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## Unpacking the Possible Effects of Working Memory and English Proficiency on Nuclear Accent Perception and Production in Chilean Learners of English

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### Abstract

Prosody is considered one of the most challenging aspects of second language (L2) speech acquisition. This study explores the role of working memory (WM) in the perception and production of English nuclear accent (NA) by L1 Spanish learners. It focuses on both default and non-default patterns of NA placement in English. Twenty-four participants from an English teacher education programme in Concepción, Chile—who had completed an English intonation course—took part in perception and production tests, a proficiency test, and a reading span task to assess WM. Results revealed that participants perceived default NA patterns more accurately, while their production was stronger for non-default patterns. An asymmetry between perception and production emerged, as no direct correlation between these skills was found. Proficiency showed weak positive correlations with most variables. In contrast, WM revealed weak negative correlations across several measures, suggesting that higher WM capacity may not enhance NA perception or production. These subtle trends challenge assumptions about the facilitating role of WM in L2 prosody and indicate the need for further research.

**Keywords:** *Prosody, Accentuation, Nuclear Accent, Working Memory, Perception and Production*

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### Introduction

Suprasegmental features, viz. intonation, accentuation, and rhythm, play a significant role in oral communication, often gaining greater importance in comparison with segmental elements

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(individual sounds) for effective interaction. This is supported by recent research studies that highlight the surge of interest in suprasegmentals in second language (L2) acquisition, emphasizing their contribution to intelligibility and comprehensibility (Gordon et al., 2013; Melnik-Leroy et al., 2022; Thomson & Derwing, 2015). Unlike segments, which involve discrete and isolated sounds, suprasegmental features operate on a broader scale, shaping, for instance, aspects such as prominence in utterances, as well as the melody and rhythm of speech. These features significantly influence how messages are perceived and understood. For example, intonation - the rise and fall of pitch across utterances- guides listeners in interpreting sentence meaning and emotional tone (Wells, 2006). However, L2 learners often struggle with these features, particularly when their first language (L1) intonational patterns greatly differ from those of the target language, leading to subsequent communication breakdowns (Casillas, 2019; van Maastricht et al., 2016). One other illustrative example corresponds to nuclear accent (NA) placement in English – i.e. where the most important pitch accent is placed in an utterance - is a key suprasegmental aspect, which is closely linked to discourse focus. In Spanish, for instance, NA placement typically adheres to a default pattern, wherein the NA is typically placed at the end of an utterance, very often on the last lexical item (LLI). Although English conforms to this rule, several exceptional NA patterns deviate from the LLI pattern (or rule). This discrepancy can result in negative transfer, where L1 Spanish learners misapply their native patterns to English (Melnik-Leroy et al., 2022). As research on suprasegmentals advances, their role in enhancing L2 communication and reducing misunderstandings becomes increasingly evident.

Research into the relationship between L2 speech perception and production reveals methodological variability and, at times, conflicting results. While early models, like Flege's Speech Language Model (SLM for short), indicated that accurate perception was a prerequisite for production, recent investigations suggest production may sometimes precede perception, influenced by proficiency or task design (de Leeuw et al., 2021). The scant research done into the relationship of between perception and production of suprasegments highlights prosodic training's role in enhancing perception and production, particularly with visual cues (Hardison, 2012; Yenkimaleki & van Heuven, 2023). For nuclear accent (NA), research emphasizes its salience for L2 learners, though further studies are needed, especially with Chilean Spanish L1 learners (Bøhn & Hansen, 2017).

Working memory (WM) appears to play a role in L2 perception and production of both segments and suprasegmentals. Learners with higher WM capacity demonstrate advantages in speech fluency, accuracy, and complexity, as well as reduced L1 interference (Fortkamp, 2000; Trude & Tokowics, 2011). WM also facilitates real-time auditory processing in L2 listening, such as parsing word sequences and making inferences (Sakai, 2018). While WM positively correlates with L2 listening in some studies (Brunfaut & Révész, 2015; Masrai, 2020), there is very little research on the relationship between WM and perception and production of NA. Thus, the aim of this study is twofold: (i) to establish how perception and production of default and exceptional nuclear accent placement behaves in L1 Spanish learners of English; and (ii) to determine whether there is a relationship between WM and the perception of default and non-default English nuclear accent placement patterns in Chilean L2 learners of English, considering the potential influence of their L1. Thus, the research questions this investigation aims to answer are as follows:

**RQ<sub>1</sub>:** How does the accuracy of perception and production of nuclear accent (NA) differ between default patterns and exceptions in L1 Spanish learners of English?

**RQ<sub>2</sub>:** What role do working memory and English language proficiency play in the perception and production of nuclear accent in L1 Spanish learners of English?

## Literature Review

### *Nuclear Accent Placement in Spanish and English*

Prosody, especially intonation and (sentence) accent, is a cornerstone of language, providing its rhythm, pitch variation, and general melody. Suprasegmental features are also found to be crucial in representing meaning, highlighting important aspects of discourse, and reflecting attitudes, feelings, and dispositions (Levis, 2024; Wells, 2006). Sentence accent—in particular the NA—is especially important of the prosodic components for marking focus and signalling the most informative part in an utterance (Cruttenden, 2017).

The nuclear accent often reflects the focal point of a message, as it carries both stress and major pitch movement. Its placement determines the intonational structure of an utterance and varies depending on the intended focus. In English, the default placement of the NA aligns with the *last lexical item* in broad focus utterances, where all the information is new (Cruttenden, 2017). For example, in the sentence “*She bought a new car\**”, the nuclear accent naturally falls on “car.” However, exceptions arise, such as with adverbials, phrasal verbs, or prepositional phrases, where the NA may shift, often to another lexical word preceding the last (Cruttenden, 2017; Wells, 2006). In narrow focus, where only a particular of information is foregrounded while the rest is treated as given information, the NA highlights specific elements: “*She bought a NEW car (not an old one).*”

For learners of English as a second language, accurately perceiving and producing the NA poses significant challenges, particularly for speakers of Spanish as a first language (L1). Spanish, like other Romance languages, often relies on syntactic flexibility to mark focus rather than prosodic elements (Frota & Prieto, 2015; Klassen, 2013). In broad focus utterances, new or important information tends to fall at the end of the intonational phrase, aligning with the NA placement. For example, in Spanish, “*Compró un auto nuevo*” mirrors the English pattern with “auto” receiving the NA. However, Spanish speakers can also mark focus simultaneously or *in situ* without changing the word order, a feature that may contribute to challenges in acquiring English intonation patterns (Gabriel et al., 2010; Hoot & Leal, 2020).

Research into the perception and production of English NA by Spanish L1 speakers remains scarce. Most studies on suprasegmentals have focused on word-level stress or broader constructs such as intelligibility and accentedness (Crowther et al., 2023; Kang, 2010; Trofimovich & Isaacs, 2012). Very few have explored NA comprehensively, particularly in spontaneous speech, which is critical for understanding its role in L2 communication (Leal et al., 2018; Hoot & Leal, 2020). Nonetheless, emerging evidence suggests that accurate NA perception significantly impacts L2 learners’ pronunciation and comprehensibility, underscoring its importance in instructional contexts (Bøhn & Hansen, 2017; Sonia & Abdelkader Lotfi, 2016).

Despite some limited progress, research remains scarce, especially in contexts involving Spanish L1 learners. Although Spanish speakers process utterances with final NA more efficiently (Hoot & Leal, 2020), this advantage does not guarantee accurate perception and

production of non-final NA in English. Such findings highlight the need for more research to address theoretical gaps and improve teaching strategies for prosodic focus.

### *English and Spanish Sentence Accentuation*

Intonational languages such as English and Spanish rely on prosodic features—specifically, rhythm, pitch, and intonation—to convey pragmatic and attitudinal information. These characteristics enable speakers to encode declarative and interrogative sentence types, express emotion or politeness, and increase the salience of differing levels of information (Prieto & Rosano, 2019). In fact, the intonation that a speaker uses in both languages can indicate whether they are asking a question, making an assertion or signalling surprise. At the heart of these prosodic features lies the concept of sentence accent and the NA, which are critical for both broad and narrow focus communication.

As suggested earlier, in both languages, NA represents the focal point of an utterance, often through the most significant pitch movement and greater prominence. In broad focus contexts, the default position for NA is the final lexical item of an intonational phrase / intonation group. In Spanish, this rule is relatively fixed, as native speakers predominantly rely on syntactic flexibility to move informative elements to the rightmost position. The final content word, therefore, carries the NA, and its prominence is often enhanced by prolonged duration (Hualde, 2005; Prieto & Rosano, 2019). Conversely, English demonstrates greater flexibility in NA placement. While the “last lexical item” (LLI) rule applies broadly, NA can deviate under specific circumstances, such as for pragmatic focus on earlier parts of the utterance (Ortiz-Lira, 1994; Wells, 2006).

For example, in broad focus, both languages might emphasize the last word naturally:

- She bought a CAR (English)
- *Se compró un AUto* (Spanish).

It must be noted, however, that there exist several cases of broad focus utterances belonging to various grammatical constructions or word classes which deviate from the LLI rule. As a way of illustration, final vocatives in English are, for the most part, not accented; the same applies to most final time and place adverbials or wh-questions ending with a verb. For instance:

- How are you DOing, Peter? (nuclear accent on *do-* and not on *Peter*)
- She won't be able to GET there (nuclear accent on *get* – and not on *there*)
- Where's the PEN I bought? (nuclear accent on *pen* – and not on *bought*)

English allows for more prosodic flexibility. In narrow focus, NA can shift to highlight a specific part of the message:

- She bought a CAR (not a bicycle)

Spanish, on the other hand, may rely on syntactic reordering to emphasize focus:

- Un AUto se compró (or un auto se comPRÓ)

Experimental studies further support these observations, highlighting both contrasts and overlaps in NA behaviour between the two languages. While broad focus utterances in Spanish predominantly mark focus syntactically, narrow focus contexts appear to allow some flexibility. Research by Domínguez and Arche (2014) demonstrated that native Spanish speakers accept *in-situ* focus (non-rightmost NA) for intransitive verbs, a pattern extended to transitive structures involving direct objects (Gupton, 2017; Heidinger, 2022; Hoot, 2016; Leal

& Slabakova, 2019). Similarly, Spanish speakers have been shown to utilize prosodic strategies alongside syntax when marking focus on specific grammatical elements such as subjects versus objects (Feldhausen & Mar Vanrell, 2015; Gabriel et al., 2010).

Despite these findings, significant asymmetries remain. Klassen (2013) notes that Spanish L1 speakers, when acquiring English, may struggle with the language's flexible NA placement, defaulting instead to syntactic strategies familiar in their L1. Hahn's (2004) study illustrates the communicative implications of such mismatches: when L2 learners misplace NA in English utterances, native English listeners rate their speech as less intelligible and struggle to recall information accurately. This suggests that accurate NA placement is not only a linguistic concern but also a vital factor in effective communication.

While NA perception and production are critical for L2 proficiency, studies have consistently reported challenges for learners, particularly those with Spanish as their L1. Research shows that L2 learners' sensitivity to prosodic NA placement remains poor, especially in early stages of acquisition (Del Saz & Grau, 2022; Kivistö-de Souza, 2017). Learners may stress too many words, fail to identify focal elements, or transfer fixed Spanish patterns into their English production. However, improvement is achievable with explicit instruction in prosody, particularly for advanced learners (Luchini & Paz, 2022).

To make matters even more complicated, individual differences such as motivation, age, and learning styles can influence L2 prosodic acquisition (Duff, 2019; Griffiths & Soruc, 2021). Learners with enhanced sensitivity to prosody may show greater success, while others may require more tailored instructional approaches. Hoot and Leal (2020) argue that comparative studies on NA placement—especially involving Chilean Spanish L1 speakers—remain insufficient. They call for more research into broad focus contexts, as most current evidence focuses disproportionately on narrow focus scenarios (Landblom & Lonin, 2022; Leal et al., 2018).

### *Perception and Production of Suprasegmentals*

The relationship between perception and production in second language (L2) suprasegmental acquisition has been a focal point in recent research, challenging earlier assumptions that accurate L2 perception is a prerequisite for native-like production. Flege's (1995) Speech Learning Model (SLM) initially posited that L2 segmental perception precedes production, but recent studies, such as those by Flege and Bohn (2021) and Kim and Ha (2024), have demonstrated a bidirectional, co-evolving relationship between these two processes. For instance, Kim and Ha (2024) found that Korean learners of English exhibited higher production accuracy than perception accuracy for English consonant clusters, suggesting that L2 learners can achieve native-like production even before fully distinguishing L2 phonemes. Similarly, de Leeuw et al. (2021) observed that Spanish-English bilinguals, despite perceptual challenges with English #sC clusters, often produced them accurately, attributing this to enhanced metalinguistic awareness and L2 exposure rather than perceptual accuracy alone.

The asymmetry between perception and production is further supported by Kartushina et al. (2015), who found that visual feedback training improved L2 vowel production in French learners of Danish without corresponding gains in perception. This suggests that production can develop independently of perception, particularly when supported by articulatory training. However, individual differences in task demands and cognitive processing, as highlighted by

Kissling (2014) and Nagle (2018), complicate this relationship. For example, Melnik-Leroy et al. (2022) found that while L2 learners achieved near-native production of French vowels, their perception lagged, particularly for challenging contrasts like /y/ and /u/. This underscores the role of task-specific factors, such as speech rate and cognitive load, in shaping perception-production dynamics.

Suprasegmental features, such as prosody, also play a critical role in L2 speech learning. Yenkimaleki (2021) demonstrated that explicit prosodic awareness training improved both perception and production in Farsi-English interpreters, although gains in perception did not always translate directly to production. This aligns with findings by Kang et al. (2010) that suprasegmental errors often impact L2 comprehensibility more severely than segmental errors. Overall, recent research highlights the complex, non-linear relationship between L2 perception and production, influenced by factors such as training type, individual differences, and task demands, while underscoring the need for further exploration of suprasegmental aspects in L2 acquisition.

### *Working Memory and Second Language Learning*

Working memory (WM), defined as a limited-capacity system for temporarily storing and manipulating information necessary for tasks like comprehension, reasoning, and learning (Baddeley, 2017), plays a crucial role in second language acquisition (SLA). WM influences cognitive processes involved in L2 perception, production, problem-solving, and comprehension (Skehan, 2015). It is particularly critical in the early stages of learning, where retrieving, selecting, and articulating linguistic terms demand significant effort. Individuals with higher WM capacity are more successful in minimizing L1 interference, perceiving and producing L2 structures accurately, and maintaining task focus (Fu & Li, 2019; Li, 2022). Additionally, WM enables learners to allocate attention to relevant linguistic resources during demanding tasks, leading to more accurate and complex linguistic perception and production. These findings underscore WM's integral role in shaping L2 learning outcomes.

WM has emerged as a critical factor in second language acquisition (SLA), influencing outcomes in foreign language learning (Wen et al., 2015). Recent studies suggest that WM may function as a distinct component of foreign language aptitude, with its capacity to process linguistic information varying across individuals and playing a key role in L2 proficiency development (Wen & Li, 2019). WM has also been identified as a potential predictor of L2 speech fluency, accuracy, and general oral production (O'Brien et al., 2007; Linck et al., 2014). Despite its recognized importance in broader SLA contexts, research specifically examining the relationship between WM and L2 pronunciation remains limited (Simard et al., 2020). This gap highlights the need for further investigation into how WM influences the acquisition of L2 phonological skills.

### *L2 Proficiency and L2 Pronunciation Proficiency*

L2 proficiency is generally conceptualized as an individual's overall competence in a second language, encompassing both organizational and pragmatic knowledge (Bachman & Palmer, 2010). It involves the ability to construct grammatically accurate utterances and to employ them appropriately across communicative contexts (Ortega & Wu, 2025). The primary dimensions for measuring L2 proficiency include complexity, accuracy, and fluency (Skehan,

1998). Complexity reflects the diversity and elaboration of language use, accuracy pertains to error-free production, and fluency denotes the ability to process language in a native-like manner. Research highlights that higher L2 proficiency levels correlate with improved segmental and suprasegmental production, which enhances comprehensibility and intelligibility (Trofimovich & Baker, 2006; Puga et al., 2017). Additionally, working memory capacity (WMC) has been found to be positively associated with L2 proficiency, particularly in facilitating fluent and accurate speech (Prebianca et al., 2014).

Within the domain of L2 oral proficiency, pronunciation is a crucial component that directly impacts intelligibility and listener comprehension (Munro & Derwing, 2015). Pronunciation proficiency is shaped by both segmental accuracy (individual vowel and consonant sounds) and suprasegmental features (stress, rhythm, and intonation) (Saito, 2021). A recent empirical study by Suzukida and Saito (2022) found that pronunciation proficiency levels are primarily differentiated by the presence of segmental errors with high communicative value and suprasegmental accuracy, particularly in word stress and syllable production. Their findings suggest that learners progressing to advanced levels of pronunciation proficiency must refine both segmental precision and prosodic features to improve overall comprehensibility. Moreover, expert rater evaluations indicate that high-level pronunciation proficiency is characterized by reduced segmental errors, appropriate stress patterns, and controlled intonation, underscoring the importance of targeted pronunciation training for L2 learners (Saito & Plonsky, 2019).

## **Methodology**

The various methodological aspects of this quantitative test-based correlational study are described below, namely the participants, ethical considerations, data-gathering instruments, and the procedure.

### *Participants*

The sample originally consisted of 25 subjects; however, all participants were required to achieve a minimum score of 80% on the (WM) processing task, and one participant obtained a score of only 70%. The participants' ages ranged from 20 to 25 years, with a mean age of 22. Thus, the study eventually involved 24 university students enrolled in an English teacher education program at a prestigious, large regional university. A non-probabilistic sampling procedure was employed, specifically convenience sampling, whereby participants were selected based on their accessibility and willingness to take part in the study, rather than through random selection. This method was chosen due to the specific characteristics required for participation, ensuring the inclusion of students with relevant linguistic backgrounds.

Participants had an intermediate to advanced level of English proficiency (B1, B2, and C1), as classified by the Common European Framework of Reference for Languages (CEFR; see Table 1 below). All participants had completed an intonation course either in the previous academic year or the preceding semester. Recruitment was conducted through an open invitation via email and personal communication.

**Table 1***Participants' Proficiency Level*

Level	Number of participants
B1	3
B2	6
B2+ -C1	15

Two exclusion criteria were applied: (i) participants with English proficiency levels below B1 were excluded, and (ii) individuals who had acquired English as their mother tongue or had resided in an English-speaking country for more than three months were not eligible to participate.

*Ethical Considerations*

The study adhered to ethical research principles. Participants were fully informed about the nature, objectives, and phases of the research. Informed consent was obtained prior to data collection, ensuring that participants voluntarily agreed to partake in the study with a clear understanding of their rights, including the option to withdraw at any stage without consequences. Additionally, anonymity and confidentiality were guaranteed, with all data being used exclusively for research purposes.

*Data Collection Instruments*

Five instruments were used in this study, which are described below.

*Perception and production tests: Measures of the dependent variable*

To determine the sentence types used in the perception and production test, eight categories of utterances were selected based on classifications proposed in the literature. These categories included words that do not adhere to the Last Lexical Item (LLI) rule and, consequently, do not receive the nuclear accent (NA) even when they appear as the final lexical item in an utterance. The categories suggested by Cruttenden (2017) and Wells (2006) informed the development of a randomized list of 28 sentences, with each category containing four sentences. The selected categories were empty words, adverbials of time, adverbials of place, prepositional verbs, phrasal verbs, final adjectives, final verbs, and event sentences.

A pilot test was conducted with 21 second-year students from the English Teaching Programme at Universidad de Concepción. Participants were given five minutes to familiarize themselves with the sentences before recording them using laboratory headsets. The recordings were submitted via email and analyzed using Praat (version 6.3.10) to assess pitch movement, intensity, and NA placement. Participants later received written feedback on NA placement and segmental errors.

Analysis of approximately 569 recordings (with three participants missing three recordings each and one participant missing ten recordings) indicated that NA placement was generally accurate in event sentences and empty words. However, the remaining categories posed challenges, particularly final verbs, adverbials of time, and adverbials of place, which had the lowest accuracy scores. Based on these findings, it was decided that the perception and production test would prioritize utterances containing adverbials of time and place, given their high frequency in spoken English.

Two tests were designed to assess learners' ability to perceive and produce correct sentence accentual patterns and to determine whether they could recognize exceptions to the NA rule. The tests included both default NA patterns and well-documented exceptions to these patterns. Each test comprised 48 sentences, divided into the following categories:

- Sentences for LLI exceptions: 12 sentences containing unaccented adverbials of time in the final position, and 12 sentences containing unaccented adverbials of place in the final position.

A native speaker of British English, an educated male in his late 50s from Leeds, was asked to record the utterances. Nuclear accent placement was verified using Praat to ensure that the accent was placed on the expected word. The list of sentences was evaluated by the native speaker, who confirmed that the emphasis was natural.

- Sentences for the default pattern (LLI): 12 sentences following the LLI, where the accented syllable of the last lexical word carried the NA, and 12 sentences following the LLI pattern, yet with a tail, i.e., where the NA-bearing syllable was followed by additional unaccented syllables.

The recordings were made using a laptop and a headset with a built-in microphone. Audio files were initially created in MP4 format and later converted to WAV format for analysis in Praat. Recordings were captured in mono at a sampling rate of 48 kHz. Background noise was removed using Audacity.

The test was administered in the Phonetics Lab on the university premises. It consisted of a multiple-choice task delivered via Google Forms. The 48 test sentences were presented in a single audio track, with a three-second pause between each stimulus to allow time for participants to respond. Before the test began, six practice sentences were provided. For each item, participants listened to an audio stimulus containing a sentence and were shown five options, each highlighting a different syllable from the sentence. They were asked to select the most prominent syllable.

The test took approximately six minutes to complete. Responses were entered into a spreadsheet, with correct answers scored as "1" and incorrect answers as "0." Overall results were calculated as percentages. Participants did not receive feedback on their performance.

#### *Measures of working memory: Reading span task*

To evaluate learners' working memory (WM) capacity, a reading span task was adapted into Spanish and validated accordingly in the context of a 4-year research project funded by the Chilean research agency. The original version was based on the English version developed by Biedroń and Szczepaniak (2012). Some sentences were directly translated from English, while others were newly created in Spanish. The test consisted of seven sentences for the trial sets and 52 sentences for the main test, divided into eight sets.

Participants were presented with sets of sentences of incremental size; they were required to read each sentence and remember the last unrelated word, which was presented in capital letters at the end of the sentence (see example below). They then had to assess whether the sentence was appropriate for everyday communication and indicate it. At the end of each set, participants were given a few minutes to recall and write down the unrelated words placed at the end of each sentence in capital letter. Thus, this dual-task assessment required simultaneous sentence processing and memory recall.

Example of sentence in reading span test:

*Los asientos delanteros del bus son preferentes para tigres. LUNA* (free translation: the front seats have been reserved for tigers. **MOON.**)

### *Online proficiency test*

An online proficiency test was administered to assess participants' L2 proficiency. The test consisted of 50 multiple-choice questions that increased in difficulty as participants progressed. It measured three key aspects of language competence: Vocabulary use, grammatical knowledge, and pragmatic knowledge

This test served as an additional measure to ensure that participants met the required proficiency levels for inclusion in the study.

By employing a combination of perception, production, working memory, and proficiency assessments, the study aimed to obtain a comprehensive understanding of learners' abilities and challenges in English sentence accent.

### *Procedure*

The perception test was administered to participants in the Phonetics Lab at the university. It consisted of a multiple-choice test delivered via Google Forms. The 48 test sentences were presented in a single-track audio recording, with a three-second pause between stimuli to allow participants time to respond. Prior to the actual test, six practice sentences were provided.

During the test, participants listened to an audio stimulus containing a sentence while being presented with a multiple-choice question featuring five response options. These options corresponded to different syllables from words in the sentence, and participants were required to select the most prominent one, i.e. identify the nuclear accent. The test had an approximate duration of six minutes. Responses were recorded in a spreadsheet, with correct answers coded as "1" and incorrect responses as "0." Final results were calculated as percentages. Participants did not receive feedback on their responses.

The production test required participants to record the designated utterances using a laptop and a headset with an integrated microphone. The recordings were initially saved in MP4 format and subsequently converted to WAV format for analysis in Praat, a phonetic software package.

All recordings were captured in mono sound with a sampling rate of 48 kHz. To ensure audio quality, the files were edited using Audacity to remove background noise.

While the four tasks were anticipated to require slightly over an hour to complete, the majority of participants finished within 40 to 45 minutes. Half of the participants completed the tests collectively in the phonetics laboratory with nine participants divided into groups of three within the same setting. Additionally, three participants, who joined the study at a later stage, completed the assessments individually in the researcher's office.

## **Results**

This section presents the results for the perception and production of nuclear accent (NA) by L1 Spanish learners of English, as well as their proficiency and working memory (WM) scores. Inferential analyses explore key differences in NA patterns and relationships among variables.

*Descriptive Statistics*

Table 2 provides the mean scores and standard deviations for English proficiency, working memory, and nuclear accent perception and production.

**Table 2***Descriptive Statistics for English Proficiency, Working Memory, and NA Performance*

Variable	M	SD
English Proficiency	72.58	13.46
Working Memory (WM)	69.23	14.72
Overall Perception of NA	61.37	12.33
Overall Production of NA	61.98	8.18
Perception of Default Patterns (LLI)	65.11	17.63
Perception of Exceptions	57.99	16.44
Production of Default Patterns (LLI)	55.56	14.15
Production of Exceptions	68.75	11.06

*Perception and Production of Nuclear Accent**Perception of nuclear accent*

Participants performed similarly when perceiving default patterns ( $M = 65.11$ ,  $SD = 17.63$ ) and exceptions ( $M = 57.99$ ,  $SD = 16.44$ ). A paired  $t$ -test revealed no significant difference,  $t(23) = 1.48$ ,  $p = .152$ ,  $d = .30$ .

*Production of nuclear accent*

A significant difference was found in production accuracy. Participants produced exceptions ( $M = 68.75$ ,  $SD = 11.06$ ) more accurately than default patterns ( $M = 55.56$ ,  $SD = 14.15$ ),  $t(23) = -3.39$ ,  $p = .003$ ,  $d = .69$ .

*Perception vs. production*

Default patterns were perceived more accurately ( $M = 65.11$ ,  $SD = 17.63$ ) than they were produced ( $M = 55.56$ ,  $SD = 14.15$ ),  $t(23) = 2.19$ ,  $p = .039$ ,  $d = .45$ . However, exceptions were produced more accurately ( $M = 68.75$ ,  $SD = 11.06$ ) than they were perceived ( $M = 57.99$ ,  $SD = 16.44$ ),  $t(23) = -2.71$ ,  $p = .013$ ,  $d = .55$ .

*Additional patterns in perception and production*

Further analyses examined adverbials of place and time, as well as LLI patterns with and without a tail:

- Perception of adverbials of place ( $M = 63.54$ ,  $SD = 22.63$ ) was significantly higher than perception of adverbials of time ( $M = 52.43$ ,  $SD = 18.63$ ),  $t(23) = 2.15$ ,  $p = .042$ ,  $d = .44$ .
- Production of LLI patterns with a tail ( $M = 66.67$ ,  $SD = 13.00$ ) was significantly higher than production of LLI patterns without a tail ( $M = 44.44$ ,  $SD = 22.75$ ),  $t(23) = -4.55$ ,  $p < .001$ ,  $d = .93$ .

- No significant difference was found between production of adverbials of place ( $M = 69.79$ ,  $SD = 15.89$ ) and adverbials of time ( $M = 67.71$ ,  $SD = 14.18$ ),  $t(23) = 0.50$ ,  $p = .623$ ,  $d = .10$ .

### *Correlations between variables*

Pearson's correlations were computed between proficiency, WM, and NA perception and production patterns (Table 3).

**Table 3**

*Correlations between proficiency, WM, and NA Performance*

Variable	1	2	3	4	5	6
1. English Proficiency	—					
2. Working Memory (WM)	-.19	—				
3. Perception of Default Patterns (LLI)	.06	.05	—			
4. Perception of Exceptions	.12	-.33	.11	—		
5. Production of Default Patterns (LLI)	.07	-.02	.04	.09	—	
6. Production of Exceptions	.29	-.22	.06	.14	-.16	—

\* $p < .05$ , \*\* $p < .01$ , \*\*\* $p < .001$ .

The results suggest that while perception and production of NA are closely related, differences emerge when distinguishing between default patterns and exceptions. Key findings include:

- Perception and production accuracy differed: Participants were more accurate in perceiving default patterns but producing exceptions.
- No significant correlations were found between working memory, proficiency, and NA performance, suggesting that other cognitive or linguistic factors may play a role.

### **Discussion**

This study aimed to examine the perception and production of English nuclear accent (NA) by L1 Spanish learners, distinguishing between default patterns and exceptions, and to assess the influence of working memory (WM) and English proficiency on these abilities.

Findings indicate that the perception of default NA patterns was significantly higher than production. This pattern suggests that learners may rely on established linguistic rules, particularly the tendency to disregard function words and focus on content words when assigning NA. Previous training in intonation most likely contributed to their perception accuracy, in line with findings in L2 phonological development, where perception typically precedes production (Kartushina et al., 2023).

In contrast, learners performed better in producing exceptional patterns (e.g., adverbials of time and place) than in perceiving them (production: 69%, perception: 58%). This discrepancy aligns with research suggesting that L1 Spanish speakers tend to default to L1 accentual patterns at sentence level, prioritizing duration over pitch in NA placement (Del Saz & Grau, 2022). Late acquisition of English likely contributed to these difficulties, as prosodic features are among the earliest acquired in L1 but remain challenging to override in an L2, even at advanced levels (Wichmann, 2015). The observed asymmetry—whereby default (unmarked) nuclear accent (NA) patterns were more accurately perceived, while LLI exceptions were

produced more successfully—suggests that L2 learners' perception and production may not align in a linear fashion, as assumed by traditional prosodic models. One possible explanation is that learners are more frequently exposed to unmarked NA patterns in natural speech, making them easier to perceive. In contrast, the relatively better production of marked (exceptional) NA patterns may reflect greater cognitive effort and heightened attention during speech production. Regarding the relationship between perception and production, no significant correlation was found, reinforcing recent research indicating that the link between these modalities is complex, dynamic, and bidirectional, and largely influenced by task design, cognitive abilities, and linguistic properties of the L2 (Nagle & Baese-Berk, 2022; Baese-Berk et al., 2024). Thus, the findings challenge some of the classic assumptions that can be found in models like those proposed by Flege, which tend to suggest a foundational role for perception. Differences in task structure, such as whether phonological rehearsal was permitted, may have impacted results (Peperkamp & Bouchn, 2011).

The study did not find a significant role of WM in NA perception or production. Participants demonstrated high processing ability but poor storage capacity, potentially depleting cognitive resources needed for accurate NA placement. Individual differences in WM capacity did not consistently predict performance, corroborating findings that WM influences lexical complexity rather than fluency or accuracy in L2 speech (Nergis, 2020). The variety of WM assessment instruments further complicates direct comparisons across studies (Fu & Li, 2019; Li, 2022; Trude & Tokowicz, 2011). The integration of psycholinguistic elements – in the form of working memory -, language proficiency, and phonology, in the form of sentence accentuation suggests that sentence-level accentuation might result from rather automatic or procedural knowledge.

Similarly, English proficiency did not significantly influence NA perception or production. While high L2 proficiency has been linked to improved segmental accuracy (Chakraborty et al., 2011; Wong, 2015), suprasegmental accuracy remains a challenge across proficiency levels. Research suggests that early exposure and quality input are key factors in mastering L2 prosody (Puga et al., 2017; Del Saz & Grau, 2022), though targeted training can enhance learners' performance at any stage.

Overall, despite prior training, L1 Spanish learners of English continue to face challenges in perceiving and producing NA, particularly in exceptional cases. The inconsistency between perception and production underscores the need for further research into how these abilities develop over time and under different learning conditions. Refining instructional approaches to incorporate explicit NA training and individualized cognitive strategies may help bridge the observed gaps in L2 prosodic competence. These results may be attributed to certain limitations, most notably the small and homogeneous sample: All participants were enrolled in the same teacher education programme and had received similar prior training. Consequently, the variability present in the broader population may not have been adequately captured in this study. Additionally, only one measure of working memory—verbal WM—was employed, which may have been insufficient to account for the more nuanced aspects of attentional control relevant to L2 prosody.

Future research could benefit from longitudinal designs that track perception and production over time, alongside other cognitive variables such as inhibitory control. Several pedagogical implications may be drawn from this study: Perception and production should be

trained using varied instructional approaches—separately, jointly, or in different sequences; visual (e.g., pitch contours) and auditory cues could be integrated into NA instruction; and explicit development of metalinguistic awareness should be incorporated into prosody training.

### **Conclusions**

This study investigated the perception and production of English nuclear accent (NA) by L1 Spanish learners, focusing on default NA placement patterns and exceptions, and assessing the role of working memory (WM) and L2 proficiency in these processes. The results suggest that while participants were more accurate in perceiving default NA patterns, they showed better production of exceptional cases of NA, suggesting an asymmetry between perception and production. Moreover, no direct correlation was observed between these two modalities, reinforcing the complex and still underexplored relationship between perception and production of prosodic features in L2 acquisition, in particular. Also, neither WM nor English proficiency showed significant associations with NA perception or production, suggesting that other cognitive or linguistic factors may be at play.

These findings stress the crucial role of prosody in L2 learning and teaching, highlighting the challenges learners face in acquiring sentence accent patterns beyond segmental aspects. Given the intonational nature of English, mastery of tones and accents is essential for deciphering meaning and attitudes in real-life communication. The study's novelty lies in the incorporation of cognitive moderating variables, contributing to a broader understanding of how they impact prosodic acquisition. However, limitations, such as the relatively small sample size, call for further research to validate these findings across diverse learner populations and learning contexts. Thus, future studies should investigate sentence accent placement in varied linguistic contexts to deepen insights into its role in effective communication.

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### **Competing Interests**

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