Anticipation of verbal suffixed based on lexical stress in Spanish by L1 Mandarin and L1 English speakers

# 1. Introduction

Humans tend to anticipate information: when watching a movie, when driving, when playing sports, when listening to music. We also anticipate information in hearing speech, when reading, or when producing a linguistic message, especially when we are immersed in our first language (L1). While prediction is so pervasive in our lives, the nature of prediction mechanisms is unknown. Here I investigate how speakers transfer their L1 predictive mechanisms onto a L2. In particular, how acoustic and function knowledge is transferred to use suprasegmentals as cues to morphosyntactic outcomes. Understanding how morphosyntactic prediction works is crucial because it modulates anticipation at other linguistic levels (Guajardo & Wicha, 2014).

To address this goal, I examine verb tense anticipation based off lexical stress in adult Spanish monolinguals and English and Mandarin Chinese intermediate and advanced learners of Spanish. The conditioning factors I consider are language experience-related: L1 transfer and L2 proficiency, and cognitive (i.e., working memory, WM). In a usage-based framework, language experience is important because it shapes grammar constantly (Bybee, 2006) and so it shifts a speaker’s attention to and inhibition of input.

L1 transfer in particular can affect the type of information that a speaker pays attention to by default because that information is important in the L1 and thus is encoded and activated in a regular basis. This inhibition effect is called blocking (Kamin, 1969) and prevents the speaker from encoding L2 cues associated to an outcome, because a previous cue transferred from the L1 is already encoded as a predictor of that outcome. Sometimes the L1 encoded cue can successfully lead to the correct outcome, but these cue-outcome mappings rarely fully overlap cross-linguistically. In cases of partial overlap, it is unclear whether the similarity or the discrepancy is stronger in impacting language processing. L2 proficiency affects the variety of linguistic contexts, words and structures that a learner has been exposed to, and the frequency with which the learner has encountered them. In theory, the larger the exposure, the easier to create a cue-outcome mapping. Language experience thus continuously influences a speaker’s ability to make predictions in any language they speak. Cognitive factors like WM may also be responsible for the inability to make L2 predictions. There are few studies, however, delving into how WM capacities affect speakers’ abilities especially in L2s to generate the predictions.

# 2. Background

## 2.1. Language anticipation

In a predictive processing view of language, language processing is facilitated and preceded by prediction of linguistic information based on cues already available at different linguistic and non-linguistic levels (e.g., Federmeier, 2007; Wicha, Bates, Moreno, & Kutas, 2003). These cues are associated with an outcome and the encoded cue-outcome mapping helps generate the correct linguistic prediction (DeLong, Urbach, & Kutas, 2005; Dikker & Pylkkanen, 2011). Speakers use a wide range of phonological, morphosyntactic, semantic and contextual cues to anticipate linguistic outcomes in their L1. Anticipation morphosyntactic information in particular is crucial because it modulates anticipation at other linguistic layers, such as semantic choices (Guajardo & Wicha, 2014). However important, morphosyntactic anticipation is rare in an L2, starting because L2 processing without anticipation is oftentimes difficult already. L2 processing might be conditioned by several factors, like L1 transfer and cognitive capacities. L1 transfer could have both positive and negative effects, where L2 speakers use L1 knowledge to ease L2 processing or where L1 knowledge blocks L2 processing, respectively. Thus, studying the influence of L1 prediction mechanisms on L2 anticipation might explain why learning and understanding L2 morphosyntax is so troublesome, and why attaining native-like morphosyntactic anticipation performance is more often than not impeded. In addition, understanding and processing an L2 is more cognitively taxing than speaking an L1 because the L2 overtakes the pool of executive functions usually applied in L1 anticipation (Linck, Osthus, Koeth, & Bunting, 2014), especially at non-proficient levels. Given that the transfer happens in our brains and that L2 processing depletes cognitive resources, the L1 influence and our cognitive capacities are likely to interact with each other, such that both factors contribute to the difficulty of L2 morphosyntactic processing and anticipation.

**2.1.1. L1 processing and anticipation**

Language anticipation is a productive and dynamic cognitive mechanism in our L1. Speakers use a wide range of morphosyntactic (Grüter, Takeda, Rohde, & Schafer, 2016), syntactic (Linzen & Jaeger, 2016), semantic (Kamide, Altmann, & Haywood, 2003; Pozzan, Gleitman, & Trueswell, 2016), and phonological cues to generate predictions on semantic (Altmann & Kamide, 1999), morphosyntactic (Grüter et al., 2016; Lew-Williams & Fernald, 2010), and syntactic-discoursive outcomes (Grüter & Rohde, 2013). The range of possible phonological cues includes coarticulation (Salverda, Kleinschmidt, & Tanenhaus, 2014), intonation (Nakamura, Arai, & Mazuka, 2012; Weber, Grice, & Crocker, 2006), lexical stress (Correia, Frota, Butler, & Vigário, 2013; Sagarra & Casillas, 2018), pauses between clauses (Hawthorne & Gerken, 2014; Kjelgaard & Speer, 1999), vowel duration (Rehrig, 2017), and tone (Roll & Horne, 2015; Roll, Horne, & Lindgren, 2011). Phonological cues are frequently associated with word suffixes as outcomes (Roll, Horne, & Lindgren, 2010; Sagarra & Casillas, 2018; Soto-Faraco, Sebastián-Gallés, & Cutler, 2001).

Phonological cues do not happen in isolation. They are embedded in a discourse, such that they are signaled by both proximal and distal sentential contexts. Proximal cues that signal lexical stress in English are a syllable’s F0, duration, and amplitude. Distal cues like meter patterns (Brown, Salverda, Dilley, & Tanenhaus, 2015) also indicate the presence of lexically stressed syllable. Distal and proximal cues therefore interact with each other during lexical segmentation and word recognition (Brown, Salverda, Dilley, & Tanenhaus, 2011). As a consequence, violating lexical stress expectations created by distal cues in terms of location and syllabic structure elicit anormal brain activity associated with a more costly processing (Domahs, Wiese, Bornkessel-Schlesewsky, & Schlesewsky, 2008). This costly processing also hinders activation of the mapped outcomes. Phonological phenomena are closely tied to morphosyntactic suffixes, with relationships that vary across languages. In Central Swedish, a low tone in the firs syllable cues the singular suffix in a noun (*fisken* ‘fish[SG]’), and a high tone cues the plural suffix (*fiskar* “fish[PL],” Roll et al., 2010; Roll, Söderström, & Horne, 2013; Söderström, Horne, & Roll, 2015). Likewise, low tone cues present tense (*skrämmer* ‘I scare’), and a high tone cues past tense (*skrämde* “I scared,” Söderström, Roll, & Horne, 2012; Roll & Horne, 2015). Similarly, lexically stressed syllables in Spanish cue present tense (*canta* ‘he sings’), while lexically unstressed syllables cue past tense (*cantó* “he sang,” Sagarra & Casillas, 2018). The presence or absence of lexical stress at the beginning of a noun in Spanish can also signal what noun should be activated when several segmental competitors are possible (*PRINcipe* “prince” vs. *prinCIpio* “beginning,” Soto-Faraco et al., 2001). In English, shorter vowel duration in verbs is associated with active voice (‘the girl was pushing the boy’), whereas longer vowel duration is associated with passive voice (“the girl was pushed by the boy;” Rehrig, 2017).

Individual variability in cognitive capacities (i.e., WM) does not exert a great impact on linguistic anticipation in typical adult individuals in their L1, at least in simple morphological structures or in speech (Ye & Zhou, 2008). The few online studies so far on the connection between WM and language anticipation generally suggest that WM variability is not a factor in determining the efficacy and characteristics of morphosyntactic prediction generation in Dutch (Otten & Van Berkum, 2009), Spanish (Sagarra & Casillas, 2018) or English (Pakulak & Neville, 2010; Tanner & Van Hell, 2014). Only Huettig and Mani (2016) found that WM could account for variability among adult L1 Dutch speakers in gender morphosyntax anticipation, and Lozano-Argüelles (2020) found that WM effects were visible in highly taxing tasks. Since these studies share with the previous ones either language studied, structure researched, or methodology employed, none of these factors can explain the different results on the influence of WM on language anticipation.

In sum, L1 speakers generate predictions at different linguistic levels. If, when and how WM could affect the capacity to generate L1 predictions has still not been established, although findings suggests WM plays a minor role. Behavioral performance and brain activity may largely be conditioned by different levels of linguistic complexity or linguistic experience, so that WM only affects linguistic anticipation in certain cases.

**2.1.2. L2 processing and anticipation**

Findings on L2 anticipation are not as straightforward as in an L1, especially in the morphosyntactic domain. Morphosyntactic anticipation has been researched with gender (Dussias, Kroff, Tamargo, & Gerfen, 2013; Hopp, 2016; Lew-Williams & Fernald, 2010), verbal tense (Sagarra & Casillas, 2018; Schremm, Söderström, Horne, & Roll, 2016), number (Marull, 2017), case (Hopp, 2015; Mitsugi & Macwhinney, 2016), and cross-linguistic form similarity (Liburd, 2014). The mixed results have been accounted for by linguistic factors like L1 transfer and L2 proficiency, but non-linguistic factors like WM could be a conditioning too.

Regarding gender, L2 German speakers may not be able to generate gender predictions (Hopp, 2016), while L2 Spanish speakers may be able to do so (Dussias et al., 2013), although only under specific linguistic circumstances (Lew-Williams & Fernald, 2010). Contrary to gender, number is more difficult to anticipate, so only advanced speakers can make number predictions (Spanish, Marull, 2017), and L2 case is not predicted (German, Hopp, 2015; Japanese, Mitsugi & Macwhinney, 2016). For verbal tense, only L2 learners at advanced levels of proficiency can generate predictions in Spanish (Sagarra & Casillas, 2018), but learners of Central Swedish can already make predictions at an intermediate proficiency (Schremm et al., 2016).

The studies above varied in whether morphosyntax was used as the cue, the outcome, or both. The L1s were also different, so L1 transfer could have interacted with the role of morphosyntax in determining whether the L2 speakers were able to generate gender morphosyntactic predictions. L2 proficiency and maybe even WM can also partially account for the ability to make L2 predictions. All these conditioning factors have often been entangled in research, so it is difficult to tease their influence apart. In gender anticipation, having a similar morphosyntactic system in the L1 can help generate predictions in the L2, even at lower levels of proficiency. This is the case of L1 Italian speakers anticipating gender suffixes in L2 Spanish at beginner stages (Dussias et al., 2013). Extrapolating L1 knowledge is also the case of L1 English speakers using definiteness in articles to predict nouns at intermediate proficiency stages (Lew-Williams & Fernald, 2010). And L1 transfer can also be seen in L1 English speakers generating predictions in L2 Dutch more efficiently when they use cue determiners that share similar forms with their L1 determiners (Liburd, 2014). In contrast, lacking such L1 system may hinder the generation of L2 predictions. This would be the case of L1 English speakers generating gender suffix predictions in L2 Spanish (Dussias et al., 2013).

Adding a phonological layer and increasing the L2 linguistic experience may aid in overcoming the morphosyntactic anticipation hurdle, especially when the structure to be predicted is absent in the L1. English is a poor language in terms of verbal morphology when compared to Spanish. However, when morphosyntax is cued phonologically through lexical stress, advanced L2 Spanish speakers overcome the obstacle and generate verb suffix predictions (Sagarra & Casillas, 2018). L2 speakers of Swedish are also able to generate tense suffix predictions based on tones at beginning and intermediate stages of proficiency (Schremm et al., 2016).

There are a few considerations to bear in mind when studying phonological effects, as they are possible mediated by L1 transfer. While having a similar structure in the L1 can facilitate L2 anticipation, it does not guarantee any kind of anticipation success. Whereas advanced L2 Spanish speakers whose L1 is English learn to use lexical stress as a cue (Sagarra & Casillas, 2018), L1 French speakers rarely if ever learn to encode lexical stress as an anticipatory cue in L2 Spanish, simply because they do not learn to discriminate it (Dupoux, Sebastián-Gallés, Navarrete, & Peperkamp, 2008) even if French also has lexical stress. In contrast, L1 Cantonese and L1 Mandarin speakers learn to discriminate lexical stress in L2 English (Chen, 2013; Li, To, & Ng, 2017), and L1 Koreans also learn to a certain extent (Hualde & Kim, 2015; Lee, Shin, & Garcia, 2019), even though none of these three languages encodes lexical stress. The question remains whether these three populations learn to use lexical stress as a cue.

Linguistic knowledge and experience affect language processing and anticipation, especially in L2ers. Evidence for that is French L1 speakers struggling to process L2 lexical stress in Spanish (Dupoux et al., 2008), arguably because their French lexical stress encoding blocks acquisition of L2 lexical stress with different properties. However, even these non- or barely sensitive individuals display individual differences. Those individuals with greater sensitivity to stress also retain stress information longer in their WM (Schwab, Giroud, Meyer, & Dellwo, 2020). Cognitive differences should therefore also be considered when studying L2 acquisition, processing and anticipatoin beside linguistic factors. WM is the cognitive skill that allows to store incoming information temporarily and process it so other complex cognitive actions can be executed (Baddeley, 2007). WM influences L2 processing but the specific nature of this influence has still not been completely figured out. Some studies have found facilitating effects of WM on morphosyntactic processing (e.g., Nuria Sagarra, 2016; Sanz, Lin, Lado, Stafford, & Bowden, 2016), while others have found no effect (e.g., Foote, 2011; Grey, Cox, Serafini, & Sanz, 2015). These differences might be explained by the interaction with other mediating factors, like variability in L2 proficiency and the cognitive load imposed by the task and the WM test (Sagarra, 2017). Speakers at a lower proficiency might then be more susceptible to WM overload (Serafini & Sanz, 2016). In L2 anticipation, higher WM learners may anticipate more easily agreement elements than lower WM individuals (Reichle, Tremblay, & Coughlin, 2016). The communication context may nonetheless condition this ability: WM may have visible effects in morphosyntactic prediction only under cognitively taxing conditions (Lozano-Argüelles, 2020). This finding is far from definitive, as a previous study revealed no effecs of WM on L1 and L2 Spanish speakers’ capacity to anticipate verbal tense based on lexical stress (Sagarra & Casillas, 2018).

The literature in L2 anticipation show that speakers can achieve some success in L2 anticipation depending on their L1, the cues they need to process, their level of proficiency, and maybe their WM capacities, but their performance will rarely be native-like (Perdomo & Kaan, 2019). A possible explanation for the varied results on L2 perception and anticipation might be found in what speakers are transferring from their L1 (acoustic knowledge vs. function knowledge) that interacts with the new L2 structures they need to encode. Whereas L2 speakers’ anticipation performance might depend on their ability to perceive the cues and what needs to be anticipated, asymmetries amongst studies and the lack of cognitive measures also difficult comparison of results. The lack of a common theoretical framework, the use of non-standardized measures to assess proficiency (self-assessment, Lew-Williams & Fernald, 2010), the variety of tasks (e.g., eye-tracking, Sagarra & Casillas, 2018; vs. offline, Dupoux et al., 2008), a variety of L1s (Hed, Schremm, Horne, & Roll, 2019), and the unclear distinction of variables (e.g., Schremm et al., 2016) call for further research where the possible factors accounting for L2 anticipation patterns are better distinguished. Here, I focus on WM and on acoustic and function transfer of suprasegmental phenomena to anticipate verb endings in Spanish.

## 2.2. Models of suprasegmental acquisition

In the case that L2 speakers create the prosodic cue and morphosyntactic outcome mappings through to L1 sound encoding transfer, the mapping may not always allow for native-like anticipation efficiency (Perdomo & Kaan, 2019). There has been no model accounting for the transfer of suprasegmentals and loss of efficiency, although the Perceptual Assimilation Model has been adapted for suprasegmentals as theoretical framework in a some studies (e.g., So & Best, 2010, 2014). The Perceptual Assimilation Model for Suprasegmentals (PAM-S, Best, 1995; Best & Tyler, 2007) states that the L2 prosodic categories are assimilated onto the L1 prosodic categories. Four types of assimilation are possible: two category, single category, uncategorized-categorized, and uncategorized-uncategorized. In two category assimilation, two L2 prosodic structures are assimilated onto two distinct L2 prosodic structures. In single category assimilation, two L2 prosodic structures are assimilated onto a single category structure. Accordingly, in the first type of assimilation, discrimination will be good and in the second bad. It could then be hypothesized that in two category assimilation, speakers should have no issues in creating mappings for anticipation, but they should in single cateogry assimilation. In uncategorized-categorized assimilation, an L2 prosodic category is assimilated to an L1 category, but another L2 category remains unassimilated. If there is overlap between the two L2 categories, creating the mapping should then be difficult. Finally, in uncategorized-uncategorized assimilation, no assimilation happens. For these two last types of assimilation, if there is no overlap between the categories, the creation of the mapping should happen smoothly.

There are two other models that could be adapted to explain L2 suprasegmental acquisition: the Speech Learning Model (SLM, Flege, 1995) and the Second Language Linguistic Perception model (L2LP, Escudero, 2005, 2009; Van Leussen & Escudero, 2015). In SLM, the characteristics of the prosodic elements are encoded in the long-term memory and this encoding evolves in both the L1 and the L2. The model propses several hypotheses, of which are relevant: 1. L1 categories block L2 categories. 2. L2 category representation is different from the representations that L1 speakers of that language have because L2 representations are characterized with different weights and because L2 speakers make an effort to deflect the L2 encoding from the encoding of their own L1. In the L2LP, a copy of the L1 sound system is created at the beginning stages and it is adjusted through a comparison algorithm. This model differs from the previous ones in that it deals with segments, while the PAM-S and the SLM deal with contrasts. The adjusting algorithm in the L2LP offers three possible outcomes: a new sound is assimilated to multiple L1 sounds, a new sound is perceived as similar to another one in the L1 system, or a new sound does not equal any category in the L1 so it requires the development of a new phonetic category for itself. Additionally, perceiving and recognizing are different in this model. Although no further hypothesis is provided on that aspect, we could hypothesize that the fact that L2 speakers are able to perceive tones or lexical stress, for example, does not imply that they will necessarily be able to recognize them in speech to use them as cues for morphosyntactic outcomes. These three models have been or could be adapted to account for L2 phonological acquisition, but none of them has taken into account how the prosodic structures function in the language. Their function, however, may be essential in how much attention is required from the L2 speaker in order to acquire them.

## 2.3. Suprasegmental phenomena

**2.3.1. Lexical stress**

Lexical stress is the prominence of a syllable that speakers hear relative to the other syllables in the prosodic word (Hualde, 2005). The characteristics of lexical stress, such as acoustic correlates or position within words, vary widely across languages. In English and Spanish, lexical stress has no fixed position, playing a phonologically contrastive function at the lexical level depending on its location. This contrastive function is more typical in Spanish than in English. In English, lexical stress is used predominantly to distinguish heteronyms or pairs of verb-noun that have no segmental differences (to “proDUCE,” verb vs. “PROduce,” noun). In Spanish, lexical stress differentiates all kinds of word categories and information, such as verbal tense and person (*CANto* “I sing” vs. *canTÓ* “s/he sang”), or nouns (*PApa* “potato” vs. *paPÁ* “dad”), or nouns from verbs (*TÉRmino* “term” vs. *terMIno* “I finish” vs. *termiNÓ* “s/he finished”).

Different acoustic correlates, their importance or weight, and how they combine cause the acoustic realization of lexical stress in each specific language to vary. In Spanish, the most reliable cues to lexical stress are pitch (F0), duration, and intensity (Hualde, 2005; Ortega-Llebaria, 2006; Ortega-Llebaria & Prieto, 2007, 2009). Pitch is higher for stressed syllables and lower for unstressed syllables, and stressed syllables sound louder and are usually slightly longer. The main cues in English are vowel duration and quality (Cooper, Cutler, & Wales, 2002; Cutler, 1986). Thus, unstressed vowels are centralized.

Because of the lexically contrastive function, lexical stress helps in activation of lexical entries in L1 Spanish (Soto-Faraco et al., 2001), such that a prosodically matching cue to the target ( *prinCI* > *prinCIpio*, “start”) results in shorter and more accurate activation times, when compared to mismatching cues ( *PRINci* > *prinCIpio* ‘start’). These results suggest that speakers use the suprasegmental cues in lexical stress to anticipate the lexical element. L1 English speakers, in contrast, may only be able to use lexical stress as a cue when more than one syllable of the word has already been heard (Cooper et al., 2002). Perdomo and Kaan (2019) provide evidence of activation through prediction in even earlier syllables in the L1 English speakers, however, more in line with the performance of the L1 Spanish speakers in Soto-Faraco et al. (2001)‘s study. This difference in performance among studies probably results from the cues that speakers use to discriminate lexical stress, and how these cues are weighted in the language. That is, English L1 speakers may be placing a larger reliance on duration to process Spanish lexical stress, so they need to compare different syllables’ duration. Spanish L1 speakers may be relying more on other cues, such as pitch and intensity, that are discarded by the English speakers because they are not as informative in English (Ortega-Llebaria, Gu, & Fan, 2013).

The differences and similarities in cue weighting can influence lexical stress perception in an L2. For example, Cooper et al. (2002) found that the similar distribution of stress in Dutch and English helped L1 Dutch learners of English transfer their knowledge of lexical stress to process it properly in L2 English. In contrast, German speakers have more difficulty perceiving stress in another free lexically stressed language such as Spanish than L1 speakers (Schwab & Dellwo, 2016), maybe due to the acoustic correlates they use to discriminate the suprasegmental. Lastly, L1 English L2 Spanish speakers can only use lexical stress as a cue in Spanish at advanced levels of proficiency (Sagarra & Casillas, 2018). A possible explanation is that the English lexical stress encoding did not match the Spanish lexical stress encoding and thus prevented the Spanish L2 speakers from using lexical stress properly until they reached a certain level of linguistic experience. Following a similar line of reasoning, Vickie and Andruski (2010) suggested that language background in the L1 can affect how lexical stress is perceived in an L2 and what correlates are used to discriminate the L2 stress. This rationaly would entail that the L1 filters how L2 suprasegmentals are perceived and processed, at least at lower levels of proficiency.

**2.3.2. Tone**

Tones are the pitch contour patterns of the voiced part in syllables (Chao, 1968). Many languages use tones, or changes in pitch-contour, at a phrasal level for pragmatic purposes. However, only a few use tones contrastively at a lexical level. The acoustic correlates for tones vary across languages: some use only pitch (e.g., most Mandarin Chinese dialects), whereas others also use length and/or register (e.g., Cantonese Chinese). Relevant to this study, in most Mandarin Chinese dialects (e.g., from Beijing and Tianjin), the main and oftentimes only acoustic correlate for tones is changes in pitch (F0) contour or changes in pitch height within a syllable (Gandour & Fromkin, 1978; Zhu & Wang, 2015). Mandarin tones facilitate word recognition (Malins and Joanisse (2010)), although segmental cues are the primary activator, especially vowels (Hu, Gao, Ma, & Yao, 2012; Sereno & Lee, 2015; Wiener & Turnbull, 2016). The role of tone is thus integration of the activated lexical item in the higher context. The role of tones in Mandarin is thus different from the role of lexical stress in Spanish. Mandarin speakers need to pay attention to the pitch variations in order to assign the correct tone to the word they are hearing.

Knowledge of the nature and function of tones in the L1 can affect L2 tone learning both positively and negatively by providing a background knowledge to which learners resort to acquire the L2 tones and compare them. Li et al. (2017) examined the influence of the L1 tonal knowledge in the acquisition of L2 tones in children. These children were L1 Cantonese speakers learning L2 Mandarin, and they had issues in categorizing Mandarin tones 1 and 4, as these tones would be assimilated to the same tone 1 category in Cantonese. In the case of these children, being a native speaker to a tonal language helped them in the perception of Mandarin tones 2 and 3, but it hindered perception of other L2 tones because the knowledge transfer from L1 tones disagreed from the L2 tone structure and interfered with it.

The studies on tones and lexical stress suggest that the acoustic properties of prosody are essential in processing and activating incoming linguistic information. The importance speakers assign to each cue might extend beyond perception and affect anticipation as well. Speakers may resort to their prosodic abilities in the L1 in order to process other prosodic structures in their L2 absent in their L1 (Vickie & Andruski, 2010), such that Chinese speakers, for example, can use pitch knowledge to discriminate lexical stress in Spanish because the correlate is the same or similar, even if they lack lexical stress in their L1. Extending this hypothesis, L2 speakers might also be able to transfer function knowledge and reassemble the encoding of a suprasegmental to include the L2 acoustic correlates and thus use it as a cue for language anticipation. If this were the case, L1 speakers of lexically free stressed languages like English may transfer the function knowledge to another structurally similar language like Spanish, and L1 tonal speakers might be able to transfer pitch knowledge to encode L2 Spanish lexical stress that is based primarily on the same acoustic correlate, namely, pitch. After lexical stress has been encoded in the L2 lexicon by means of L1 pitch knowledge, L2 speakers might also learn to use this new prosodic structure as the basis for L2 prediction so as to reduce the processing cognitive load.

If both function and acoustic knowledge transfer happen, the question is then, if there are more processing costs associated with one or the other. Since pitch variations are the basis for lexical stress in Spanish, Mandarin speakers might be able to transfer their sensitivity to pitch changes to process and use pitch to anticipate linguistic information more easily than English speakers. However, they need to learn the lexical stress function. In comparison, pitch variation is not as important an acoustic correlate in English lexical stress, so L1 English speakers may not be sensitive to L2 pitch information in lexical stress, at least in beginning and intermediate stages of proficiency, but they do have the function knowledge. Therefore, L1 English speakers need to learn to distinguish pitch variations since they can only transfer function knowledge, while Mandarin speakers may transfer pitch knowledge but need to learn function in using lexical stress to anticipate verbal tense in L2 Spanish.

# 3. This study

L2 morphosyntactic prediction is a hard nut to crack. When cued phonologically, L2 speakers can sometimes use acoustic and prosodic resources to anticipate oncoming nouns (Perdomo & Kaan, 2019) and verbal morphosyntax (Lozano-Argüelles, Sagarra, & Casillas, 2019; Sagarra & Casillas, 2018; Schremm et al., 2016). This ability depends largely on proficiency (Lozano-Argüelles et al., 2019), but possibly on other factors too like L1 transfer and WM.

In this project, we investigated how suprasegmental function transfer vs. acoustic knowledge transfer differ during L2 acquisition and what are the processing costs associated with each of them. For that purpose, a group of English native speakers and a group of Mandarin native speakers with L2 Spanish at different levels of proficiency completed an eye-tracking linguistic anticipation task. In this task, Spanish verbal suffixes were cued by lexically stressed or unstressed syllables. These populations were chosen because English speakers can transfer lexical stress contrastive function knowledge, and Mandarin speakers can transfer pitch knowledge. We further explored how the transfers are mediated by individual WM. The research questions guiding the study are:

*Do Spanish monolinguals, and intermediate and advanced Mandarin and English learners of Spanish use lexical stress to anticipate verbal suffixes in Spanish? If so, are prediction abilities mediated by verbal WM?*

Our predictions are that monolingual Spanish speakers will anticipate verb tense when cued by stressed and unstressed syllables (Lozano-Argüelles et al., 2019; Sagarra & Casillas, 2018), but WM will not be responsible for individual variability (Otten & Van Berkum, 2009; Sagarra & Casillas, 2018; Tanner & Van Hell, 2014). English speakers will generate the predictions at advanced levels of proficiency (Lozano-Argüelles et al., 2019; Sagarra & Casillas, 2018). Mandarin L2 speakersL1 English speakers will generate the predictions at intermediate levels of proficiency (Schremm et al., 2016). Acoustic knowledge transfer (Li & Grigos, 2018) would therefore be more efficient than function transfer. Increased verbal WM will not affect extrapolation efficiency positively (Sagarra & Casillas, 2018) since cognitive capacities are not taxed by any other task (Lozano-Argüelles, 2020).

# 4. Methods

## 4.1. Participants

30 monolingual speakers of Spanish (20 females), 42 L2 Spanish L1 English speakers (30 females), and 43 L2 Spanish L1 Mandarin speakers (33 females) participated in the study. All participants were living in Madrid, Spain at the time of data collection. English L1 speakers had been in a Spanish-speaking country for a mean of 31.5 months ( *SD* = 28.6) and the L1 Mandarin speakers for a mean of 43.9 months ( *SD* = 43.6). All speakers were raised in monolingual families in monolingual communities of their L1. The monolingual Spanish speakers were local to the Madrid area and spoke no other language fluently nor had lived abroad. The participants belonging to all L2 groups started learning Spanish after age 12. At the time of data collection, the L1 Mandarin speakers used Spanish a mean of 47.3% of the week ( *SD* = 21.2) and the L1 English speakers a mean of 34.4% ( *SD* = 16.6). The age range for all groups was 18-45 (Spanish: mean = 26.2, *SD* = 8.82, English: mean = 25.7, *SD* = 4.27; Mandarin: mean = 24.5, *SD* = 4.39). All participants had normal to corrected-to-normal hearing and vision, and no motor disability.

## 4.2. Materials

**4.2.1. Screening tasks**

A proficiency test was administered to the L2 participants to screen them and to assign them a level of proficiency. The proficiency test was a shortened version (Sagarra & Herschensohn, 2010) of the *Diploma de Español como Lengua Extranjera* (‘Certificate of Spanish as a Foreign Language’, by Instituto Cervantes). The test consisted of 56 questions: 16 on grammar, 10 on vocabulary, and 20 on reading comprehension.

Participants were also interviewed and completed a language background questionnaire that contained questions related to their age, handedness, what language they spoke in their household while growing up, how old they were when they started learning Spanish, how long they had lived in Spanish-speaking countries, how much they used each language per week at the time of data collection, and other languages that they spoke fluently.

At the end, participants completed a vocabulary test with some of the words from the eye-tracking task. This test was a multiple-choice test with 17 screens with 8 words each. For each word in Spanish, they had to choose between 8 possible meanings in the participants’ L1. An extra option was provided to mark in case they did not know the meaning of the word in Spanish.

### 4.2.2. Linguistic anticipation task

A visual-world paradigm was used to asses participants’ abilities to predict verbal suffixes when cued through stressed or unstressed syllables. The eye-movements during the task were recorded through an EyeLink 1000 Plus desktop mount eye-tracker from SR Research (sampling rate: 1k Hz; spatial resolution was less than .05o; averaged calibration error: .25-.5o). Participants read two verbs on a computer screen side by side (*salta* ‘s/he jumps,’ *saltó* ‘s/he jumped’) and heard a sentence containing one of the two verbs (*El ladrón saltó la valla* ‘the thief jumped over the fence’). The particiants’ task consisted of selecting the verb they heard as fast as possible. There were 4 practice sentences, 16 experimental sentences, and 80 fillers. The verbs were the present tense and preterit tense 3rd person singular forms of regular -ar verbs. Bisyllabic Spanish regular verbs have 2 cues to tense: initial syllable stress and word ending morphology. Stressed initial syllables indicate that the tense is present (*salta* ‘s/he jumps’), and unstressed initial syllables indicate that the tense is past preterit (*saltó* ‘s/he jumped’). The verb suffix indicates tense, person and aspect. In total there were 16 verbs, so 16 pairs of present and preterit verbs, 32 final forms: 16 in each condition. All verbs had two syllables in either tense. The first syllable had a CVC structure and the second syllable a CV structure. Participants never heard the two conditions for a single verb. The number of verbs in each tense on each side of the screen was counterbalanced across trials and across participants.

The aural sentences were 5 words long with a neutral structure NPSUBJ-V-NPOBJ. The sentences for each condition within a pair were the same. The sentences were distributed into blocks by means of a Latin square design. There were 8 blocks. Each block contained 2 experimental sentences, one of each type, and 6 filler sentences. The blocks appeared in a randomized order. Within and across the blocks, the sentences were pseudo-randomized to avoid two experimental sentences of the same condition appearing one after the other.

**4.2.3. Verbal WM materials**

An aural version of Unsworth, Heitz, Schrock, and Engle (2005)’s Operation Span task (OSpan) was used to measure verbal WM capacities. This task generates measures of storage and processing speed. In a single trial, participants heard first a word and then a simple mathematical problem that could be either true (e.g., 2 + 2 = 4) or false (e.g., 2 + 2 = 5). Along the mathematical problem, they saw the words TRUE and FALSE on the screen. They had to select as fast as possible the correct word depending on whether what they heard was true or false by pressing the left- or right-shift keys corresponding to the side on which true and false appeared. This sequence of word-mathematical problem would repeat a certain number of times until a set was complete. At the end of each set, participants were prompted to write down the individual words they had heard before each problem in the same order they had heard them.

There were two practice sets of 3 words and simple mathematical problems, and three experimental sets of three, four, five and six words and mathematical problems. The words and mathematical problems that participants heard in the sets appeared in a fixed order across participants. The words TRUE and FALSE that participants needed to select in response to the mathematical problems appeared counterbalanced on each side across participants. The whole task was set up in the participant’s L1.

## 4.3. Procedure

Data collection was conducted in a single session with each participant individually. Participants could take breaks between tasks. Only the researcher accompanied the participants during this time, and all interactions happened in Spanish. The room was isolated from external noise and light. Participants completed the tasks in this order: Spanish proficiency test (only L2 learners; 15-20 minutes), language background questionnaire (10 minutes), eye-tracking task (25 minutes), OSpan (15 minutes), and vocabulary test (10 minutes). First, participants listened to an overview of the tasks and signed the consent form. Participants provided oral responses for the language background questionnaire. They completed the remaining tasks on a computer.

*Visual-world paradigm.* For the visual-world paradigm, participants rested their head on a chin rest, completed an 11-point grid calibration task, and received the task instructions orally and in writing. Then, they completed the practice trials and were given the opportunity to ask questions. Afterwards, they fulfilled the task. Both the practice and the task trials followed the following order. First, participants looked at a fixation sign in the middle of the screen for 250 ms. This fixation sign allowed the researcher to recalibrate manually when necessary. Second, two words appeared in the screen side to side for 1000 ms. At this point, a sentence started playing and continued until reaching the last word. That is, the sentence did not stop when participants selected the word they heard. Participants were instructed to select the word on the screen they heard on the sentence as fast as possible by pressing the right- or left-shift keys. A green rectangle appeared on the screen around the selected word when participants pressed the key to make their choice. Response recording was set up to be registered only when the press happened after the start of the verb in the sentence. Previous presses where not recorded so the task setting forced participants to press again until they saw the green rectangle appear. No feedback was provided. See Figure 1 for an example of an experimental trial.

A close up of text on a white background

Description automatically generated

Figure 1. Sample trial of the visual-world paradigm

*OSpan.* The OSpan task was divided into practice and experimental trials. For each trial, participants first heard a word and then heard a simple mathematical problem, all in their L1. During the mathematical problem, participants saw the words TRUE or FALSE on each side of the screen, and they had to press the corresponding key (left-shift key for the word on the left, right-shift key for the word on the right) depending on whether the problem heard was correct or not. After each problem, they saw a fixation point for 500 ms. and another word-equation pair was presented. This process was repeated until the word RECALL or a linguistic equivalent in the L1 of the participant was shown on the screen, at which moment participants had to write on a piece of paper the words they had heard for that set in the order they were presented. The RECALL screen marked the end of a set. The task started with three sets of three trials, then three sets of four trials, and so on until the third set of six trials. No feedback was provided. Figure 6 shows a sample trial.

A close up of text on a white background

Description automatically generated

Figure . Sample trial of the OSpan task

## 4.3. Statistical analysis

Statistical analyses were conducted on R (R Core Team, 2019) using the packages lme4 (Bates, Mächler, Bolker, & Walker, 2014) and multcomp (Hothorn et al., 2016). The gaze-fixation data was shifted 200 ms. to account for the time it takes to plan and launch a saccade (e.g., Fischer, 1992; Saslow, 1967), downsampled to 10 ms. and 50 ms. bins and centered at the onset of the last syllable of target items. The empirical logit transformation was applied to binary responses (fixations on target or distractor; Barr, 2008). The 10 ms. bins were run through independent t-tests to find out whether participants were anticipating the correct verbal tense upon hearing a stressed or unstressed initial syllable. The 50 ms. bins were used to model a growth curve analysis (Mirman, 2016) to observe how the pattern of gaze fixations changed as suprasegmental and segmental information became available. The models with the time course were implemented by using linear, quadratic, and cubic orthogonal polynomials with the independent variables group and lexical stress. The monolinguals served as baseline. Lexical stress had been sum-coded. By-subject and by-item random effects were also tested. Nested model comparisons were implemented to assess main effects and interactions. For the OSpan, reaction times to the mathematical problems were averaged and used as score, since different languages have different memory score and therefore are not comparable. The proficiency was analyzed as a continuous scale. OSpan scores were analyzed as homogeneity measure and as a continuous scales to observe how verbal WM capacity affects language processing and anticipation.

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