempo. | Mariano talks about the weather. | | absolute interrogative | ¿Mariano habla del tiempo? | Does Mariano talk about the weather? | |

# 3. Background and Motivation

## 3.1 Autosegmental Metrical Framework

While some languages simultaneously use F0 to encode semantic meaning at the lexical level (e.g., Mandarin Chinese or Swedish), all languages make use of F0 to encode pragmatic meaning (Arvaniti & Fletcher, 2020) such as sentence type or affect. Spanish and English are among the languages that modulate F0 to provide syntactic structure (Steinhauer et al., 1999) and pragmatic information (Ladd, 2008).

The Autosegmental Metrical (AM) model of intonation (Ladd, 2008; Pierrehumbert, 1980) attempts to map the continuous F0 contour to phonologically discrete, sequential tone targets. Tone targets can be H(igh), L(ow), or a combination of the two to represent rises (LH) or falls (HL), which are organized as either pitch accents, anchored to the stressed syllable, or edge tones anchored to prosodic boundaries. Edge tones are furthered divided into phrase accents and boundary tones, anchored to non-terminal prosodic boundaries and the Intonation Phrase boundary, respectively. Using the Tones and Breaks Indices (ToBI), the annotation tool used within AM, pitch accents are indicated with \* (e.g., H\*); non-final edge tones with - (e.g., H-); and boundary tones with % (e.g., H%). These representations and phonetic realizations are part of a many-to-many relationship, such that a single representation, such as H+L\*, may have various phonetic realizations. This parallels segmental phonology, where a single segment, such as the Spanish /b/, may have various realizations depending on numerous contextual factors, such as a bilabial plosive, bilabial approximant, or labio-dental fricative.

Furthermore, the final pitch accent (deemed the nuclear pitch accent) combined with the boundary tone receive a special status as the nuclear configuration, which is typically mapped to sentence type (Prieto & Roseano, 2010). However, Pierrehumbert (1980) proposed that prenuclear accents (i.e., pitch accents that occur to the left of the nuclear pitch accent) also contribute information to the sentence. The current study investigates the contribution of prenuclear pitch accents to on-line sentence processing and prediction of sentence modality.

## 3.2 L1 Intonation Processing

Although intonation is typically viewed as ancillary to the core grammar of a language, there have been recent pushes to consider the integrity of intonation and its place in encoding semantico-pragmatic functions such as speech act marking, information status, belief status, and politeness (Prieto, 2015). Neurocognitive studies on intonation have repeatedly demonstrated that manipulating intonation inhibits sentence processing (Li, 2018; Mourão, 2006; Steinhauer et al., 1999), supporting claims by intonational phonologists that intonation is a critical component of a language’s grammar.

Some of the earliest studies on intonation discovered a late ERP component, the Closure Positive Shift (CPS), which is associated with the right side of an Intonational Phrase (Steinhauer et al., 1999). This component is found even during reading, indicating that intonation is implicitly activated during this activity (Steinhauer, 2003). Importantly, these components, deemed “wrap-up effects”, may mask other ERP components elicited at the same temporal moment. It is therefore difficult to examine utterance-final on-line processing. Due to this difficulty, the present study focuses on processing of earlier cues in the speech stream, instead of the final boundary tone.

The N400 component, typically elicited by semantically incongruous or “unexpected” elements in a sentence (Kutas & Hillyard, 1980), have also been found to be elicited by inappropriate or missing pitch accents. For example, Magne et al. (2005) investigated anomalous pitch accents in question-answer dialogues in L1 French. For example, they provided participants with the questions “Did he give his fiancée a ring or a bracelet?” or “Did he give a ring to his fiancée or his sister?” The answer to both questions were syntactically and lexically identical, “He gave a ring to his fiancée”, and differed only in pitch accents on “ring” and “fiancée” (e.g., “He gave a *ring* to his fiancée” would be an inappropriate response to the latter question). Participants were tasked with judging if the answer was a coherent response with respect to the question. Magne et al. (2005) found that incongruous pitch accents in sentence-medial positions elicited the P3a and P3b components, while those in sentence-final position elicited the N400. They interpreted these results as increased difficulty in sentence processing. The results from Magne et al. (2005) have also been seen, although with slight variation to the specific ERP components, in English (Johnson et al., 2003) and Japanese (Ito & Garnsey, 2004).

Li (2018) investigates the temporal processing of intonation in Mandarin Chinese by comparing F0 changes produced by intonation or lexical tone in two tasks. In the intonation task, participants identified whether the sentence was a statement or question; in the tone task, participants identified the tone (tone 2 or tone 4) of the final word. They found that participants processed intonation first in both tasks: around 150-200ms in the first task after the target word, and 100ms in the second. Li (2018) took these results to indicate the primacy that intonation has in language, appealing to evolutionary roots that prosodic cues have in human language.

The cited studies indicate that intonational cues are integrated during on-line sentence processing in L1 speakers.

## 3.3 L2 Intonation Learning Theory

AM has been primarily developed to investigate L1 intonation, but there have been recent attempts to expand intonation investigation into the L2 domain. For example, Mennen (2015) has proposed the theoretical model L2 Intonation Learning Theory (LILt). Four dimensions of intonation are recognized under this model with the goal of characterizing the similarities and differences between the intonation inventories between two languages:

1. The inventory and distribution of categorical phonological elements (“systemic” dimension)
2. The phonetic implementation of these categorical elements (“realizational” dimension)
3. The functionality of the categorical elements of tunes (“semantic” dimension)
4. The frequency of use of the categorical elements (“frequency” dimension)

The LILt model, as demonstrated by the specified dimensions, are primarily concerned with L1-L2 transfer effects. That is, it is predicted that a language learner acquiring an L2 will experience positive transfer effects when the intonation systems align along one or more dimensions, whereas they will experience negative transfer when they do not align. For example, English and Spanish differ in how they express polite responses to wh-questions. Where English uses a broad pitch range in its rises, represented with by the nuclear configuration L+¡H\* (where **¡** represents an extra high tone), Spanish uses a narrow pitch range, represented by L+H\* (Estebas-Vilaplana, 2014).

The differences here have a significant impact on the acquisition of Spanish by L1 English speakers. English speakers have available to them L+H\* (Dilley & Heffner, 2013), the expected contour in Spanish (“systemtic” dimension). It is realized phonetically similarly, although the English L+H\* typically has a broader pitch range (for English: Beckman & Elam, 1997; for Spanish: Prieto & Roseano, 2010) (“realizational” dimension”). The “frequency” dimension is defined at a more general level by Mennen (2015) and would require more space than attributed here to investigate the frequency differences of tone primitives in English and Spanish. However, crucially, there is a mismatch in the *semantic* dimension. Where English uses L+¡H\* as an appropriate, polite response to a wh-question, Spanish does not pattern in this way; instead, it is mapped to an “over-excited” response, which could give rise to misinterpretation when learners interact with monolingual L1 Spanish speakers.

Relevant to the present study, no research investigating the LILt model using neurocognitive methodologies were found. Furthermore, early intonation components (i.e., prenuclear pitch accents) are oftentimes left unexamined in favor of the more salient nuclear configuration (i.e., the final pitch accent and boundary tone), which is typically mapped to sentence type (Ladd, 2008). The present study investigates the integration of prenuclear pitch accent information in on-line sentence processing, which will provide valuable information for assessing the LILt model’s predictions about L2 intonation acquisition.

## 3.4 L2 Intonation Acquisition (Behavioral Studies)

Accurate parsing of intonation is critical in Spanish, as induced earlier, to accurately interpret if an utterance is a declarative or absolute interrogative (among other functions), but it remains an understudied topic (Sanchez, 2020). Recent behavioral research has investigated the acquisition of intonation in L2 Spanish speakers, specifically investigating the perception of declaratives versus interrogatives (Brandl et al., 2020; Casillas et al., 2023).

Brandl et al. (2020) realized a two-alternative forced choice task with L1 English L2 Spanish speakers of varying proficiency, which they operationalized as Beginners I and II, Intermediates I and II, and Advanced. Participants were shown a sentence on the computer screen which ended with a terminal stop (.) or a question mark (?), and they had to decide if the auditory stimulus of the same sentence given to them matched the punctuation. They found that absolute interrogatives were the most difficult sentence type for Spanish learners to process, finding a jump in accuracy between Intermediate II and Advanced. Furthermore, reaction times for yes-no questions were the only sentence type for which match and mismatch conditions did not differ significantly.

Importantly, Brandl et al. (2020) included 8 dialects of Spanish in the stimuli, two of which were Caribbean varieties. Caribbean varieties of Spanish are known to use a falling boundary tone to mark absolute interrogatives (Armstrong, 2010). In light of LILt (Mennen, 2015), identifying Caribbean absolute interrogatives would be particularly difficult for L1 English L2 Spanish learners, as English absolute interrogatives are typically signaled with rising boundary tones. Despite this, Brandl et al. (2020) did not include speaker variety as a variable in her analysis.

Casillas et al. (2023) presented a conceptual replication of Brandl et al. (2020). In the presentation of stimuli, Casillas et al. (2023) presented only audio stimuli in a two-alternative forced choice task in which participants had to decide if the utterance was a question or not. Included in their analysis was the effect of speaker variety on accuracy and reaction time. Casillas et al. (2023) found that participants were least accurate when identifying sentence modality for Puerto Rican and Cuban speakers, in line with the LILt model’s (Mennen, 2015) predictions on L2 intonation acquisition. In regards to overall accuracy, Casillas et al. (2023) had similar results to Brandl et al. (2020). That is, the accuracy of yes-no questions increased dramatically as proficiency increased, indicating the difficulty of identifying absolute interrogatives for L2 Spanish learners.

The present study focuses on the perception of secondary cues for identifying absolute interrogatives in Spanish learners, a sentence type that has been shown to be particularly difficult for learners to acquire. Although the boundary tone is seen to be the most important cue to identifying sentence modality (Face, 2007), it seems that native speakers use earlier, secondary cues to predict if a sentence is a declarative or interrogative. The present study investigates the integration of those secondary cues in the on-line sentence processing of Spanish learners.

## 3.5 L2 Intonation Processing (Cognitive Studies)

The Interface Hypothesis (Sorace, 2011) proposes that L2 speakers will have difficulties when they must combine cross-domain information (e.g., prosody and syntax), but behavioral evidence suggests that this is L1-dependent, and the actual difficulty is, at least in part, modulated by transfer effects. For example, Ortega-Llebaria & Colantoni (2014) performed a study with L1 Mandarin and L1 Spanish speakers learning English. L1 Mandarin and L1 Spanish speakers were presented a question (e.g., “Did Bobby fall out of the tree?”) and they had to choose the appropriate response from three possible options, all of which differed only in intonation (e.g., “TOBY fell out of the tree”; “Toby FELL OUT of the tree”; “Toby fell out of the tree). It was found that L1 Mandarin speakers performed similarly to L1 English speakers, but L1 Spanish speakers were significantly less accurate. Ortega-Llebaria & Colantoni (2014) attributed the differences to L1-L2 transfer effects: Mandarin and English pattern similarly in marking focus using prosodic strategies, whereas Spanish typically uses syntactic strategies to mark focus.

Associative Learning theory (Kamin, 1969) proposes individuals who learn a particular stimulus-outcome situation, later stimulus that map to the same outcome are more difficult to acquire. That is, early learners of a language tend to focus on only one cue that maps to an outcome. Ellis & Sagarra (2010), for example, demonstrated that individuals who were trained to focus either on adverb or verb conjugation to acquire tense in Latin tended to ignore the cue that they were not explicitly taught. That is, they had a one-to-one mapping, instead of the many-to-one mapping that is typical of language.

Associative Learning theory may also be seen in a study by Ganga et al. (2024). Ganga et al. (2024) investigated prosodic transfer effects, focusing on the perception of contrastive pitch accents triggered by *only* in L1 Dutch L2 English using EEG. English *only* and the Dutch equivalent *alleen* are similar semantically and always coupled with a pitch accent elsewhere in the utterance. Crucially however, English *only* typically remains in preverbal position regardless of the focused element, whereas Dutch *alleen* is placed adjacent to the focused element, whether it be the verb or object. Ganga et al. (2024) hypothesized that the English learners would perform similarly to native English speakers when *only* was adjacent to the focused element, but differently when nonadjacent. Although their first hypothesis was supported, there was evidence against their second hypothesis: L1 Dutch and L1 English performed similarly when *only* was nonadjacent, both demonstrating a N400-like component. They attributed these unexpected results to prediction: since object-focus with *only* doesn’t allow for a pitch accent on the verb, participants can already predict that the focused item will be the object when they hear the unaccented verb, and so they ignore the superfluous pitch accent on the object. This could be interpreted as supporting the Associative Learning theory, in that individuals are paying attention to only one cue in the sentence for cue-to-outcome mapping.

Both the Interface Hypothesis and the Associative Learning theory may be applied to the current study. From the Interface Hypothesis, it would be expected that L1 English L2 Spanish speakers would have difficulties identifying sentence type in Spanish, due to the cross-domain interface (i.e., intonation and pragmatics). This prediction is borne out in behavioral studies (Brandl et al., 2020; Casillas et al., 2023). However, this would be modulated by transfer effects, as both English and Spanish mark absolute interrogatives with similar utterance-final rises. The current study is further informed by the Associative Learning theory, which predicts that early Spanish learners will pay attention to *only* the boundary tone, and ignore any other cues, such as the height of the initial pitch accent.

# 4. The Present Study

Traditional analysis of Spanish intonation posits that the final boundary tone determines if a sentence is a declarative (L%) or an absolute interrogative (H%) (Tomás Navarro, 1944). However, Face (2007) has found that there exist other intonational cues earlier in the speech stream that cue sentence modality. In a behavioral gating experiment, Face (2007) determined that L1 Spanish speakers can accurately determine sentence modality as early as the first pitch accent (i.e., the first stressed syllable) of an utterance due to the higher pitch peak in interrogatives. Although the final boundary tone was found to be the most informative cue for sentence modality, almost deterministic in nature, it appears that native speakers make use of the first pitch peak as a secondary cue to determine sentence modality.

With respect to Spanish learners, Bedialauneta Txurruka (2023) investigated secondary cue to determine sentence modality in a two-alternative force task, where participants had to identify if an auditory stimulus was a question or not. Although she did not report proficiency for L2 participants, all L2 participants had over 5 years of Spanish learning experience. She found that participants relied on universal tendencies to interrogation, primarily using the final boundary tone to identify sentence modality, whereas native speakers variably integrated other cues to determine sentence modality.

Although intonational cues in the speech stream before the boundary tone are evidently not deterministic for deciding sentence modality (Bedialauneta Txurruka, 2023; Face, 2007), Spanish learners may still be sensitive to them during on-line sentence processing. The present study investigates if Spanish learners are sensitive to early intonational cues during on-line sentence processing while determining if a sentence is a declarative or information-seeking absolute interrogative. This study builds on the previous work by reporting proficiency scores and language use information for participants.

# 5. Research Questions and Hypotheses

Due to the limited research on on-line processing of intonation in L2 speakers, the research questions are exploratory in nature, and the hypotheses are informed by behavioral research.

1. Are Spanish learners sensitive to early intonational cues that signal if an utterance is a declarative or absolute interrogative?

From behavioral studies, L1 Spanish speakers seem to be sensitive to the first pitch accent of an utterance for determining if the utterance is a declarative or absolute interrogative. Due to the difficulty that Spanish learners have when identifying sentence modality (Brandl et al., 2020; Casillas et al., 2023), I predict that learners will not universally show sensitivity to the secondary intonational cue (i.e., the height of the first pitch accent). This will be demonstrated by a lack of an N400 on the following pitch accents, including the final nuclear configuration. However, it is predicted that sensitivity will be modulated by other factors, such as proficiency and study abroad experience.

1. Is sensitivity to early intonational cues modulated by proficiency?

It has been seen that L2 proficiency modulates behavioral accuracy when identifying sentence type (Brandl et al., 2020; Casillas et al., 2023). This study will provide cognitive evidence for the role of proficiency on the sensitivity to secondary intonation features during on-line sentence processing by Spanish learners. It is predicted that high-proficiency Spanish learners will be able to integrate more intonational information in the speech stream during on-line sentence processing, such that they will pay more attention to the first pitch accent to determine if an utterance is a broad focus declarative or information-seeking absolute interrogative.

# 6. Methodology

## 6.1 Participants

This study focused on L1 English L2 Spanish late bilinguals with varying levels of proficiency. *n* participants (*n* females), with an age range of *min* to *max* (mean = *mean*) were recruited to partake in the study. Late bilingualism, in this study, was operationalized as individuals who began to learn Spanish after the age of 13. Participants were recruited from college Spanish classes. Participants spoke a language other than English in their household, or who self-reported proficiency in another language other than English and Spanish, were excluded. All participants included in this study were right-handed. Participant proficiency ranged from *min* to *max*, as we were interested in how the acquisition of secondary intonational cues developed in a range of proficiencies.

## 6.2 Stimuli

The stimuli were recorded by a native speak of *VARIETY* Spanish. The speaker produced syntactically and lexically identical utterances, once produced as a broad focus declarative utterance ([Figure 1](#fig-original-d)) and again as an information-seeking absolute interrogative ([Figure 2](#fig-original-q)). The utterances were then manipulated using the stylize pitch feature in Praat (Boersma & Weenink, 2024). For the manipulated stimuli, the first pitch accent was manipulated to heighten or lower the peak for the declarative ([Figure 3](#fig-manipulated-d)) or interrogative ([Figure 4](#fig-manipulated-q)), respectively. The modified pitch peak heights were decided based on the corresponding utterance’s pitch peak height.

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| Figure 1: Original spectrogram with pitch contour for the broad focus declarative, ‘Ana lleva el abrigo’ (Ana is wearing the coat). |
| Figure 2: Original spectrogram with pitch contour for the information-seeking absolute interrogative, ‘¿Ana lleva el abrigo?’ (Ana is wearing the coat?). |
| Figure 3: Manipulated pitch contour for the utterance ‘Ana lleva el abrigo.’ (Ana is wearing the coat) |
| Figure 4: Manipulated pitch contour for the utterance ‘¿Ana lleva el abrigo?’ (Is Ana wearing the coat? |

In total, there were four conditions in a 2X2 design: (1) the original declarative, (2) the original absolute interrogative, (3) the declarative utterance with the first pitch accent peak lowered, and (4) the interrogative utterance with the first pitch accent peak heightened. All conditions can be seen in [Table 2](#tbl-conditions). Each condition had 80 items, for a total of 320 items.

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 2: Stimuli.   | Condition | Sentence Type | First Pitch Accent Peak | | --- | --- | --- | | declarative | info-seeking absolute interrogative | original | | absolute interrogative | info-seeking absolute interrogative | lowered | | declarative | braod focus declarative | original | | absolute interrogative | braod focus declarative | heightened | |

## 6.3 Tasks

All data were collected individually in one session (approximately 1.5 hours). Participants first completed a Spanish proficiency test before the experiment (15 min), and then completed the two-alternative forced choice task, which was monitored using EEG (1 hour).

### 6.3.1 Proficiency Assessment

Participants first completed a Spanish proficiency test. The test was an abbreviated version of the *Diploma de Español como Lengua Extranjera* (DELE), which has been used in previous studies (e.g., Lozano-Argüelles & Sagarra (2021)). The test consists of 56 multiple choice questions that assess grammar and vocabulary knowledge. Correct answers receive one point, and incorrect answers receive zero. No minimum score was required to participant in this experiment, as a range of Spanish proficiencies was desired for analysis.

### 6.3.2 Two-Alternative Forced Choice Task

For the two-alternative forced choice task, participants were tasked with identifying if an item was a question or not using the keyboard. Participants typed “1” for “yes” (i.e., “yes, this is a question”) or “0” for “no” (i.e., “no, this is not a question). Each participant completed one of two versions of the task, which included 20 target items from each condition. Participants did not encounter any lexically/syntactically identical items (such that if a participant was exposed to”Ana lleva el abrigo” in Condition 1, they were not exposed to the same utterance in any other condition). In total, participants were exposed to 80 total target items.

## 6.4 Procedure

Subjects were seated in a comfortable chair located in a sound and electrically attenuated room. They were instructed to keep their eyes fixated on a fixation cross on the monitor and to avoid movement as much as possible, including eye movements, blinks, and jaw clenching, as well as to remain as relaxed as possible. Acoustic stimuli were presented via *computer information* through *headphone information*.

Participants were familiarized with the task through the same 32 training items. They were instructed to decide if an utterance was a question or not by using the keyboard (0 for no, 1 for yes) as accurately as possible once the audio stimulus ended. They were signalled to respond once the audio ended with a question mark “?” that appeared on the screen. They did not receive feedback for accuracy during the training or during the experimental items. After the training, participants were randomly assigned Version 1 or Version 2 of the task.

During the training and experimental items, participants were instructed to fixate on a fixation cross on the computer screen. The fixation cross remained on the screen during the entirety of the audio stimulus, and as soon as the audio stimulus finished, a question mark “?” appeared on the screen, signalling for them to decide if the utterance was a question or not. The interval between stimuli varied between 2.5 and 5.0 s. Every 15 items, participants took a 3-5 min break, during which they could move about and stretch.

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