

Running head: L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

The association between linguistic and non-linguistic anticipation in monolinguals and bilinguals

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L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Abstract

Some scholars claim that language is associated with larger domain-general cognitive functions, but the extent of this association is yet unknown. This study explores whether linguistic and non-linguistic prediction abilities are associated. In particular, this study explores the effects of three factors on prediction of word endings in native speakers and adult L2 learners: (1) a person's ability to predict non-linguistic information (pitch, rhythm, space), (2) a learner's linguistic experience bias due to their native language (L1 transfer) (English vs. Chinese learners of Spanish), and their second language (L2 proficiency) (intermediate vs. advanced), and (3) cognitive individual differences (working memory). Previous studies show that rhythmic abilities are associated with prosodic abilities (Cason, Marmursztejn, D'Imperio, & Schön, 2019), linguistic tonal experience with musical pitch discrimination performance (Deutsch, Dooley, Henthorn, & Head, 2009), and general language abilities with visuospatial processing (Bochynska, Vulchanova, Vulchanov, & Landau, 2020). However, no study has investigated whether these associations between linguistic and non-linguistic perception abilities also apply to the realm of prediction, and, if they do, whether language experience and individual differences in working memory play a role. This dissertation fills this gap to understand how different cognitive functions are related and how capacities in each of them influence the rest.

To investigate the role of these three factors on linguistic anticipation, Spanish monolinguals, intermediate and advanced English learners of Spanish, and intermediate and advanced Chinese learners of Spanish completed three non-linguistic anticipation tasks (two musical—pitch melodic variations and rhythm imperative tone— and one visuospatial—moving object—), one linguistic anticipation task (visual-world paradigm), and two working memory tasks (Operation Span, Unsworth, Heitz, Schrock, & Engle, 2005; Corsi-block Tapping, Milner, 1971). In the pitch

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

task, participants had to anticipate the direction of a pitch change. In the rhythm task, participants had to anticipate the start of a beat in a rhythmic pattern. In the moving object task, participants had to anticipate when a car was going to reappear from behind a mountain. Finally, in the linguistic task, participants had to select what word they heard as soon as possible while their eye-movements were recorded. The target words were disyllable verbal tenses in Spanish that differed in whether the first syllable was stressed or unstressed (e.g. busca ‘(s)he searches’ vs. buscó ‘(s)he searched’). Spanish lexical stress is marked predominantly through pitch. English lexical stress uses vowel quality and duration. Chinese has tones instead of lexical stress, but tones are also marked through pitch. In the Corsi-block tapping visuospatial memory task participants had to remember sequences of increasing squares changing colors and repeat the sequence by tapping on them. In the Operational Span verbal working memory task, participants heard a word followed by a simple mathematical sum or subtraction; after the set, participants needed to remember all the word of the set in the order heard. The Operational Span task was administered in the participants’ L1. The findings of my dissertation will determine how different cognitive functions are interrelated and affect each other.

Keywords: language, music, visuospatial, anticipation, eye-tracking

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

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1. Introduction

Some linguistic accounts consider language to be an independent module in the human cognitive domain (e.g., Chomsky, 1986; Fodor, 1983). In other models language is an independent cognitive capacity associated with other domains (e.g., Hasson, Egidi, Marelli, & Willems, 2018), but the nature of this dependency is unknown. In the field of language anticipation (henceforth, linguistic anticipation and linguistic prediction), many scholars advocate for a more global view where language is not necessarily independent but its correct functioning depends on the collaboration of a larger non-linguistic cognitive capacities (e.g., Ryskin, Levy, & Fedorenko, 2020). In a predictive processing view of language, a more general point of view does not sound implausible. There is abundant evidence that all species make predictions (e.g., animals, Alcaro & Panksepp, 2011; Wilson & Lindstrom, 2011; plants, Appel & Cocroft, 2014). And humans do not only have the unique ability to generate linguistic predictions (e.g., anticipating the end of words) but additionally make non-linguistic predictions (e.g., while driving, Morando, Victor, & Dozza, 2016; Stahl, Donmez, & Jamieson, 2016; or while playing sports, Nakamoto & Mori, 2012; Wright, Bishop, Jackson, & Abernethy, 2010).

In my dissertation, I investigate whether there is an association between a person's ability to make non-linguistic and linguistic predictions. Finding an association between linguistic and non-linguistic domains and the nature of it if there is one is essential given that anticipation is a basic cognitive action deployed continuously to facilitate information processing in all possible domains. Understanding the association among domains would clarify how different types of cognitive abilities are related, and how different types of cognitive experiences affect encoding

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

and processing of the other theoretically unrelated domains, like for example music and driving.

To address this question, I examine auditory (pitch, rhythm) and visual-spatial (object in motion) non-language anticipation and language anticipation (a word's suffix) in adult Spanish monolinguals and English and Mandarin Chinese intermediate and advanced learners of Spanish. Auditory anticipation was selected because numerous studies show that processing in language and other auditory domains such as music are interrelated. For pitch, musicians of a non-tonal L1 are more sensitive to linguistic tone differences than non-musicians of the same L1 (Chua & Brunt, 2014), and non-musician speakers of tonal L1s perform musical tasks better than non-musician speakers of non-tonal L1s (e.g., Bidelman, Hutka, & Moreno, 2013; Ngo, Vu, & Strybel, 2016). However, no study has examined whether this extrapolated ability can also be used for prediction or only in perception. For rhythm, rhythm perception and production abilities are positively correlated with foreign prosody perception, and in particular with lexical stress (Cason et al., 2019). In contrast to pitch, prediction studies on rhythm have shown that rhythm anticipation is linked to linguistic abilities. For instance, typically developing children anticipate upcoming beats better than dyslexic children (Persici, Stucchi, & Arosio, 2019). Finally, for visual-spatial processing, some scholars propose that children's dyslexia is caused by deficits in visual-spatial attention rather than to limited phonological processing (Vidyasagar & Pammer, 2010). However, it has not been studied either how these deficits in visual-spatial processing are related to anticipation of linguistic and visual-spatial information.

In addition to exploring the role of anticipatory experience (association between non-linguistic and linguistic prediction), I investigate the role of language experience (L1 extrapolation; L2 proficiency) and working memory in adult second language acquisition (SLA). In a usage-based framework, language experience is important because it shapes grammar constantly (Bybee,

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

2006) and so it shifts a speaker's attention to and inhibition of input. Thus language experience keeps affecting the ability to make predictions in any language. The inhibition effect is called blocking (Kamin, 1969) and consists of cues predicting a certain outcome not being encoded as cues because another cue is already encoded as a predictor of that outcome. That is, the speaker has learned to pay attention to that reliable association (learned attention, Mackintosh, 1975). In the usage-based framework, a speaker in the L2 should be able to resort to that association for successful L2 prediction. However, cue-outcome associations do not always overlap completely, so in the case of partial overlap, it is unknown whether the similar or the discrepancy are stronger in impacting language processing.

The ability to make cue-outcome associations and use them in prediction may well be conditioned by working memory. Working memory has been shown to contribute to language anticipation sometimes (Huettig & Mani, 2016) but not others (Otten & Van Berkum, 2009). The main structures selected to research the influence of working memory on anticipation have been morphosyntactic. The function it plays may, however, be the responsible for the differences in working memory findings. Huettig and Mani (2016) researched anticipation of morphosyntax as an outcome in L1 Dutch and did find working memory differences, while Otten and Van Berkum (2009) used morphosyntax as the cue and found no effects of working memory. It is however not possible so far to draw many conclusions from the available results on the role of working memory on linguistic anticipation as they are scant. The grounds set by the differences in the use of morphosyntax in language anticipation in Huettig and Mani (2016) and Otten and Van Berkum (2009)'s studies may be a source of findings on the role of working memory on language processing and anticipation if that line of research is further pursued.

Indeed, morphosyntactic anticipation in general has been very productive in providing insight

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

into how the mechanisms of linguistic prediction. Overall, morphosyntactic information such as gender can be predicted in an L1 (Kamide, Altmann, & Haywood, 2003) and already in an L2 when the L1 has a gender system as well at beginner stages (Dussias, Kroff, Tamargo, & Gerfen, 2013). Other types of morphosyntactic information such as noun number (Roll, Horne, & Lindgren, 2010) and tense (Sagarra & Casillas, 2018) can also be predicted based on phonological cues.

To investigate the influence of language experience on morphosyntactic prediction based on phonological cues, I compare English and Mandarin Chinese learners of Spanish. Relevant to my dissertation, Mandarin, English and Spanish differ in the presence of tones (present in Mandarin, absent in English and Spanish), lexical stress (present in English and Spanish, absent in Mandarin, although Mandarin tones share the main acoustic correlate with Spanish lexical stress), and morphology (null in Chinese, poor in English, rich in Spanish).

Studies on learning experience have revealed that adults can anticipate linguistic information in their L1 (e.g., Roll, Söderström, & Horne, 2013) and might do so in their L2 (e.g., Dussias et al., 2013), although only extensive active practice result in L2 performance comparable to L1 performance (Lozano-Argüelles, Sagarra, & Casillas, 2019). L2 processing and anticipation capabilities are largely constrained by the speaker's proficiency (e.g., Sagarra & Casillas, 2018) and the cross-linguistic effects from the L1 (e.g., Dupoux, Sebastián-Gallés, Navarrete, & Peperkamp, 2008), although how and when the L1 affects L2 processing and anticipation is not clear.

Studies on the association of auditory abilities have demonstrated that processing and comprehension abilities are not only extrapolated across languages (e.g., Ghaffarvand Mokari & Werner, 2018), and also in terms of language and pitch and rhythm abilities (e.g., Tsukada, Xu, &

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Rattanasone, 2015; Cason et al., 2019, respectively). However, no study has explored the possibility that this extrapolation also reveals itself in anticipation, even though anticipation is present in other auditory domains such as in rhythms [a] or melodic processing [a]. Similarly, a relationship has been found between speech processing abilities and visual-spatial abilities (Phillips, Jarrold, Baddeley, Grant, & Karmiloff-Smith, 2004), but no research on how this relationship extends to anticipation performance has been undertaken.

The goals of this project are to study cross-linguistic associations over different levels of L2 proficiency, to examine the ability to associate acoustic knowledge to predict non-linguistic information (pitch, rhythm, space), and to explore the role of cognitive individual differences, i.e. working memory, in each of these cases. This project is hence split into three studies: transfer within domain (L1>L2), within modality but between domains (speech>music), between modalities and domains (speech>vision). By completing these studies, this project will inform models of phonological transfer as well as models of working memory, by establishing how different cognitive domains are interrelated.

2. Background

2.1. Anticipation

Anticipation alleviates the load of constantly processing the information that we receive from the world. At a large scale, we anticipate what is going to happen in movies and books. At smaller scales, we anticipate movements in sports, other drivers' actions, and we also anticipate what we read and what we hear. In non-linguistic auditory domains, like music, we anticipate the melody through pitch and rhythm. In non-linguistic visuospatial anticipation, we use the position and movement of objects to anticipate how long it will take an object to reach a certain point, or

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

to anticipate the trajectory it is following. Finally, in linguistic anticipation, we use cues of different kinds (contextual, phonological, morphosyntactic) to predict oncoming linguistic information. Predictive processing in language is especially efficient in the L1, and mediated by factors such as L1 transfer, L2 proficiency, or working memory in the L2. These factors may interact with each other to generate successful or unsuccessful predictions.

2.1.1. Non-linguistic anticipation.

2.1.1.1. Auditory anticipation.

There is abundant evidence supporting a cognitive association between different cognitive domains in an auditory modality. Here, I will focus on the relationship between language, rhythm and pitch. Rhythm and pitch are essential in music, and thus music is the usual framework used to make research on those abilities. Importantly however, the use of a common framework to conduct research on those auditory abilities does not mean they are inseparable. Previous research suggests that pitch-deafness and beat-deafness are dissociated (Phillips-Silver, Toiviainen, Gosselin, & Peretz, 2013). Following this rationale, pitch and rhythm abilities are independent although they interact when put into practice for music perception, processing and production. The independence and interrelation between two auditory abilities, as well as findings on the relationship between pitch and language, and rhythm and language, open the possibility that anticipation in the auditory domain is also underpinned by a shared network of domain-general mechanisms. Offline studies on the relationship between music and language show that higher musical abilities yield more effective reading comprehension skills in children (Anvari, Trainor, Woodside, & Levy, 2002). Behavioral online studies have revealed that musical abilities influence positively the production and perception of linguistic sound structures in L2 learners (Slevc & Miyake, 2006). These results have been replicated in neurocognitive studies in the same population (Marques, Moreno, Lui's Castro, & Besson, 2007), as well as in children

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

(Magne, Schön, & Besson, 2006) and adults (Wong, Skoe, Russo, Dees, & Kraus, 2007).

Similarly, other neurocognitive studies reveal that musicians process speech in a more enhanced way and more synchronously to its onset than non-musicians (Musacchia, Sams, Skoe, & Kraus, 2007).

The influence of music in language starts early during childhood. Regarding syntax, Jentschke, Friederici, and Koelsch (2014) found that music and language follow a similar time course of acquisition of syntactic regularities. Degé and Schwarzer (2011) compared the effects of a music program and a phonological skills program on children's phonological awareness, and they found that phonological awareness of small and large phonological units improved from a pre-test to a post-test for both treatment groups, while no improvement was observed for a control group. In a similar fashion, Lebedeva and Kuhl (2010) explored whether infants were able to discriminate phonetic from melodic patterns in songs. Results indicated that 11-month-old infants could discriminate between 4-note sung melodies, but the infants did not show any preference towards familiar or unfamiliar spoken strings containing a syllable order change when the intonation contour remained stable for both strings. However, when the melodies were presented without the phonetic cue, and thus were not sung only instrumental, infants did not show any preference, suggesting that they were not discriminating the melodies based on their melodic contour alone. Taken together, the findings of the tasks Lebedeva and Kuhl (2010) deployed suggest that infants use the phonetic content of melodies to process a melodic line, even if they are not able to understand fully what they are hearing. Findings like the one by Lebedeva and Kuhl (2010) and the resemblance in processing between music and language have even led some scholars to suggest that language is processed as a type of music by the early developing brain (Koelsch & Siebel, 2005).

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

The music-language association found in children is also reported in adult native speakers and L2 learners. In amusic individuals, that is, individuals who have lost or with impaired musical capacity due to different reasons (e.g., congenital, accidents, Benton, 1977), ERPs have shown that syntactic irregularities in music (i.e. notes incompatible with the scale used) and language (i.e., disagreement of number) produce similar reduced or non-existent ERAN and LAN responses in comparison to healthy individuals, while processing semantic irregularities (e.g. “Linda is feeding two kites”) did not produce any changes, as shown by a typical N400 signal (Sun et al., 2018). Yu et al. (2017) conducted a fMRI study particularly designed to test how different components of music and first language are associated. They compared the results from a group of participants undergoing music training group and a control group in language tests (an animal-word cancellation test and an onset cancellation test) and music tests (an interval test and a rhythmic test). The training group performed better in all tests, and what is more, the accuracy in the animal-word cancellation test and the accuracy in the interval test were positively correlated. With regard to L2 learners, multiple studies have tested how musical abilities and L2 performance at different levels. Between pitch in particular and the segmental level of speech, Ghaffarvand Mokari and Werner (2018) studied whether there was any kind of association between general musical abilities and L2 vowel learning with L1 Azerbaijani learners of English. The participants were split into control group and experimental group, who underwent phonetic training. Both groups completed music ability tests (chord analysis, pitch change and tonal memory) and linguistic tests (discrimination and production). Results point that the increased accuracy in discrimination and production of L2 sounds from the pre- to the post-test is not related to the musical ability in general, although tonal memory was significantly correlated to the gained skill to discriminate L2 vowels. At the suprasegmental level, the influence between

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

music and language is bidirectional. On the one hand, musical knowledge of pitch facilitates perception of L2 tones in musician speakers of non-tonal L1s (Ngo et al., 2016). On the other hand, non-musician speakers of L1 tonal languages have increased ability in pitch and music perception in general (Bidelman et al., 2013).

Regarding rhythm and L2 abilities, Swaminathan, Schellenberg, and Venkatesan (2018) explored if and how rhythm perception was associated with reading abilities in both the L1 and L2, and they found however that better rhythm perception was not associated with increased reading abilities in either type of language. In speech, suprasegmental information like stress is also linked to musical abilities. Cason et al. (2019) investigated how rhythmic abilities were related to the perception and production of L2 stress placement. Rhythmic production scores were a reliable predictor of L2 stress placement.

In sum, research suggests that at least some cognitive faculties underlying music and language are shared. Sharing the faculty might be determined by the area we are focusing on, like speech vs. reading. Previous research also suggests that anticipation is an important mechanism in both realms, especially in relation to rhythm, but to the best of my knowledge, no study so far has tested whether this processing mechanism is also interdependent to each domain or shared.

Positive correlation between linguistic anticipation and other types of anticipation common in music, such as rhythmic or tonal, could indicate that there are domain-general predictive cognitive mechanisms underpinning auditory anticipation as a whole.

Pitch

Pitch is the frequency associated to a sound wave; this frequency places the sound within a scale ranging from low to high in perception (Klapuri, 2006). Pitch in music plays a similar role to the one it plays in language. In language, a listener must process the melodic contour of speech, that

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

is, the changes up and down of pitch in order to understand the meaning conveyed by prosody (Dilley, 2005). For example, a rising pitch contour signals a question (“Coffee?”), while a falling intonation signals a statement (“Coffee.”). Apart from the phrasal and sentential intonation, pitch also affects tones and predominance against other syllables within a word. In music, pitch affects the note we hear.

Pitch is not only a common acoustic correlate in speech and music. Knowledge and perception abilities of pitch in one of the two auditory domains translates in many but not all cases into increased perception abilities in the other domain (Bidelman et al., 2013; Chan & Leung, 2019). This relationship shows between perception of pitch in tonal languages and absolute pitch in music (e.g., Chua & Brunt, 2014; Deutsch et al., 2009; Ngo et al., 2016). The relationship does not show in other areas, like relative pitch and L1 tone knowledge (Ngo et al., 2016). Atypical populations have also provided evidence of a relationship between pitch and speech (in amusia, Patel, Wong, Foxton, Lochy, & Peretz, 2008; in Williams Syndrome, Martí'nez-Castilla & Sotillo, 2014).

In typical populations, L1 speakers of tonal languages are better and faster at discriminating and detecting absolute pitch in music (e.g., Chua & Brunt, 2014; Deutsch et al., 2009; Tsukada et al., 2015), since tones in music depend on pitch, like tones in many languages. Music in different cultures around the world vary on how their scales are organized (as well as on the patterns of strong-weak pulses, Morrison & Demorest, 2009), but the basis for the scales is always pitch. Pitch collections may be different from one music culture to another, but the range is shared. Bidelman et al. (2013) tested how L1 Cantonese listeners, non-tonal speaking musically-trained participants and a non-tonal speaking non-musician control group performed in a three-alternative forced-choice task, an auditory inspection time paradigm, a short-term pitch memory

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

task and a melody discrimination task to compare their measures of auditory pitch acuity, music perception, and general cognitive ability. The Cantonese speakers outperformed the control group on most pitch and music perception measures, and performed similarly to the musicians' group. Because of the good performance of the Cantonese group, who had no musical knowledge, the authors suggested that music and language abilities transfer bidirectionally. Additionally, musicianship contributes to better lexical tone perception even in a tonal language (Tang, Xiong, Zhang, Dong, & Nan, 2016).

In contrast to the studies described so far, other studies have failed to obtain evidence that there is a music-language association in typical populations. Chan and Leung (2019) studied the creation of L2 tone-segment connections in musicians and non-musicians. Their results indicate that musical experience did not promote tone-segment connection in a tonal L2 when the L1 was non-tonal, but a tonal L1 did promote L2 tone-segment connection and the creation of a rule-like system of L2 tone information. Likewise, only musical experience can be beneficial in relative pitch perception in music, while tonal-language experience has no effect in relative pitch perception performance (Ngo et al., 2016). From this set of results, it is possible to deduce that there is a limit in the reciprocal influence between music and language (musical and linguistic pitch for the purpose of this project), but where this limit lies has not been ascertained.

An area the relationship between pitch and language is clearer is atypical populations. Research on atypical populations like amusics (individuals with reduced or lost musical ability, such that comprehension and production of music, and ability to read and/or write musical notation are impeded, Pearce, 2005) or individuals with Williams Syndrome (WS, a rare genetic disorder that results in cognitive impairments and other biological alterations, Jones & Smith, 1975) has produced larger evidence of a connection between pitch and language. In a study in amusia, Patel

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

et al. (2008) observed that amusic individuals distinguish changes in pitch but are unable to detect the direction of the change, such that they can discriminate changes in intonation, but cannot really tell what the prosodic change means. This ability to perceive pitch and its changes is probably one of the most studied aspects of the relationship between music and language.

Martí'nez-Castilla and Sotillo (2014) investigated whether children with WS processed pitch in music and language through common mechanisms. For that purpose, the WS children and typically developing children completed a musical pitch discrimination task, a short-item discrimination task and a long-item discrimination task. The WS group performed well above chance in all tasks, but their scores were significantly lower than those of the control group of typically developing children. In the case of the experimental group, the scores for the musical pitch discrimination-task and the short-item discrimination task were also correlated.

In sum, some areas of music and language are connected, but influence from music to language and vice versa may be blocked. What these specific areas are is not completely known. While the shared processing mechanisms between music and language have been previously researched, no study so far has looked into how the anticipation mechanisms may be shared by the different auditory domains, or how the different acoustic correlates may affect anticipation in these domains. Separately, there is evidence for the existence of prediction processes in music (e.g., Salimpoor, Zald, Zatorre, Dagher, & McIntosh, 2015) as well as in language. Like in language, anticipation in music can be cued through syntactic structure (Sammler, Novembre, Koelsch, & Keller, 2013) or acoustic properties (Loui & Wessel, 2007). Anticipation has been particularly examined in rhythm, as synchronization to a rhythm is intrinsically keeping track of the interval structure, and therefore anticipation of the next event.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Rhythm

Rhythm is defined as a pattern of recurrent time intervals that usually occur periodically (Berlyne, 1971). This periodic nature allows to predict the start of an interval or the next recurring event based on what has already been perceived (Fraisse, 2013; Martin, 1972). Given hence the nature of rhythm, synchronizing to a rhythm is basically anticipating when the next interval is coming and acting accordingly. One of the most natural ways to accompany the predicted rhythm is through movement, like body movement. This ability to anticipate events and synchronized with them based on rhythmic patterns is already evident in babies as young as one year of age in their rocking to musical rhythms (Fraisse, Pichot, & Clairouin, 1949). And by the age of three or four we are able to tap along metronome beats. This sensorimotor behavior is usually based on anticipation of when the next beat is coming, especially at slow tempi (Nozaradan, Peretz, & Keller, 2016; Steen, Jacoby, Fairhurst, & Keller, 2015), and the anticipation grows in accuracy with years of musical training (Nozaradan et al., 2016). Prediction of oncoming beats is also present in rhythms with tempo changes (Steen et al., 2015).

The ability to synchronize to beats or changes in rhythm is conditioned by (1) motor limits, (2) the fractured memory of a slow sequence, (3) sensory difficulties at perceiving successiveness at fast tempi (Bartlett & Bartlett, 1959), and (4) the complexity of the rhythm (Fraisse & Repp, 2012). However, the adaptation is fast, since it can take as few as three consecutive taps accompanying each a consecutive beat in a novel rhythm to achieve a relative simultaneity (Fraisse & Repp, 2012). The rhythm structure affects the synchronization pattern, as some tempo speeds are easier to adjust to than others. When the interval between beats is on or under 1500 ms, the synchronization behavior tends towards anticipation of the next beat, while this anticipation rate starts to decrease with beat onset intervals of 1800 ms (Miyake, Onishi, &

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION (Poppel, 2004).

Rhythms can happen in multiple formats, so they can be perceived multisensorily too. For example, rhythms can be visual, like the bouncing of a ball, or heard, like a march. So being impaired in a hearing, for instance, does not mean that an individual is unable to perceive and synchronize to rhythms. Within the auditory modality, music is probably the most obvious instance of rhythm, but other domains such as language also follow rhythmic patterns. Rhythmic abilities across domains have been shown to be associated. Rhythmic musical abilities are associated with linguistic performance in children (Carr, White-Schwoch, Tierney, Strait, & Kraus, 2014), L2 speakers (Cason et al., 2019), and atypical populations (Lagrois, Palmer, & Peretz, 2019).

Rhythms can be perceived visually, as research with deaf individuals show. Iversen, Patel, Nicodemus, and Emmorey (2015) investigated how the accuracy of visual timing abilities and rhythmic perception are affected by developmental experience by comparing deaf and hearing adults in a tap synchronization task with three types of isochronous rhythmic stimuli: a flashing visual square, an animated bouncing ball and auditory tones. Results revealed that synchronization driven by a silent moving visual stimulus can be as accurate as that driven by sound, and that deaf individuals could synchronize their movements as well or even better than hearing individuals when presented with visual stimuli. However, rhythms are perceived primarily through our auditory pathways, like speech.

Rhythms perceived auditorily are the ones that have been used to research hearing populations, regardless of whether the studies also included visual tasks, like reading. Swaminathan et al. (2018) studied the existence of an association between rhythm perception and reading ability in adults in their L1 and L2 and found no evidence. In contrast, Cason and Schön (2012) did find

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

that on-beat sequence primes yielded faster L1 speech processing than off-beat primes in adults through EEG recordings. The contradictory results obtained from these populations suggest that the effects of rhythm in hearing adults may not be as extensive as in deaf individuals in the visual domain. Maybe because hearing individuals do not need to hone their visual perception and processing abilities. Alternatively, there might be some “loss” in the extrapolation of rhythmic abilities from a visual domain to an auditory domain or vice versa, causing the relationship between rhythm and language in different modalities to be weaker. This conclusion would be supported by findings suggesting that within a modality, the relationship between rhythm and language, in this case speech, is stronger.

Like in tone and pitch, there is evidence that rhythm is associated with language in children, L2 speakers, and atypical populations (beat-deafness, dyslexia and WS) within the auditory modality. Starting with children, Carr et al. (2014) had their typically developing children complete a series of linguistic, verbal memory, rhythmic and musical in general tasks to investigate the relationship between rhythmic synchronization and the encoding of syllable envelopes in pre-schoolers. Those children who synchronized better also had better perceptual and cognitive language skills. They were faster at naming objects and color, and their neural encoding of the speech envelope was also better. Encoding of sound is also favored by rhythmic perception in the L2 experience. Cason et al. (2019) and Bhatara, Yeung, and Nazzi (2015) tested stress placement and rhythmic abilities in L1 French speakers and L2 Spanish. The rhythmic production scores of the participants predicted correct placement of nuclear stress in a L2 lexical stress imitation task; and rhythm perception was actually positively associated with L2 learning experience. These studies suggest that rhythm is indeed related to speech in typical populations within a modality, and specifically, within the auditory domain.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Studies with atypical populations have also yielded positive results supporting a relationship between heard rhythms and speech. Lagrois et al. (2019) tested beat-deaf individuals, that is, individuals who have a documented deficit in tracking musical beat, to analyze how they synchronized to speech. Participants had to tap along sentences in three conditions: regularly spoken, naturally spoken and sung, and were compared to a matched control group. The beat-deaf group showed more variability in its tapping regardless of the condition. The irregularity remained when they tapped to a metronome or at their own pace and was larger than in the typical non-musician control group. These results show that the deficiency in time-keeping mechanisms might underlie both domains rather than being domain-specific. In the same vein, Persici et al. (2019) supported this conclusion when they compared the anticipation abilities of children with developmental dyslexia and typically developing children, and the results showed that children with dyslexia achieved lower scores than their peers in morphosyntactic and rhythmic processing. Therefore, noun prediction based on this information looked alike for both groups, but phonologically- and/or grammatically-based anticipation was hindered for the dyslexic children. Similarly, Sun et al. (2018) explored brain responses to syntactic violations in music and language in amusics. Brain responses to incongruities in both domains were reduced, but brain responses at later stages of processing, that is, during semantic processing, were unaffected or showed the same pattern as brain responses in typical individuals to semantic incongruencies. Based thus on previous findings suggesting the delayed anticipation in rhythm, phonology and morphosyntax, it is not unlikely that structure-based prediction is contingent to a cognitive mechanism common to the auditory mode in general, rather to domain-specific abilities.

From the previous investigations on rhythm, we can see that synchronization is basically

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

prediction of the rhythm timings. The findings on the relationship between rhythmic abilities and linguistic competence suggest that this relationship might only surface in certain cases, and that extrapolation from modalities may affect how strong the relationship is. Some of the factors conditioning the existence of a connection between the two domains are atypical development, early stages of cognitive development, nature of L1, or linguistic area in L2 learning.

Investigations from other auditory areas, such as speech anticipation, may clarify if and how rhythmic abilities and linguistic abilities are related. One of the main visuospatial cues related to rhythm is movement. Taking into account how rhythm imbibes from visual and spatial cues might be helpful in establishing the nature of the rhythm-language relationship, as keeping a rhythm requires gauging of space in order to be timed correctly. And movement, like language, is entrenched in our everyday life. We use movement to respond to virtually everything, not only rhythms. When driving, we anticipate what other drivers or pedestrians are going to do and adjust accordingly by making foot, manual and head movements. When catching an object in a free fall, we anticipate (more or less successfully) the trajectory and the speed to move our arm and hand fast enough and try to grab the object before it hits the floor.

2.1.1.2. Visuospatial anticipation.

Visuospatial abilities refer to the ability to process, work with and remember information in space perceived visually. The visuospatial domain can interact with language through written texts in the way we read and write (e.g. Schmalz, Marinus, Coltheart, & Castles, 2015), but it can also interact in how we process information. Both typical and atypical populations have shown evidence of how the spatial reference system interacts with linguistic representation of space in comprehending and producing language (e.g. Bochynska et al., 2020; Landau & Hoffman, 2005). In written language, we can write and read left to right, or right to left, and also up downwards,

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

depending on the language. In any language, be it alphabetical, abjad, syllabary, or any other type of language, there are strict rules on how their different components should be arranged spatially.

In sign languages, space cognition may be important both in lip reading and in signed communication. Even in normal speech, language reflects how space is visually perceived; or from the opposite point of view, maybe how space is visually perceived determines how language conceptualizes space. In any case, if a lay person is asked in a European country where each cardinal direction lies, they may have a hard time guessing it. That is because their space perception is mainly egocentric and hence defined by concepts such as up, down, next to, or behind in reference to the speaker. In other languages, such as the Aboriginal Australian Guugu Yimithirr group, geocentric referents are taken, so position and directions are expressed in terms of north, south, east and west. Even within a single language, we need to create a representation of space to talk about concepts such as distance, and thus use the demonstrative system correctly. This idea is actually supported by empirical evidence that linguistic and non-linguistic spatial representations rely on a common axis-structure, at least in English (Crawford, Regier, & Huttenlocher, 2000; Huttenlocher, Hedges, & Duncan, 1991).

In typical populations, interference of visuospatial abilities in language has been proven in languages with orthographic depth, like English. Orthographic depth is the linguistic phenomenon by which written words need to be processed semantically in order to be pronounced correctly (Liberman, Liberman, Mattingly, & Shankweiler, 1980). Thus, English is a deep language in the sense that the same letter or string of letters can be pronounced differently depending on the word, so the speaker needs to process the word semantically first to know which pronunciation to assign to the letter or string of letters (Katz & Frost, 1992; Schmalz et al., 2015). In contrast, languages like Italian or German are shallow, as a letter or string of letters

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

tend to be pronounced the same regardless of its position in a word or the word they appear in. In a meta-study of visuospatial interference in language, Estes and Barsalou (2018) found that visuospatial interference was larger in deep languages, while it was nearly non-existent in shallow languages.

Associations between the linguistic and the visuospatial systems also manifest in different pools of atypical populations. But for a few exceptions (Lukács, Pleh, & Racsmany, 2007), WS has been particularly prolific in providing evidence of a connection between visuospatial representation and linguistic performance [e.g., Farran, Atkinson, and Broadbent (2016); Landau and Hoffman (2005)]. Landau and Hoffman (2005) set to investigate if WS individuals reflect in linguistic and non-linguistic tasks having structured representations of reference systems. While certain patterns present analogies between the experimental and the control typically developing children group, children and adults with WS showed poorer performance compared to controls in trials where they had to locate orally and by gestures objects farther apart from the reference object, especially when located on the horizontal axis. While the results suggest that WS individuals use a structured system of axes as reference to represent space, the system lacks certainty in some areas, namely the horizontal axis, that translates into their comprehension and production of spatial linguistic terms. Phillips et al. (2004) compared the visuospatial representation system of WS against a group of children with moderate learning difficulties. WS participants made more errors in comprehending those sentences containing a spatial component than both the typically developing controls and the population with moderate learning difficulties. The results from this population suggest that WS problems stem from a deficit in processing of spatial descriptions rather than from semantics (Laing & Jarrold, 2007). This deficit influences in turn the interaction between language processing and spatial abilities.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Research with other atypical populations, i.e. autism and dyslexia, has led further support to the conclusions reached after exploring the vision/space-language relationship in WS. Bochynska et al. (2020) conducted a series of eye-tracking, offline and production experiments with autistic individuals to test the nature of the relationship between space representation and spatial language. The particular target structure that served as object of the studies was the axial reference system. In terms of spatial language production, autistic participants used a smaller set of terms to describe the images they saw regardless of the condition, whereas typical participants used a wider range of terms for trials where the circle was placed or moved along the axes of the square. Additionally, the autistic group was significantly less accurate in the descriptions. The eye-tracking data showed similar patterns for both groups but were noisier for the autistic participants. This noise is probably due to the uncertainty provoked by weaker representations of spatial terms. Furthermore, Bochynska et al. suggest that weaker representations of spatial terms may be linked to less efficient processing of spatial language, similarly to the case of WS.

Dyslexia has also provided some evidence of the existence of the relationship between space and language. This relationship, however, is more obvious in dyslexic children than in dyslexic adults. Giovagnoli, Vicari, Tomassetti, and Menghini (2016) tested children with developmental dyslexia in order to explore how reading and visuospatial abilities change according to the educational stage. The younger dyslexic children performed worse in a mental rotation task, a more-local visuospatial task, a more-global visual-perceptual task, and a visual-motor integration task as compared to age-matched typically developing children. The older dyslexic children had caught up with their age-matched typically developing peers in all but one task, the visual-perceptual task. The visuospatial abilities therefore may be contributing to reading capacities as a more global perception strategy. Interestingly, Von Károlyi and Winner (2004) found that

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

visuospatial deficits were also present in adults and older teens, although to a lesser extent. In their studies, visuospatial abilities were inferior in dyslexic individuals than in typical controls, except for global visual spatial tasks, in which dyslexics were actually enhanced. Another ability in which dyslexic individuals may be superior is in analytic spatial abilities, at least in older children and younger teens (Duranovic, Dedeic, & Gavrić, 2015). In sum, research on atypical populations in particular has yielded a hodgepodge of mixed results. The impact of the visuospatial domain in language may be larger in some populations, such as WS (Landau & Hoffman, 2005), than in other, such as dyslexics (Von Károlyi & Winner, 2004). And certain linguistic deficits may even be linked to increased visuospatial abilities (Duranovic et al., 2015). However, most of this research was performed offline (with the exception of Bochynska et al., 2020) or on subjects whose age range was too broad (Phillips et al., 2004). Focusing on online measures, such as eye-tracking, can reveal more fine differences in information processing caused by the interaction between the linguistic domain and the visuospatial domain. While it is possible that individual differences in visuospatial representation and processing may affect atypical populations more visibly (Bochynska et al., 2020), online measures can provide further insight into how processing of the visuospatial domain is related to linguistic processing in typical populations too, instead of just focusing on representation systems and offline measures. Anticipation offers a good new perspective to further investigate how the visuospatial and linguistic domains are associated, as both in language and in visuospatial domains humans anticipate events and measures have to be online. In other words, data are not stained by processing yet. In the visuospatial domain, when a moving object disappears and is bound to appear again, we tend to anticipate when it will do so by adjusting our eye movements to the speed at which the target was going before it disappeared (Bennett & Barnes, 2004, 2005, 2006;

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Orban de Xivry, Bennett, Lefèvre, & Barnes, 2006). In a real world environment, driving is a good example of anticipation put into practice. Fronto-central negative ERP activity suggests that drivers anticipate randomized car accidents in a passive, ecological driving simulation (Duma, Mento, Manari, Martinelli, & Tressoldi, 2017). In order to anticipate and try to avoid the threat of a car accident, drivers use somatosensory and visual cues (Morando et al., 2016). When exposure to these cues is interrupted, the drivers' ability to anticipate a hazard on the road decreases (Borowsky et al., 2016). If humans therefore anticipate both in visual and auditory modalities, it is possible that there is some relationship between the prediction abilities in cognition in general. If there were some type of positive relationship, this association would suggest that the supporting cognitive mechanisms of anticipation are primarily not only domain-general, but domain- and modality-general.

2.1.2. Linguistic anticipation.

In this project, I adopt a predictive processing view of language. That is, language processing is facilitated and preceded by prediction of linguistic information based on the already available information, which acts as prediction cues. The underlying mechanisms of how prediction works are still a matter of debate. Linguistic prediction might well be domain-specific, but research on populations with reduced/loading executive resources resulting in underachieved prediction suggests that linguistic anticipation is actually related to more general cognitive resources. Thus, children's executive resources do not reach maturity until early adulthood (Davidson, Amso, Anderson, & Diamond, 2006; De Luca & Leventer, 2010); this lack of cognitive development has been used to account for their inability to predict linguistic correctly (e.g., Friedrich & Friederici, 2005; Gambi, Gorrie, Pickering, & Rabagliati, 2018). On the other end, the executive functions in adults over 45 years of age have already declined enough

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

to slow prediction (e.g., Dagerman, MacDonald, & Harm, 2006; Federmeier & Kutas, 2019). In a different context, L2 learners (e.g., Lew-Williams & Fernald, 2010; Mitsugi & Macwhinney, 2016) load the pool of executive functions that they would otherwise use for anticipation in their L1 (Linck, Osthus, Koeth, & Bunting, 2014), although in their case, lack of prior linguistic experience also affect their ability to generate linguistic predictions (Cuetos, Mitchell, & Corley, 1996). Lack of enough language experience as a factor determining anticipation performance could naturally be applied to children to. Similarly, even adults in their L1 constantly readapt their expectations based on previous linguistic input (e.g., Levy, 2008; Ryskin, Qi, Duff, & Brown-Schmidt, 2017).

2.1.2.1. L1 speakers.

Just like in any other realm of life, humans tend to anticipate linguistic information. We anticipate semantic (Altmann & Kamide, 1999) and morphosyntactic (Grüter, Takeda, Rohde, & Schafer, 2016; Lew-Williams & Fernald, 2010) information by using morphosyntactic (Grüter et al., 2016), syntactic (Linzen & Jaeger, 2016), semantic (Kamide et al., 2003; Pozzan, Gleitman, & Trueswell, 2016) and phonological cues. Relevant to my dissertation, the phonological cues that speakers may use to anticipate in their L1 are numerous: 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). Linguistic prediction allows listeners to anticipate upcoming words and regions (Brennan & Hale, 2019; Yang, Gryllia, Pablos, & Cheng, 2019), and word endings (Roll et al., 2010; Sagarra & Casillas, 2018; Soto-Faraco, Sebastián-Gallés, & Cutler, 2001). Here, I will focus briefly on

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

suffix prediction. Predictions of morphosyntactic elements can be generated through determiners

(in Dutch, Huettig & Mani, 2016; in Spanish, Dussias et al., 2013; Lew-Williams & Fernald, 2010; in German, Hopp, 2013; in French, Dahan, Swingley, Tanenhaus, & Magnuson, 2000).

Determiners can provide information about number (Marull, 2017), gender (Dahan et al., 2000), and case (German Hopp, 2015; Japanese, Mitsugi & Macwhinney, 2016).

Within the very word containing the suffix to be predicted, phonological information such as tone or lexical stress can cue the generation of the correct anticipation of word endings. Swedish speakers use tonal cues to predict noun number (if low tone, then singular, *fisken* “fish_[SG]”; if high tone, then plural, *fiskar* “fish_[PL],” Roll et al., 2010, 2013; Söderström, Horne, & Roll, 2015) and verb tense (if low tone, then present, *skrämmer* “I scare”; if high tone, then past, *skrämde* “I scared,” Söderström, Roll, & Horne, 2012; Roll & Horne, 2015). Similarly, Spanish speakers use lexical stress to predict verbal tense (if first syllable stressed, then present; if unstressed, then past: *CANta* “he sings” vs. *canTÓ* “he sang,” Sagarra & Casillas, 2018) and noun ending (*PRINcipe* “prince” vs. *prinCIPIO* “beginning,” Soto-Faraco et al., 2001). Finally, English natives use vowel duration to predict voice (if shorter vowel duration, then active: “the girl was pushing the boy”; if longer vowel duration, then passive: “the girl was pushed by the boy,” Rehrig, 2017).

Although findings on anticipation in L1 show that typical L1 speakers tend to perform predictive language processing, it is unclear how individual variability in cognitive capacities, i.e. working memory, can affect the efficacy of the predictions. Huettig and Mani (2016) found through eye-tracking that the variance between participants in fixating on the correct target noun based on gendered article in Dutch could be accounted for working memory. However, Sagarra and Casillas (2018) found also by means of eye-tracking that working memory played no role, or a

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

marginal one, in L1 Spanish speakers' capacity to anticipate verbal tense based on lexical stress.

Similarly, Otten and Van Berkum (2009) found no effect of working memory on L1 anticipation in an ERP study. It is difficult to interpret these results, as whereas the technique was the same in the eye-tracking studies, the domains under research cannot explain the differences. Sagarra and Casillas (2018) found none focusing on the role of prosodic cues, and Huettig and Mani (2016) found a working memory effect focusing on the role of morphosyntactic information, but Otten and Van Berkum (2009) found no effect either also focusing on the role of morphosyntactic information but using a different online method. It is possible that different levels of linguistic complexity interact with behavioral or brain activity performance, and only in certain cases the impact of differences in working memory capacities are visible in linguistic anticipation. However, the scant amount of research on the interaction between linguistic anticipation and working memory capacities forces to make interpretations of the findings so far with caution.

2.1.2.2. L2 speakers.

Anticipation in L2 speakers is controversial because different studies revealed different findings. Particularly in morphosyntactic anticipation, some studies find that L2 speakers can generate predictions (Dussias et al., 2013), while others have found they cannot (Hopp, 2016), or only in certain situations (Lew-Williams & Fernald, 2010) or specific levels of proficiency (Sagarra & Casillas, 2018). Two of the factors that could account for the variability in L2 anticipation performance and that often appear together are proficiency and cross-linguistic differences. Another factor that could explain the ability to predict in an L2 or not is whether morphosyntax is the cue, the outcome, or both. It is difficult to disentangle the influence of L1 transfer and L2 proficiency because they are often confounded variables in studies lacking language pairs with different L1s. Furthermore, the combination of L1 transfer and L2

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

proficiency can happen at different levels of linguistic processing, from the smaller parts like morphology to higher-order levels. At higher-order levels research is very scant. Grüter and Rohde (2013), Grüter, Rohde, and Schafer (2014) and Grüter et al. (2016) explored whether L1 speakers of Korean or Japanese could anticipate the correct oncoming syntactic structure in the discourse in L2 English based on coreference. While L2 speakers were sensitive to the cue, they did not use it to anticipate the structure of the syntactic event. At lower levels where phonology and morphosyntax are involved, there is some more research.

Anticipation of and based on morphosyntax in an L2 has been tested primarily with gender (e.g., Hopp, 2013). As opposed to L1 anticipation, however, morphosyntactic anticipation in the L2 is determined by the listener's proficiency in the L2 (Sagarra & Casillas, 2018) and their L1. The L1 linguistic system can both help (Dussias et al., 2013) and hinder (Dupoux et al., 2008) L2 processing. In L2 morphosyntactic anticipation, the gender in the determiner is a reliable cue to gender suffixes in nouns, although some restrictions apply. In L2 German, determiner gender is reliable if the L2 speaker uses the gender system target-like (Hopp, 2013, 2016). In L2 Spanish, predictions may be generated if the L1 also has a gender system (Dussias et al., 2013), or in case the L1 lacks a gender system, if the predictions are to be made on novel nouns (Grüter & Rohde, 2013), or if the nouns are highly frequent (Lew-Williams & Fernald, 2010). Other morphosyntactic elements such as number are not as reliable as cues (Marull, 2017), and for others, like case, the cue-outcome connection is directly not created (Hopp, 2015; Mitsugi & Macwhinney, 2016).

In morphosyntactic anticipation other factors might be at play, like L1 transfer and L2 proficiency. The workings of these factors start at lower levels of proficiency. Dussias et al. (2013) examined L1 Italian and L1 English learners of L2 Spanish's ability to use gender

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

agreement as an anticipation cue. L1 Italian speakers could make use of the gender cue partially to make agreement anticipations at lower levels of proficiency, whereas L1 English speakers could not. L1 English speakers can only start to use gender as a cue at high-intermediate levels, under frequency or novelty conditions of the noun (Grüter & Rohde, 2013; Lew-Williams & Fernald, 2010, respectively). Italian speakers were presumably transferring their gender agreement knowledge from the L1 to the L2 in order to make the correct predictions. English speakers, however, lack this knowledge in their L1 so no extrapolation was possible.

Additionally, it has been argued that lacking the representation of gender marking in the L1 might not only prevent prediction in an L2 based on that cue, but also hinder it (Hopp, 2016).

This proposal fits with Lew-Williams and Fernald (2010) findings that L1 English speakers at an intermediate level of proficiency cannot use gender marking to anticipate oncoming nouns in L2 Spanish, but they can use definiteness in articles to anticipate known nouns.

While gender has been the cue more widely researched, but shared forms, number and case have also been included in past investigations. Having a similar system in terms of form can be helpful. Liburd (2014) examined the abilities of beginning learners of L2 Dutch with English as L1 to use determiners with similar, different, and unique forms in English and Dutch to anticipate nouns. The eye-tracking data collected suggest that the English speakers were faster and more accurate in generating their predictions when the form was similar in their L1 and L2. Apart from gender, the influence of L2 proficiency is also visible in other cues such as number. Intermediate English speakers of L2 Spanish cannot use number to anticipate numbers suffix in a noun but advanced speakers can (Marull, 2017). In the case of case, the difficulty is never overcome, regardless of the L2 speaker's proficiency (Hopp, 2015). In Hopp's study, the L1 of the speakers was English. Like with gender, lacking a case system representation in the L1 might be

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

preventing, and even hindering, the creation of case cue-suffix outcome connection.

The conclusion that lack of L1 representation prevents L2 anticipation might only be applicable to morphosyntactic cases, or cases of lower proficiency, as it does not account for anticipatory behavior regarding phonology. Rehrig (2017) investigated whether L2 speakers could use suprasegmental information in a word stem like vowel lengthening to predict its suffix when their L1 lacked representation for those phenomena. They found that proficient L2 speakers did use the suprasegmental information, but learners at lower proficiencies did not. Similar studies focusing on tone have yielded similar results (e.g. Schremm, Söderström, Horne, & Roll, 2016; Berthelsen, Horne, Brännström, Shtyrov, & Roll, 2018).

When the acoustic correlate does have a representation in the L1 but it differs from the one typical in the L2, results become messier. On the one hand, Sagarra and Casillas (2018) found that L1 English speakers with advanced L2 Spanish could use lexical stress as a cue to anticipate verbal endings when the stress appeared in CVC syllables but not in CV syllables, and L2 Spanish beginners could not use stress to anticipate verb suffixes in either case. On the other hand, Dupoux et al. (2008) found that speakers of L1 French do not improve overtime in their discrimination of lexical stress in L2 Spanish, and hence cannot use it as an anticipatory cue. In contrast, Cantonese and Mandarin L1 speakers can learn to discriminate lexical stress in an L2 (Chen, 2013; Li, To, & Ng, 2017) and Korean L1 speakers do so to a certain extent (Hualde & Kim, 2015; Lee, Shin, & Garcia, 2019) even though neither of those languages require lexical stress encoding. Whether they can use lexical stress to anticipate other linguistic information has not been researched, although other suprasegmental cues such as tones (Hed, Schremm, Horne, & Roll, 2019; Schremm et al., 2016) suggest that L2 speakers can learn to use suprasegmental cues in an L2 to anticipate linguistic morphosyntactic information, even if this learned ability does not

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

reach L1-like performance (Perdomo & Kaan, 2019). Three models have been proposed as frameworks for phonological knowledge transfer.

The models that have been proposed to account for cross-linguistic phonological effects were designed particularly with phoneme production in mind. However, it is possible to extend some of their tenets to provide a framework with which to study transfer and comprehension of suprasegmental information. Here I am going to describe those tenets relevant for this investigation. The three models are the Speech Learning Model (SLM, Flege, 1995), the Perceptual Assimilation Model for L2 (PAM-L2, Best, 1995; Best & Tyler, 2007), and the Second Language Linguistic Perception (L2LP, Escudero, 2005, 2009; Van Leussen & Escudero, 2015). SLM focuses on ultimate attainment of L2 phonology and how age constraints target-like phonological success in an L2. In this model, a speaker can exploit the same mechanisms and processes they used in the acquisition of their L1 phonological system to acquire the L2 sound system. The language-specific characteristics of sounds are encoded in the long-term memory, and the encoding and different speech categories in the long-term memory evolve with L1 and L2 knowledge to reflect the realization of sounds on both languages. Lastly, bilinguals differentiate the co-existing L1 and L2 phonetic categories. From these postulates, Flege elaborated on seven hypotheses regarding phoneme categorization and production in the L2. Two of these hypotheses are relevant for this project. First, a L1 phonetic category can block the creation of a similar category in the L2 due to equivalent classification. Therefore, the L1 phonetic category will be used to perceive sounds in both the L1 and the L2. Second, the L2 phonetic categories may present different characteristics from what L1 phonetic categories of that language present for two reasons, either the speaker is trying to keep the L2 category “deflected” from a category in their L1 in the common phonological space, or the L2 category in a bilingual speaker is

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

characterized with different features or weights than the L1 category in a monolingual speaker.

PAM-L2 was originally proposed to account for L1 phonological acquisition, but it later morphosed to account for L2 phonological development. Like in SLM, age of the speaker determines L2 perception learning, as well as other social factors, such as length of residence in an L2 environment. Importantly for this project, L2 perception in this model is going to be constrained by nonnative speech perception principles, that is, how similar or different the new sounds are compared to an already established sound system. L2 sounds can thus be assimilated to a L1 category, assimilated as uncategorizable to an existing sound, or discarded for being considered non-speech sounds. The last model is L2LP. This is the only one among the three models that was thought out to explain and predict L2 sound perception phenomena. In L2LP, L2 sounds are perceived through the L1 filter, that is, how they would be perceived if they were pronounced in the speaker's L1. Therefore, the acoustic similarities and discrepancies between the two phonological systems will shape the development of the encoding in the bilingual's mind. In L2 sound acquisition, a copy of the L1 system is created during the initial stages, this copy starts to adjust with exposure via the Gradual Learning Algorithm, a comparison of the L1 system and the perceived L2 sounds. The algorithm offers three possibilities: 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 a new category for itself. Recent revisions to the model have further proposed that perceiving is not the same thing as recognizing, but there is still not enough research in this direction to formulate any hypothesis.

As a recap, the literature in L2 anticipation show that speakers can achieve some success in L2 anticipation depending on the cues and the context at more advanced levels of proficiency, but their performance will not be native-like (Grüter et al., 2016; Sagarra & Casillas, 2018). A

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

possible explanation for the varied results on L2 perception and anticipation might be found in

what speakers are transferring or extrapolating from their L1 that interacts with L2 new

structures, such as the use of lexical stress. 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 et al.,

2019), and the unclear distinction of variables (Schremm et al., 2016) call for further research

where the possible factors accounting for L2 anticipation patterns are better distinguished. To

address the limitation of confounding the L1 transfer and L2 proficiency variables, Sagarra and

Casillas (2018) carried out a study where the possible transfer would be the same for all

participants if there was any, and found that advanced learners of English could learn to use

lexical stress as anticipatory cue in L2 Spanish. In that same study, working memory did not

generally explain possible individual differences. The studies reviewed above point towards the

impact that cross-linguistic associations may have on the ability to process and anticipate

language in an L2. However, it is yet to be found out whether the ability to process in an L2 an

unencoded or differently encoded prosodic element in the L1 also enables its use for linguistic

anticipation. Additionally, it is yet to be found out whether speakers associate function

knowledge or acoustic knowledge from the L1 encoded representations, and how this association

interacts with models of phonetic transfer.

2.2. Working memory Working memory (WM) is the cognitive skill to store temporarily and process incoming information so complex cognitive actions are executed; WM is limited and

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

its capacity varies from person to person (Baddeley, 2007). WM is deployed in all interactions with the world. It affects both linguistic and non-linguistic processing, and the interaction between different types of processing. As of today, many models have been proposed explaining how WM works.

Three models stand out: Just and Carpenter (1992)'s domain-specific single-resource model, Baddeley (2007)'s domain-specific multiple-resource model, and domain-free connectionist models. In Just and Carpenter (1992)'s model, language learning and processing is constrained by the WM, and there is a trade-off between the ability to process and to store linguistic information. This trade-off happens as a result of a competition for a shared pool of cognitive resources that need to be divided amongst the different actions required. Therefore, when a task depletes or overtax the WM of a person, their storage capacity may diminish and their processing slows down. In Baddeley (2007)'s model linguistic performance is also constrained by WM, but the cognitive resources are organized differently. There is in this model a central executive that controls three subsystems: short-term storage phonological loop, short-term storage visuospatial sketchpad, and an episodic buffer. These three slave systems have independent limited capacities and are managed by the central executive. The two short-term memory systems focus on content, while the episodic buffer connects its sister systems with the long-term memory. The central executive coordinates the activity of the whole entity by filtering the information received, assembling information from different sources into meaningful episodes, regulating the flow of information among the subsystems, shifting tasks and shifting retrieval strategies. Lastly, connectionist models are domain-free as language capacities are determined by domain-general cognitive abilities. Specifically, by the ability to select which information to pay attention to and which information to inhibit, regardless of the nature of that information. In connectionist models

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

there is no difference between processing and storage. Instead, WM is the activation of part of the long-term memory according to short-term patterns of activations related to domain-specific stores (e.g., Cowan, 2016).

WM gets deployed in a variety contexts, be them visual or auditory. In the visuospatial domain, WM is used for object searches. A successful and efficient search relies on spatial memory accuracy, such that when the spatial memory is busy with something else, search efficiency diminishes (Woodman & Luck, 2004). When WM is totally invested in the search, a search for an object will be efficient even when the individual needs to remember a concurrent object at the same time (Woodman, Vogel, & Luck, 2001). In the case of several stimuli in the visual field, processing capacity is biased towards those stimuli matching current objects already in the WM (Desimone & Duncan, 1995), even when the cue in memory is held unconsciously (Pan, Lin, Zhao, & Soto, 2014).

WM also gets deployed in auditory or verbal modalities other than language. Previous research using a model like Baddeley (2007)'s suggests that children attending music classes score higher in phonological loop components tasks and central executive WM tasks than children who do not receive music training (Roden, Grube, Bongard, & Kreutz, 2014). In rhythmic synchronization, WM has been shown to be a reliable predictor of beat timing calculation in non-musicians (Colley et al., 2018a). More precisely, Miyake et al. (2004) defend that anticipatory synchronization may be influenced by WM in the interstimulus-onset interval of 1800-3600 ms (Miyake et al., 2004).

Cross-domain research indicates that processing abilities in different areas are associated, and that better WM in one domain can produce effects in another. These effects would be a consequence of the distinct domains sharing span capabilities, while short-term capabilities are

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

more unique to each domain (Kane et al., 2004). In contrast, span capabilities are more structurally diverse than short-term capabilities are. In music, for instance, visual signals such as gestures promote better temporal anticipation and synchronizaiton of both musicians and non-musicians (Colley et al., 2018b). Children undergoing music training improve their simple spatial spans, forward and backward digit spans, non-word spans, and operation spans; and adults improve their digit and non-word span skills (Lee, Lu, & Ko, 2007). Furthermore, the improvement in both visual and auditory WM in children and teenagers is not a matter of experiment training, but it is proportional to the time spent on music practice per week in real music education over long periods of time (Bergman Nutley, Darki, & Klingberg, 2014). The positive effect of music training on both the visual and the auditory domain also reflects on faster updating of WM and the re-allocation of neural resources to auditor stimuli (George & Coch, 2011).

Empirical evidence of an association between different auditory and visual domains with language is provided by research on bilinguals. Bilinguals of two languages with an alphabetic system like English and a logosyllabic system like Chinese have enhanced visuospatial WM than bilinguals of two alphabetic systems, like English and Spanish (Ma, 2016). Observing bilinguals in general, both visual and auditory memory maintenance and manipulation capacities, and bilingual experience interact especially at an L2 intermediate level, while at advanced levels the interaction goes back to a more monolingual-like state (Yang, 2017).

The changes in interaction might be due to the progress of the L2 acquisition. At intermediate L2 levels, L2 acquisition is in full progress. The L2 has been activated enough to recruit WM to compensate for the lack of linguistic experience, and thus WM is enhanced. At lower levels of proficiency, the brain has not had time yet to create a response to L2 input; and at higher levels,

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

linguistic experience is enough to process, understand and produce the L2, so the supplementation of WM is no longer needed.

In language alone, WM is one of the main factors that may be determining individual differences in linguistic performance both in the L1 (e.g. Gathercole & Baddeley, 1990) and the L2 (Huetting & Mani, 2016 found an effect; Otten & Van Berkum, 2009 did not), but how profound its impact is depends on whether the language is being acquired, processed, or anticipated.

Prior research on WM suggests that linguistic abilities in both the L1 and the L2 are importantly related to other non-linguistic abilities in language learning. For instance, Gathercole, Willis, Emslie, and Baddeley (1992) demonstrated how important non-word repetition abilities were in L1 learning in children; and Gathercole and Baddeley (1990) found that children with language disorders had lower WM that resulted in poorer performance in non-word repetition tasks in their L1. More generally, WM is essential in L1 comprehension regardless of the type of population to which the speaker belongs (Engle, 2002). These findings may as well be applied to L2 abilities: non-word repetition performance can predict L2 vocabulary and syntax acquisition success two years later in children (e.g. Cheung, 1996; Gathercole, Hitch, Martin, & others, 1997; Service, 1992). Some differences arise, though, when WM is too taxed or impaired and show symptoms only in learning an L2. For example, a person might have a phonological WM deficit and underperform only when learning words in a foreign language (Baddeley & Wilson, 1988), or when the cognitive load is too taxing, learning new words might be impeded only in foreign languages (Papagno, Valentine, & Baddeley, 1991).

WM may affect morphosyntactic L1 and L2 processing and anticipation as well as language acquisition. With regard to WM and L1 and L2 morphological and morphosyntactic processing, findings point towards different directions. In L1 morphological and morphosyntactic processing

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

there is not much room for WM effects. Tanner and Van Hell (2014) found no association between WM and a dominance of N400 or P600 in morphosyntactic violations in limited semantic context. Likewise, Ye and Zhou (2008) found by means of EEG no effect of WM on reanalysis of voice violations either when there was more linguistic context. These authors did find, however, that participants with lower control abilities, implausible sentences produced positivity between 350 and 750 ms while plausible sentences provoked nothing regardless of the syntactic complexity. Individuals with higher control abilities, on the contrary, showed different activity according to syntactic complexity: anterior negativity between 350-600 ms for active implausible sentences, and positivity between 350-850 ms for passive implausible sentences. In a similar vein, Pakulak and Neville (2010) found that WM had no effect on the processing of morphosyntactic violations in monolingual speakers of English with different socioeconomic status and level of education. Such findings suggest that individual differences in L1 processing are due to the contribution of other factors. WM has been indeed associated with L1 processing of semantic and syntactic information (Kim, Oines, & Miyake, 2018; Nakano, Saron, & Swaab, 2010), but any individual differences in morphological and morphosyntactic processing are conditioned but something else.

In L2 morphosyntactic processing, results are not as clear-cut. Some studies have found facilitating effects of WM on morphosyntactic processing (e.g., Nuria Sagarra, n.d.; 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 variability in L2 proficiency and the cognitive load imposed by the task and the WM test (Sagarra, 2017). For instance, speakers at a lower proficiency might be more susceptible to WM overload (Serafini & Sanz, 2016). Therefore, WM differences might play a larger role in L2 morphological and

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

morphosyntactic processing than they do in the L1. This role is likely to be also regulated by other factors, such as L1 transfer and L2 proficiency.

Moving on to anticipation, findings on L1 anticipation show that typical L1 speakers tend to perform predictive language processing. How individual variability in cognitive capacities, i.e. WM, can affect the efficacy of the predictions is still unclear. Huettig and Mani (2016) found through eye-tracking that the variance between participants in fixating on the correct target noun based on gendered article in Dutch could be accounted for through working memory. However, Sagarra and Casillas (2018) found also by means of eye-tracking that working memory played no role, or a marginal one, in L1 Spanish speakers' capacity to anticipate verbal tense based on lexical stress. Similarly, Otten and Van Berkum (2009) found no effect of working memory on L1 anticipation in an ERP study. These three studies researched the interaction of working memory and morphosyntax in different ways. In Huettig and Mani (2016)'s study morphosyntax was the cue to morphosyntax of a different word, and in Otten and Van Berkum (2009)'s study morphosyntax was the cue too but the outcome was a whole noun coming after some adjectives in between. In return, morphosyntax was the outcome in Sagarra and Casillas (2018)'s study, but the cue there was phonological, and both were part of the same word. It is possible that the distance between the cue and the outcome, or the combination of morphology with other linguistic domains interacts with working memory.

Regarding L2 anticipation, only Sagarra and Casillas (2018) has looked into the influence of verbal WM on prediction in an L2. Sagarra and Casillas (2018) studied anticipation of verbal tense morphosyntax when cued by lexical stress in L1 English learners of L2 Spanish, and found no effects, either in beginner or advanced learners. It is possible that WM differences, if they have any impact, only manifest in reduced contexts, such as morphology predicting morphology,

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

or when WM interacts with other factors, such as L1 transfer or lack of a representation in the L1.

To summarize, WM plays a role in language learning, processing, and anticipation, but the particular cases in which it exerts the influence, or the conditions that need to exist in order for the effects to be visible are unclear. While WM helps in predictive processing of morphology in the L1 (Huetting & Mani, 2016), when larger (Otten & Van Berkum, 2009) or smaller elements (Sagarra & Casillas, 2018) are involved, the influence is not so obvious. In the L2, WM effects fluctuate according to other factors like L2 proficiency (Serafini & Sanz, 2016), L1 transfer, or even anticipation abilities transferred from other related non-linguistic domains, such as rhythm, to account for predictive processing performance regarding morphology. However, this interaction has not been tested, so it is not possible to draw conclusions on why some studies report WM effects and not others.

2.3. Linguistic phenomena

2.3.1. Lexical stress.

Stress is the prominence of a syllable that speakers hear relative to the other syllables in the prosodic word (Hualde, 2005). The particular characteristics that define lexical stress, such as acoustic correlates or position within words, change drastically across languages. In English and Spanish, for example, lexical stress has no fixed position. Thus lexical stress is phonologically contrastive at the lexical level in both languages although to different degrees. That is, lexical stress can be used to distinguish between words, but the contrastive use is nevertheless much more typical in Spanish than in English. In English it is used predominantly to distinguish heteronyms or pairs of verbs-nouns that have no segmental differences. For instance, to “PROduce,” verb vs. “proDUCE,” noun. In Spanish, lexical stress differentiates all kinds of words and information, such as verbal tense and person (*CANto* ‘I sing’ vs. *canTÓ* ‘s/he sang’),

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

or nouns (*Papa* ‘potato’ vs. *paPÁ* ‘dad’), or nouns from verbs (*TÉRmino* ‘term’ vs. *terMIno* ‘I finish’ vs. *termiNÓ* ‘s/he finished’).

The acoustic realization of lexical stress is caused by different acoustic correlates depending on the language. Stress is the combined result of many parameters in action, among which we can find F0 variations, duration, overall intensity, and vowel formant frequencies (Gordon & Roettger, 2017), and the different importances or weights assigned to each of these correlates cause the nature of stressed syllables in each language to vary. In Spanish, the most reliable cues to 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; regarding intensity, stressed syllables are louder; and lastly, stressed syllables are usually slightly longer. In contrast, the main cues in English are vowel duration and quality (Cooper, Cutler, & Wales, 2002; Cutler, 1986), although other cues such as intensity and pitch (F0) (Beckman, 1986; Fry, 1955, 1958, 1965; Sluijter & Van Heuven, 1996; Sluijter, Van Heuven, & Pacilly, 1997) play minor roles. Thus, unstressed vowels are reduced to [ə].

The different weight assigned to each cue in these languages may explain why L1 English speakers encounter difficulties in Spanish lexical stress perception (Face, 2006; Ortega-Llebaria, Gu, & Fan, 2013) and production (Lord, 2007). The different cue weights are also related to the prosodic structure of the language. Vowel reduction is linked to the rhythmic pattern of stressed-timed languages, like English, where the intervals between stressed syllables have similar durations. Spanish, on the contrary, is defined sometimes a syllable-timed language, as syllable duration is quite stable, and thus vowel trajectory length is approximately the same for all syllables regardless of their tonicity (Colantoni, Steele, Escudero, & Neyra, 2015; Hualde, 2005). In English, the stressed syllable signals a rhythmic unit that can be composed of multiple sub-

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

units until the next stressed syllable and thus rhythmic unit arrives; while in Spanish, stress is simply part of a syllable, and each syllable is a new rhythmic unit.

The different weights assigned to each cue in different languages interact with lexical stress processing particular to each language. As mentioned above, lexical stress helps 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 decision making times, when compared to mismatching cues (*PRINci* > *prinCIpio* ‘start’). These results are taken to suggest that participants in Soto-Faraco et al. (2001) study were anticipating the lexical element based on suprasegmental cues such as lexical stress. Contrarily, it is unclear whether L1 English speakers are able to use stress alone as a cue to anticipate and facilitate lexical activation. On the one hand, Cooper et al. (2002) tested L1 English speakers in a similar study to that of Soto-Faraco et al. (2001) and found that the English natives were only able to use the suprasegmental cues when more than one syllable of the word was present. On the other hand, Perdomo and Kaan (2019) did find in an eye-tracking study that the presence of lexical stress elicited fixations on the oncoming target noun. It is possible that the L1 English speakers were using the relative low emphasis in previous syllables to activate the cue role for lexical stress in the syllables that were perceptually more prominent; similarly to what the L1 Spanish might have done, as the target words came at the end of a context sentence. This difference in performance amongst studies is probably due to what cues speakers use to discriminate lexical stress, and how these cues are instantiated in the language. That is, English L1 speakers may be placing a larger reliance on duration to process Spanish lexical stress. This reliance would be transferred from L1 English processing. 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 used to resorting to

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

them, and that are more prominent in the language as compared to the one English L1 speakers are using (Ortega-Llebaria et al., 2013).

The differences and similarities in cue weighting can no doubt 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. But, in contrast, German speakers have more difficulty perceiving stress in another free lexically stressed language such as Spanish than L1 speakers (Schwab & Dellwo, 2016); again, maybe due to the acoustic correlates they use to discriminate the suprasegmental. Following this line, 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.

The studies above suggest that the acoustic properties of prosody are essential in processing and activating language. The importance speakers assign to each cue might extend beyond perception and affects anticipation as well. Studies like the one by Vickie and Andruski (2010) further suggest that speakers can resort to their prosodic abilities in the L1 in order to process other prosodic structures in their L2 absent in their L1, such that Chinese speakers can use pitch knowledge to discriminate lexical stress in Spanish. Extending this hypothesis, L2 speakers might be able to extrapolate acoustic knowledge and reassemble it into new prosodic structures that are encoded in the L2 lexicon and use it as cues for linguistic anticipation. Specifically, tonal language speakers might be able to transfer pitch knowledge to an L2 to encode lexical stress based primarily on pitch along with the word to which it belongs. After lexical stress has been encoded in the L2 lexicon thanks to L1 pitch knowledge, L2 speakers might learn to use this new prosodic structure as the basis for L2 prediction so as to reduce the processing cognitive load.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

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., Mandarin Chinese), whereas others also use length and/or register (e.g., Cantonese Chinese). Relevant to my dissertation with Mandarin Chinese speakers, in most Mandarin Chinese dialects (e.g., from Beijing and Tianjin), the main acoustic correlate for tones is changes in pitch (F0) contour or changes in pitch height within a syllable (Gandour & Fromkin, 1978; Zhu & Wang, 2015). Importantly, tones in Mandarin Chinese do not cause shorter and longer syllables. Therefore, Mandarin is described as a syllable-timed language in terms of rhythm (Grabe & Low, 2002; Lin & Wang, 2007; Mok, 2009), just like Spanish.

In Mandarin, tones facilitate word recognition (Malins & Joanisse, 2010). They are nevertheless not the most important factor in that process, as vowel especially but also consonant identity comes first (Hu, Gao, Ma, & Yao, 2012). In other words, while tones confirm that the correct word is activated, the main vehicle to access a lexicon entry in Mandarin are other cues, mainly segmental cues. Wiener and Turnbull (2016) investigated the degree to which segmental (vocalic and consonantal phonemes) and suprasegmental cues (tones) constrained lexical access in Mandarin Chinese. L1 Mandarin speakers were presented different types of stimuli containing different types of violations (tonotactic, phonactic) and had to decide as fast as possible if what they were hearing was a real word or not. Words with tonotactic violations were more often endorsed as real words than other types of violations, such as vowel or consonant change. These results led the authors to conclude that tone information is not as important as consonant and especially vowel information in lexical access. Hu et al. (2012) reached a similar conclusion in a

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

ERP study. Hu et al. (2012) studied the relevance of tone and vowel information at different

stages of lexical access, for which they selected fixed Chinese idioms and isolated words as

context. Vowel mismatches evoked earlier (N1 effect) than tone mismatches (N400). The N1

effect was taken to suggest that vowel was playing a role on word selection, while the N400

effect signals a failure of the integration of the word in the sentential context. Sereno and Lee

(2015) obtained similar results in two priming experiments in Mandarin. Participants were slower

in discriminating words where the only difference was tonal. Primings where both vowel and

tone matched were the fastest one, followed by primings where only vowel matched. The three

studies led to the conclusion that the functions of vowels and tones in Mandarin are distinct.

Namely, that vowel plays a major role in activation, while the role of tone is integration in the

higher context.

The knowledge of the nature and function of tones in the L1 can affect L2 tone learning

positively by providing a background knowledge to which learners can resort to acquire the L2

tones. However, L1 tone knowledge can also affect L2 tone learning negatively when the

association with the L1 tone knowledge interferes with the nature of the L2 tones. 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 association with L1 tones disagreed from the L2 tone structure and

interfered with it.

Although it seems the role of tones is not as pre-eminent of lexical stress in Spanish, it still helps

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

in word activation and must be encoded in the lexicon. Mandarin speakers need to pay attention to the pitch variations in order to assign the correct tone to the word they are hearing. Since pitch variations are the basis for lexical stress in Spanish, Mandarin speakers might be able to extrapolate their sensitivity to pitch changes to process and use pitch to anticipate linguistic information more easily than English speakers. In English lexical stress, pitch variation is not as important as an acoustic correlate so the information it contains in an L2 is mostly overlooked by L1 English speakers. For L1 English speakers, learning to distinguish the pitch variations may be more difficult than simply extrapolating the sensitivity, and thus Mandarin speakers may outperform English speakers in using lexical stress to anticipate verbal tense in L2 Spanish. Lexical stress and tones are different prosodic structures with functions that may differ or not across languages. Lexical stress can be used contrastively at the lexical level, like in English, or it might not, like in French. Likewise, tones can also be contrastive, like in Mandarin. They are different prosodic structures, and lacking a representation in the L1 can hamper their acquisition in an L2. They can share, however, their acoustic correlates to some extent. Both structures make use of correlates like pitch or vowel quality to perform their function. Extrapolating this knowledge can be helpful in processing sounds in a different language. But how effective and helpful this knowledge extrapolation is might depend on the interplay of other factors, such as working memory, L2 proficiency, or other auditory abilities.

3. Research questions and hypotheses

The relationship between language and other cognitive capabilities in humans is still unclear. In language processing, connectionist accounts argue that processing is dependent on a larger domain-general cognitive structure. And in a predictive processing view of language,

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

anticipation is essential to language processing and comprehension (e.g., Wicha, Bates, Moreno, & Kutas, 2003; Van Berkum, Brown, Zwitterlood, Kooijman, & Hagoort, 2005). Whether and how the ability to generate linguistic predictions relates to other cognitive faculties is unknown. In order to make accurate linguistic predictions, a listener needs to recreate a faithful representation of the linguistic and non-linguistic context in which they are receiving the message. It is reasonable therefore to call linguistic and non-linguistic executive functions into work to take into account all contextual information during language processing (see Ryskin et al., 2020 for a review).

A domain-general mechanism for linguistic predictive processing is reasonable, as humans can also generate non-linguistic predictions (e.g., while driving, Morando et al., 2016; Stahl et al., 2016; or while playing sports, Nakamoto & Mori, 2012; Wright et al., 2010). In addition, other animals (Alcaro & Panksepp, 2011), birds (Wilson & Lindstrom, 2011) and even plants (Appel & Cocroft, 2014) also have the ability to generate (non-linguistic) predictions. There is no research on how the linguistic and non-linguistic anticipatory abilities in humans relate, but there is evidence that different processing domains are related in certain cases.

Two domains have been related to language: auditory and visuospatial. Pitch knowledge in music, for instance, has been associated with better performance in L2 tone perception when the L1 did not have tone representation (Tang et al., 2016). Non-musician L1 tonal speakers perform better in absolute pitch discrimination tasks than their peers from non-tonal L1 languages (Bidelman et al., 2013). Rhythm performance has also been linked to speech perception and production, in particular as far as L2 lexical stress is concerned (Cason et al., 2019). Regarding visuospatial abilities, there is a positive link between the visuospatial domain and reading abilities in languages with orthographic depth. In addition, representation of space affects L1

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION processing in atypical populations (Landau & Hoffman, 2005).

In case anticipatory abilities from different linguistic and non-linguistic domains are associated, it is possible that this association is conditioned by other factors. These factors can be general and apply to all cognition, such as WM, or be more specific and apply only to language, like L1 transfer and L2 proficiency. I conducted a series of studies with L2 speakers of Spanish who speak Mandarin or English as their L1 and compared their performance in several anticipatory and WM tasks with the performance of a monolingual group of Spanish speakers to delve into the possible relationship between linguistic and non-linguistic domains. These studies further explored how other situational factors mediate the cross-domain effects. Participants completed a visual-world paradigm that measured the participants' ability to generate morphosyntactic predictions based on lexical stress, a rhythm anticipation task, a melodic anticipation task based on pitch changes, a visuospatial anticipation task, a verbal WM task, and a visuospatial WM task. Following the above rationale, the overarching questions for the project are:

Study 1

RQ1. 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?

H1. In line with previous similar research, 1) monolingual speakers of Spanish will encounter no difficulty in using stressed and unstressed syllables as cues to verb suffixes, (Lozano-Argüelles et al., 2019; Sagarra & Casillas, 2018), and 2) WM will not be responsible for individual variability among L1 Spanish speakers (Otten & Van Berkum, 2009; Sagarra & Casillas, 2018). Regarding L2 speakers As for L2 speakers and L1 transfer, L1 Mandarin

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

speakers are expected to extrapolate their knowledge on pitch successfully to make use of lexical stress as a prediction cue (Li & Grigos, 2018). L1 English speakers are expected to extrapolate their knowledge on lexical stress contrastive function to make use of lexical stress in Spanish as an anticipatory cue (Lozano-Argüelles et al., 2019; Sagarra & Casillas, 2018). Regarding L2 proficiency, both groups are expected to be able to use lexical stress as a cue only at advanced levels of proficiency. Finally, an increased verbal WM is expected to affect extrapolation efficiency positively (Huettig & Mani, 2016) and to bring the start of the effects of cross-linguistic association forward in the L2 acquisition process.

Study 2

RQ2. Is linguistic prediction of word morphology associated with auditory prediction in Spanish monolinguals, and intermediate and advanced Chinese and English learners of Spanish? If so, how do WM, L1 transfer and L2 proficiency mediate this relationship?

H2. *Pitch* In monolingual speakers, no effects of better pitch anticipation are expected to have an effect on individual variability of morphosyntactic anticipation based on lexical stress, as all participants are non-musicians and come from a similar linguistic background. WM is only expected to have an effect on non-linguistic auditory prediction abilities (Roden et al., 2014). In L2 speakers, Mandarin L1 speakers are expected to anticipate melodic information faster than any of the other populations since they will be extrapolating their pitch knowledge from language to music. However, the performance in anticipating melodic information will not be correlated with their L2 anticipation performance. That is, the influence will be unidirectional from language to music. No association between pitch and speech prediction abilities in the English learners groups. L2 proficiency and pitch anticipatory abilities are not expected to be correlated,

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

as facilitative processing of L2 speech by pitch has only been confirmed with musicians (Slevc & Miyake, 2006). All auditory anticipation scores will be positively correlated with verbal WM scores in the L2 speakers (Yang, 2017).

Rhythm Contrary to pitch, better rhythm anticipation abilities are expected to be associated with individual variability of speech anticipation in monolingual speakers of Spanish. This result would stem from on-beat timings facilitating L1 speech processing (Cason & Schön, 2012), so individuals with better rhythm synchronization abilities would be resorting to their rhythmic abilities to anticipate speech based on prosody more efficiently. Like with pitch, WM is only expected to have an effect on non-linguistic auditory prediction abilities (Colley et al., 2018a). Contrarily, rhythmic anticipation abilities are expected to be positively correlated with L2 anticipation performance, as rhythmic abilities are a reliable predictor of lexical stress placement (Cason et al., 2019), and therefore of lexical stress comprehension. This influence will be visible at all levels of proficiency and regardless of the L1. That is, better rhythmic abilities will translate into better anticipation performance based on lexical stress when compared to peers around the same proficiency range in both L1s. Like before, L2 proficiency and rhythm anticipatory abilities are not expected to be correlated, because while better rhythm promotes correct L2 perception and production (Cason et al., 2019), anticipation adds another layer of processing difficulty that has been proven to be too complex in the L2 (e.g., Hopp, 2015; Mitsugi & Macwhinney, 2016). All auditory anticipation scores will be positively correlated with verbal WM scores in the L2 speakers (Roden et al., 2014).

Study 3

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

RQ3. Is linguistic prediction of word morphology associated with visuospatial prediction in Spanish monolinguals, and intermediate and advanced Chinese and English learners of Spanish? If so, how do WM, L1 transfer and L2 proficiency mediate this relationship?

H3. Language prediction abilities in the L1 are not expected to be associated with the visuospatial domain. I am comparing two different modalities: auditory (speech) and visuospatial. While there is a relationship between space representation word processing in reading (Katz & Frost, 1992; Schmalz et al., 2015), I hypothesize that speech and space representation are cognitively too far apart to influence each other. Verbal WM will not be associated with speech anticipation performance, but it might be associated with visuospatial WM due to cross-domain influence (Colley et al., 2018b). Visuospatial WM performance will in return be associated with visuospatial anticipation, as visual performance is generally more clearly associated with WM (e.g., Pan et al., 2014; Woodman & Luck, 2004). No association between anticipation in the visuospatial domain and the speech domain is expected to be found in L2 speakers either, for the same reasons. Therefore, it does not matter what the L1 or the L2 is, or the proficiency in the L2, increased abilities to anticipate movements in space through vision will not be associated with speech in any way. Verbal WM will not be associated with speech anticipation performance (Sagarra & Casillas, 2018). Visuospatial WM performance will be associated with visuospatial anticipation, and with verbal WM (Ma, 2016), at least in intermediate L2 speakers (Yang, 2017).

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

4. Methods**4.1. Participants**

Participants proceeded from five different pools: 30 monolinguals speakers of Spanish (MON, females = 20), 30 L2 Spanish intermediate with L1 English (IEN, females = 14), 30 L2 Spanish advanced with L1 English (AEN, females = 16), 30 L2 Spanish intermediate with L1 Mandarin (IMA, females = 13), and 30 L2 Spanish advanced with L1 Mandarin (AMA, females = 20). All participants grew up in monolingual regions and houses. Participants of the five groups were aged 18-45 (MON: mean = 26.2, $SD = 8.82$; IEN: mean = 24.9, $SD = 3.75$; AEN: mean = 26.3, $SD = 4.64$; IMA: mean = 24.1, $SD = 3.97$; AMA: mean = 24.8, $SD = 4.72$). Participants were all right-handed. Additionally, speakers were homogenized for verbal WM. Participants had normal to corrected-to-normal hearing and vision and no motor disability. All data were collected in Spain, to avoid possible biases of context in comparing the L2 speakers (Beatty-Martínez et al., 2019).

The monolingual speakers were native to a Peninsular variety of Spanish and did not speak any other language fluently. They might have traveled abroad, but not stayed for a long period of time. They all had completed at least high school.

The Mandarin speakers came from Mandarin-speaking regions in China. In some of these regions, dialects might be spoken, but the differences consist mainly of lexical choices. Some of the Chinese speakers also spoke English, but at a maximum of intermediate proficiency. They had never received bilingual English-Mandarin education, or lived in an English-speaking country. IMA had resided in Spain for 6 months to 11 years, and AMA for 2 months 16 years. The English natives came from English-speaking countries. The L2 speakers were matched through DELE (see section 4.3.1.) in terms of proficiency across levels and they were all late

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

learners of Spanish. That is, all L2 participants had started learning Spanish after 12 years of age (IEN: mean = 22.3, $SD = 4.32$; AEN: mean = 19.9, $SD = 2.91$; IMA: mean = 21.6, $SD = 4.31$; AMA: mean = 20.6, $SD = 3.40$). On average, all L2 groups used Spanish less than 50% of the time on a normal week (self-reported; in percents, IEN: mean = 31.1, $SD = 18.7$; AEN: mean = 37.2, $SD = 14.5$; IMA: mean = 47.4, $SD = 19.8$; AMA: mean = 47.2, $SD = 22.6$). All L2 participants had also completed studies up to high school at least. Participants were only allowed to take part in the studies if they had lived in Spain or any other speaking country for at least 2 months. None of the L2 participants had lived in non-monolingual communities in Spain, or in non-Spanish speaking countries. The residing time in Spain range for IEN was 3 months to 5 years and a half, and for AEN 7 months to 10 years.

4.2. Visual-world paradigm methodology

Visual-world paradigm is an eye-tracking technique in which a target word or image is projected on a screen accompanied by distractors (Cooper, 1974). Usually, participants hear some audio at the same time related to the target. At the same time participants hear the audio track, their eye-movement patterns between the target and the distractors are recorded. These recordings can be set up to include information such as gaze fixations, saccades, blinks, or pupil dilation. There are many other eye-tracking techniques employed for other types of research such as examining reading patterns (e.g. Carpenter & Just, 1977; Child, Oakhill, & Garnham, 2020). All eye-tracking techniques are based on the idea that we bring our attention to a specific area in our visual field by fixating our gaze —i.e. pupil— there. It is possible to use these movements to know how and when each piece of information is processed (Duchowski, 2007). This link between information processing and eye-movements happens because the non-linguistic context mediates language recognition and processing (Tanenhaus, Spivey-Knowlton, Eberhard, &

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Sedivy, 1995), and this search for connection between language and environment becomes

apparent through eye-movements. One of the advantages of eye-tracking is that it is an online method, by which we can see almost real-time how information is processed (Altmann & Kamide, 2007; Huettig, Rommers, & Meyer, 2011; Salverda et al., 2014). This characteristic offers an alternative to offline methods that provide only deliberate responses that show nothing of how information is processed and used to anticipate future information even if speakers are not required to do anything else, like press a button or answer a comprehension question.

Although visual-world paradigm has some limitations (unnecessary priming, Ito, 2016; unnatural priming, Huettig & Mani, 2016), its convenience has made it a fairly popular technique in anticipation studies with different linguistic structures: phonetic (Salverda et al., 2014), phonological (Allopenna, Magnuson, & Tanenhaus, 1998), morphosyntactic (Huettig & Mani, 2016; Lew-Williams & Fernald, 2010), syntactic (Pozzan et al., 2016; Staub & Clifton Jr, 2006), semantic (Altmann & Kamide, 1999; Dijkgraaf, Hartsuiker, & Duyck, 2017), and even in structures that reveal world biases (Kamide et al., 2003). This technique has been used to research both L1 anticipation (e.g., Altmann & Kamide, 2007) and L2 anticipation (e.g., Sagarra & Casillas, 2018).

In the current project, the linguistic anticipation task consisted of a visual-world paradigm in Spanish that measured L1 and L2 speakers of Spanish's ability to anticipate morphosyntactic information (i.e. verbal tense) based on suprasegmental prosodic cues (i.e. lexical stress) with fine detail regarding time effects. The options among which participants chose were two written verbs. I used words instead of images to avoid possible confusion caused by abstractness in drawings (Huettig & McQueen, 2007) or the need to anticipate too much visual context

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

information. In order to minimize excessive priming (Huettig & Mani, 2016), the target word and the distractor were previewed only for one second.

4.3. Materials

Participants completed a series of tasks that allowed to filter them in or out of the studies, to measure their linguistic anticipation abilities (visual-world paradigm), their auditory anticipation abilities in melodies, i.e. pitch, and rhythm, their visuospatial anticipation abilities, their visuospatial WM, and verbal WM.

4.3.1. Screening tasks.

The first screening task was a proficiency test. 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. The L2 participants were split into two groups for data collection according to their scores in the test. Participants whose scores ranged from 25 to 39 were assigned to the intermediate groups, and participants whose scores were located at or above 40 were assigned to the advanced groups. Only participants scoring within those two ranges were accepted for the study.

Once in the data collection session, participants were interviewed and completed a language background questionnaire, to make sure that they qualified for the study. The background questionnaire 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 have lived in Spanish-speaking countries, how much they use each language per week at the time of data collection, other languages they speak fluently, what musical, sport and

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

driving abilities they have. Finally, participants also completed a vocabulary test with some of the words from the linguistic anticipation task. This test had 17 screen with 8 words each, and participants had to select the best equivalent in their L1 for the words provided. One of the options provided was “??”, meaning “I do not know the word.”

4.3.2. Linguistic anticipation task (Visual-world paradigm).

An eye-tracking visual-world paradigm task assessed the ability to form stress-suffix predictive associations. The eye movements while hearing the sentences 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). The monitor used to show the target verbs was a BenQ XL2420TE at a resolution of 1920 x 1080 pixels. The rest of the tasks were administered in PsychoPy v3.2. In all tasks, the instructions were given both orally and in written. The written instructions were in the participant’s L1. 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’). Their task consisted of selecting the verb they had heard as fast as possible by pressing the right- or left-shift key. When they made their selection, a green rectangle appeared around the selected verb. There were 4 practice sentences, 16 experimental sentences, and 80 fillers.

Visual stimuli The words that appeared on the screen were presented as images created with PhotoScape X version 3.0.3., set with Helvetica font and the size 300. The size of each image was set at 1920 x 1080 pixels. The background was white and the color of the letters black. The position of the words on each side of the screen was counterbalanced. In the case of the experimental words, this means that half of the present verbs appeared on the right, and the other half on the left. Counterbalancing changed from participant to participant so a given target would

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION not always appear on the same side.

There were three types of filler words. The first type were nouns for anaphora resolution (*papel* ‘sheet of paper’ vs. *plano* ‘map’). These nouns referred to one of two professions mentioned previously in the sentences that contained them. The nouns were composed of 2, 3 or 4 syllables. The pairs of nouns had always the same length. The second type were adjectives for gender agreement (*nuevo* ‘new_[MASC]’ vs. *nueva* ‘new_[FEM]’). These adjectives were always shown in singular and referred to a noun mentioned previously in the sentences that contained them. The two possibilities shown for each trial were the same adjective with the different gender morphology. The noun the adjectives were modifying could be either transparent or opaque in its gender morphology. The noun was combined with definite articles (*el* ‘the_[MASC]’, *la* ‘the_[FEM]’) that gave away the gender needed, or with the possessive article *su* ‘his/her’ that hides the gender cue. The adjectives were composed of 2 or 3 syllables. The third type was a variety of nouns and adjectives that completed idiomatic expressions. The category selected was called for according to the specific idiom. Categories were not mixed within trials. The possible words completing the idioms had from 2 to 4 syllables in length. The pairs of words had always the same number of syllables. One of the words is the typical word in the idiom, and the other word rendered the string of words possible and meaningful but non-idiomatic. The experimental words consisted of 32 pairs of verbs corresponding to the 32 experimental sentences. The experimental verbs were regular, had two syllables, had a CVC initial syllable, all belonged to the -ar conjugation, and were conjugated in the 3rd person present and preterit tense. As a reminder, Spanish regular verbs have 2 cues to tense: initial syllable stress and word ending morphology. Regarding stress, stressed initial syllables indicate that the tense is present (*salta* ‘s/he jumps’), and unstressed

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

initial syllables indicate that the tense is past (preterit, *saltó* ‘s/he jumped’). Regarding morphology, the verb suffix indicates tense, person and aspect.

Auditory stimuli The sentences were recorded three times spoken by a female native speaker of a Peninsular Spanish variety similar to that spoken in the region of data collection. For the recording, sentence order was pseudorandomized three times, so there were three recordings of each sentence. Sentences belonging to different conditions for one item were always read one after the other. The first recording was discarded, and the version included in the task was selected between the remaining two recordings. The recordings were done in a professional sound-attenuated booth with a Shure SM58 microphone and a Marantz Solid State Recorder PMD670 at 16 bits, 44.1 kHz, and an intensity of ~75 dB.

The oral sentences were between 5 and 13 words long. The sentences were distributed into blocks by means of a Latin square design. There were 8 blocks. Each block contained only one sentence of each type, so each block contained 2 experimental sentences and 6 filler sentences, two of each type. 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.

There were three types of filler sentences: 32 sentences contained anaphora resolution (*Mientras el secretario interrumpe al arquitecto, está guardando un papel en el armario* ‘While the clerk interrupts the architect, he is putting a sheet of paper away in the cabinet’), 32 sentences contained gender agreement of adjectives based on determiner and noun (*Dice que su colegio nuevo cuesta mucho dinero* ‘He says that his new school is very costly’), and 16 contained idiomatic expressions (*La niña no cambia por nada del mundo su muñeca* ‘The little girl does not change her doll for anything in the world’).

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

The experimental sentences (*El ladrón saltó la valla* ‘The thief jumped over the fence’) had all identical syntactic structure and length (exactly 5 words). The verb was only preceded by an NP (the subject) to avoid possible biases towards the present or the preterit verb. The object following the verb was also a NP. Half of the experimental sentences contained a present verb and the other half a preterit verb, but a given participant was only exposed to one of the two conditions for a given sentence (e.g., for sentence number 30, a given participant was only exposed to condition 1 and another to condition 2). In total, each participant was exposed to 16 experimental sentences (half with present verbs and half with preterit verbs). There were four practice sentences, one of each type of sentence included in the task.

4.3.3. Non-linguistic anticipation tasks.

4.3.3.1. Auditory anticipation tasks.

Pitch anticipation task

A pitch task measured participants’ ability to predict melodic information based on previously occurring associated pitch changes. This task was inspired by the melody discrimination tasks typically used in music research. This task was divided into a familiarization phase and a testing phase. In the familiarization phase participants listened to the melodies with which they were going to work in the task. They heard each melody twice and at the same time saw an arrow indicating in which direction the pitch in the melody changed. In the experimental phase, participants saw two arrows on the screen side by side, one pointing upwards and the other pointing downwards. At the same time they heard a melody that changed pitch direction after the third tone. Their task consisted of selecting the arrow that matched the pitch change direction as fast as possible by pressing the right- or left-shift key associated with the corresponding arrow. When they made their selection, the arrow selected turned blue. Two practice melodies were used as practice items, and 6 melodies were played as experimental items. The practice items were

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

repeated twice each, and the experimental melodies were repeated 8 times each. The order of appearance of the melodies was pseudorandomized, so the same melody would not play twice in a row. After the first two practice melodies feedback was provided for accuracy of response. The second time the practice melodies played no feedback was provided. No feedback was provided either during the experimental phase. The melodies were created in pairs, such that each pair started the same, but the fourth note differed. The experimental melodies were played at a tempo of 60 bpm in a scale of A4. The melodies were pairs, such that two melodies started the same and would differ after the third tone. One of the melodies grew higher in pitch, while the other melody grew lower. A higher note than the base always signaled a following still higher note, while a lower note always signaled a following even lower note. The first changing tone in each melody was meant to act as a cue for participants to make their choice on whether the fifth note would be higher or lower. After the variation in pitch, the melody remained at that newly reached level so as not to confuse participants on which change to judge. The experimental melody pairs were therefore 1) G#-G#-G#-B-C-C and G#-G#-G#-F-E, 2) C-C-C-C#-E-E and C-C-C-C#-E-E, and 3) E-E-E-F-F#-F# and E-E-E-D#-D. The practice melody pair was A-A-A-B-C-C and A-A-A-G-F#-F#. The test was built and run on PsychoPy v3.2. The melodies were created with BeepBox 3.0.8 (<http://www.beebox.co>) and saved as mp3.

Rhythmic anticipation task

A rhythm tapping task adapted from Pagliarini (2016) assessed the participants' abilities to adapt to a rhythm and thus predict when changes were coming. This task was divided into a familiarization phase and a testing phase for each rhythm. The testing phase of each rhythm consisted of 10 trials of the same rhythm, with no pauses in between. Participants heard the rhythms and one of the beats cue them to press a key on the start of the following beat. When

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

they pressed the key, a green dot appeared at the center of the screen. Otherwise, the screen was blank. No other feedback was provided at any time. The familiarization phase had the same length as one trial of the testing phase (~5-6 s). In the familiarization phase participants simply listened to the rhythm. There were 2 practice rhythms and 4 experimental rhythms. Each trial in all rhythms consisted of 8 beats. Of these 8 beats, six were context, one was the cue or imperative beat and the remaining one the tap-along beat. These two last beats always appeared together in a random position in the sequence except in the first and last positions. The tones were always pure tones. The base tones had a frequency of 440 Hz, and the imperative beat was added a harmonic to make it distinguishable, so its frequency was 880 Hz. All rhythms were at a reference tempo of 80 bpm.

The first practice rhythm contained eight homogeneous beats of 250 ms at 650 ms onset-to-onset intervals. The second practice rhythm contained 8 beats of 200 ms each. The onset-to-onset intervals alternated between 400 and 800 ms, resembling the heart beat. In the experimental phase, the first beat rhythm sequence contained a total of eight beats at 750 ms onset-to-onset intervals. Each beat lasted 200 ms. The second beat rhythm also contained eight beats at 750 ms onset-to-onset intervals. Four of the beats were strong and the other four were weak. They always appeared in the sequence strong-weak-strong-weak. The intensity of the weak tones was half of the intensity of the strong tones, and the strong tones lasted 200 ms and the weak ones 100 ms. The third beat rhythm contained four strong and four weak beats in the order strong-weak-strong-weak. The strong tones lasted for 200 ms and the weak ones for 100 ms. Between a strong and a weak beats the onset-to-onset interval was 990 ms, and between the weak and the strong beats, the onset-to-onset intervals was 510 ms. The last beat rhythm contained equal tones of 200 ms duration, but the onset-to-onset intervals were $750 \text{ ms} \pm$ a random error of 30% of a duration of

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

750 ms. This sequence was unpredictable and served as base condition. There were two extra beat rhythms that served as practice sequences. The task was created and administered on PsychoPy v3.2.

4.3.3.2. Visuospatial anticipation task.

An adapted version of the ZBA task (*Zeit- und Bewegungsantizipation* “Time and Movement Anticipation,” Schuhfried Wiener Testsystem; System, 2013) was used to measure visual-spatial predictive associations. In this task, a car on the screen moved from left to right or right to left at three different speeds: low (3.342 cm/s), medium (5.160 cm/s), and fast (7.087 cm/s). The car then disappeared behind a mountain. The participants had to calculate according to the size of the mountain and the speed of the car when the car should reappear from the other side of the mountain, marked with a checkered flag. When they thought the car should reappear, participants were to press a key. There were 8 trials for each speed and direction, therefore 48 experimental trials. There were four additional trials serving as practice. The speed in those trials was set at either 4 cm/s or 6 cm/s. The car would move in an opposite direction in each of the two trials for each speed. When participants pressed the key signaling the car should reappear, the car appeared on the screen at the spot where it was at that moment. By showing the position at that time point, participants received feedback on their tally. In the next practice trials and the experimental trials, participants did not see the car’s position upon pressing the key. The trial ended automatically upon the key press and the following trial started. If participants waited for long enough that the car would “leave” the screen, the trial finished automatically and the next trial started.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

4.3.4. Working memory tasks.

4.3.4.1. Operation Span task (verbal WM).

An adapted version of Unsworth et al.'s (2005) Operation Span task (henceforth, OSpan) was used to assess verbal WM span. This task generates independent measures of storage and processing speed. In a single trial, participants heard a word and heard a simple mathematical problem that could be either true or false (e.g., $2 + 2 = 4$). At the same time they heard the mathematical problem, they saw the words TRUE and FALSE on the sides of the screen. They had to select as fast as possible the correct word depending on what they heard was true or false by pressing the left- or right-shift key corresponding to the side on which their response was. When they selected the word, it turned blue. This process 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. The whole task was administered in the participant's L1.

There were two practice trials 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. No feedback was ever provided.

4.3.4.2. Corsi-blocks tapping task (visuospatial WM).

Finally, an adapted version of (Milner, 1971)'s Corsi-blocks test served to assess WM applied to the visuospatial domain. In each trial, participants saw a grid 4 x 4 empty squares on a white background. Some of the squares would flash red for 1 s. and then turn white again one by one. Participants then had to recreate the sequence of flashed squares. There were no time

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

constraints. There were two practice sequences, and 21 sequences split into sets of three. The first set started with sequences of 3 squares. After the third sequence, a new set of three sequences one square longer followed. The longer trials had sequences of 9 squares. The sequences were random. No feedback was ever provided.

4.4. Procedure

Data collection took place in a single session of about 1 hour and 30 minutes to two hours depending on the participants. Apart from the participant, only the researcher was present. All interaction happened in Spanish. The room for data collection 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), rhythm task (10 minutes), pitch task (10 minutes), time/movement task (10 minutes), Corsi-blocks task (5 minutes), and OSpan (15 minutes), and a 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 in a computer, using a 24" computer monitor and Sol Republic 1601-32 headphones.

Linguistic anticipation task

For the visual-world paradigm, participants rested their head on a chin rest, completed an 11-point grid calibration task, and received task instructions both orally and in written. Then they completed the practice trials and were given the opportunity to ask questions. Afterwards, they performed the task. Both the practice and the task trials followed this order. First, participants looked at a fixation sign in the middle of the screen for 250 ms. This allowed the researcher to

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

recalibrate when necessary manually. Then, two words appeared in the screen side to side. Once the words had been on the screen for 1000 ms, the 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 were not recorded so the setting forced participants to press again until they saw the green rectangle appear. No feedback was provided, regardless of whether they selected the correct word or not. See Figure 1 for an example of an experimental trial.

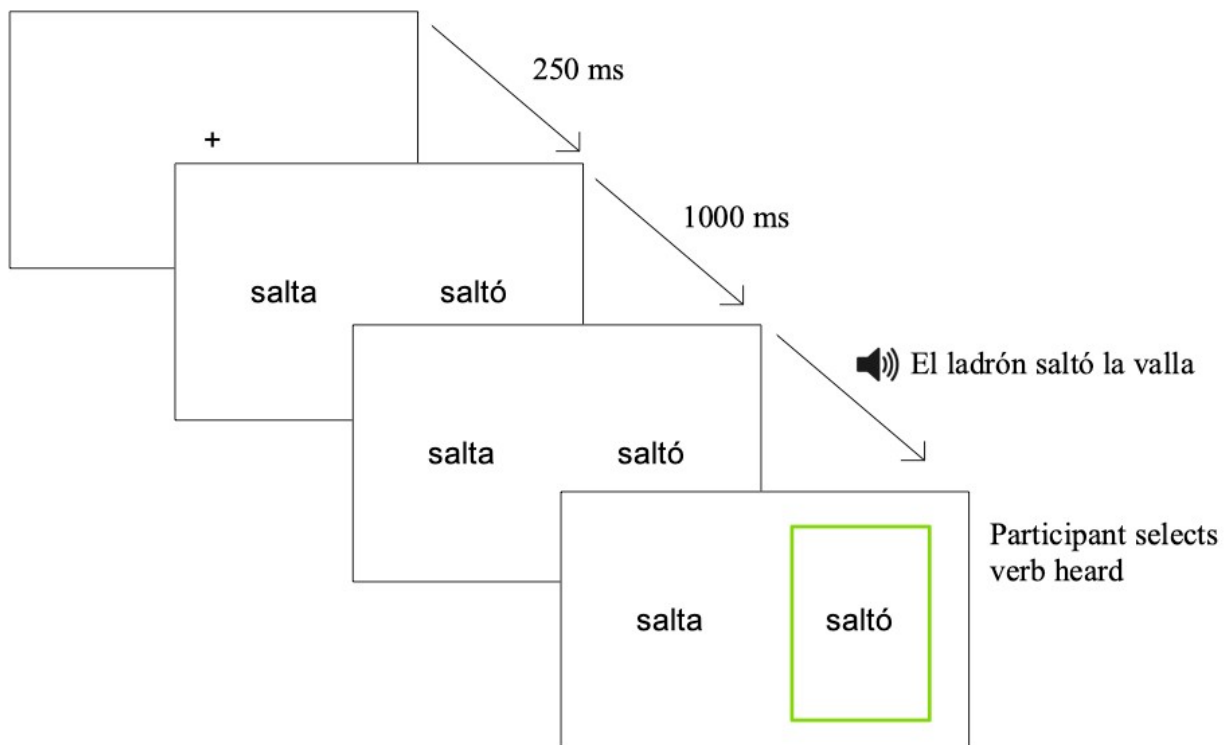


Figure 1: Sample trial of the visual-world paradigm

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Rhythm anticipation task

The rhythmic anticipation task consisted of a familiarization phase and a testing phase. There were 2 rhythms for practice, and 4 experimental rhythms. For each rhythm, participants listened to 6 seconds of the rhythm to become familiarized with it. In the testing phase, one of the beats in the rhythm was replaced by a beep or imperative tone that cued the participants to press the spacebar on the start of the following beat. That is, the order of the sections in the task was:

- 1) Practice:
 - 1.a) Familiarization phase 1
 - 1.b) Experimental phase 1
 - 1.c) Familiarization phase 2
 - 1.d) Experimental phase 2

- 2) Test:
 - 2.a) Familiarization phase 3
 - 2.b) Experimental phase 3
 - 2.c) Familiarization phase 4
 - 2.d) Experimental phase 4
 - 2.e) Familiarization phase 5
 - 2.f) Experimental phase 5
 - 2.g) Familiarization phase 6
 - 2.h) Experimental phase 6

There were ten experimental trials for each rhythm in the testing phase, but participants heard no pause between trials. The rhythms sounded as if the trials were all part of the same rhythmic unit. When participants pressed the space bar after the imperative tone, a green dot appeared on the center of the screen. Otherwise, the screen remained blank (see Figure 2 for a trial representation of the rhythm anticipation task).

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

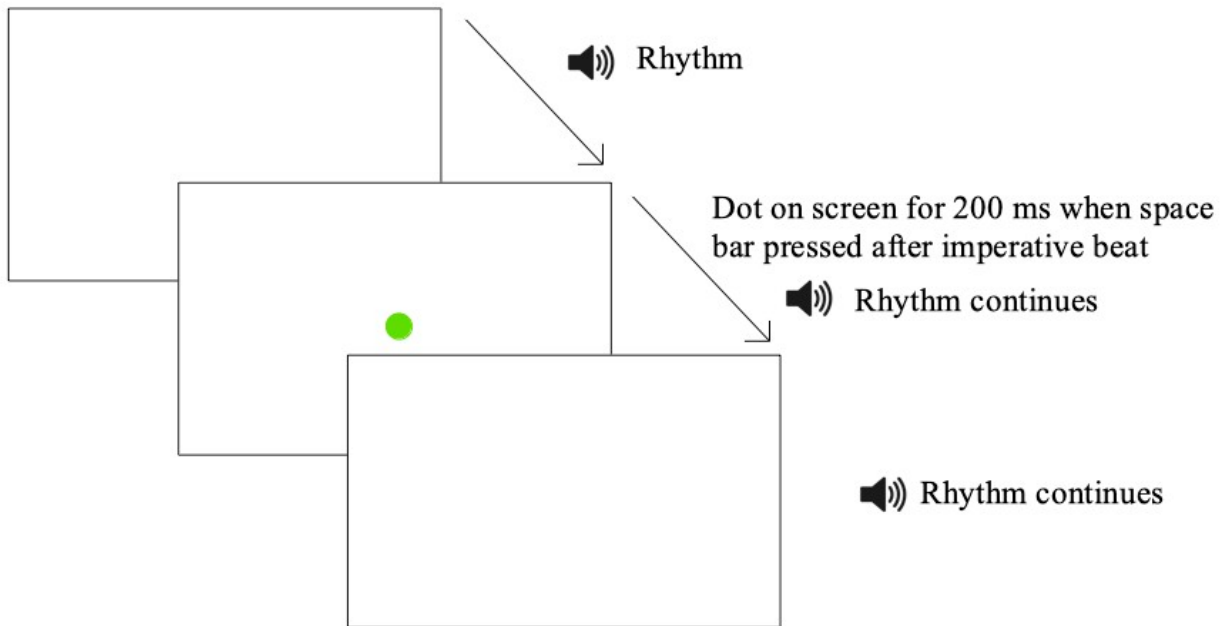


Figure 2: Sample trial of the rhythm anticipation task

Pitch anticipation task

The pitch anticipation task also contained a familiarization and a testing phase, but in different order. In the pitch anticipation task, participants were familiarized with all the melodies first. The section order was therefore as follows:

- 1) Familiarization
- 2) Practice
- 3) Test

The melodies were four pairs of short melodies. Each pair started the same, but the fourth note differed. Participants were not told about this pairing explicitly. During this familiarization phase, a number and an arrow appeared on the screen. The number (from 1-8) indicated what melody it was but contained no relevant information for the task. The arrow could point upwards

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

or downwards and accompanied the direction of the pitch change. During the practice and testing phases, an upwards arrow and a downwards arrow appeared on the screen, each on one side. The side where each arrow appeared was counterbalanced across participants. Participants needed to select the arrow corresponding to the pitch change direction as fast as possible by pressing the keys associated with the arrows. The key associated with the arrow on the left was the left-shift key, and the key associated with the arrow on the right was the right-shift key. There were four practice trials. In the first two trials, participants received visual feedback on their arrow choice (right vs. wrong), and in the last two practice trials they received no feedback, imitating the format of the experimental trials. The correct sides were counterbalanced across participants. A fixation cross appeared for 250 ms between trials. A representation of a trial can be seen in Figure 3.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

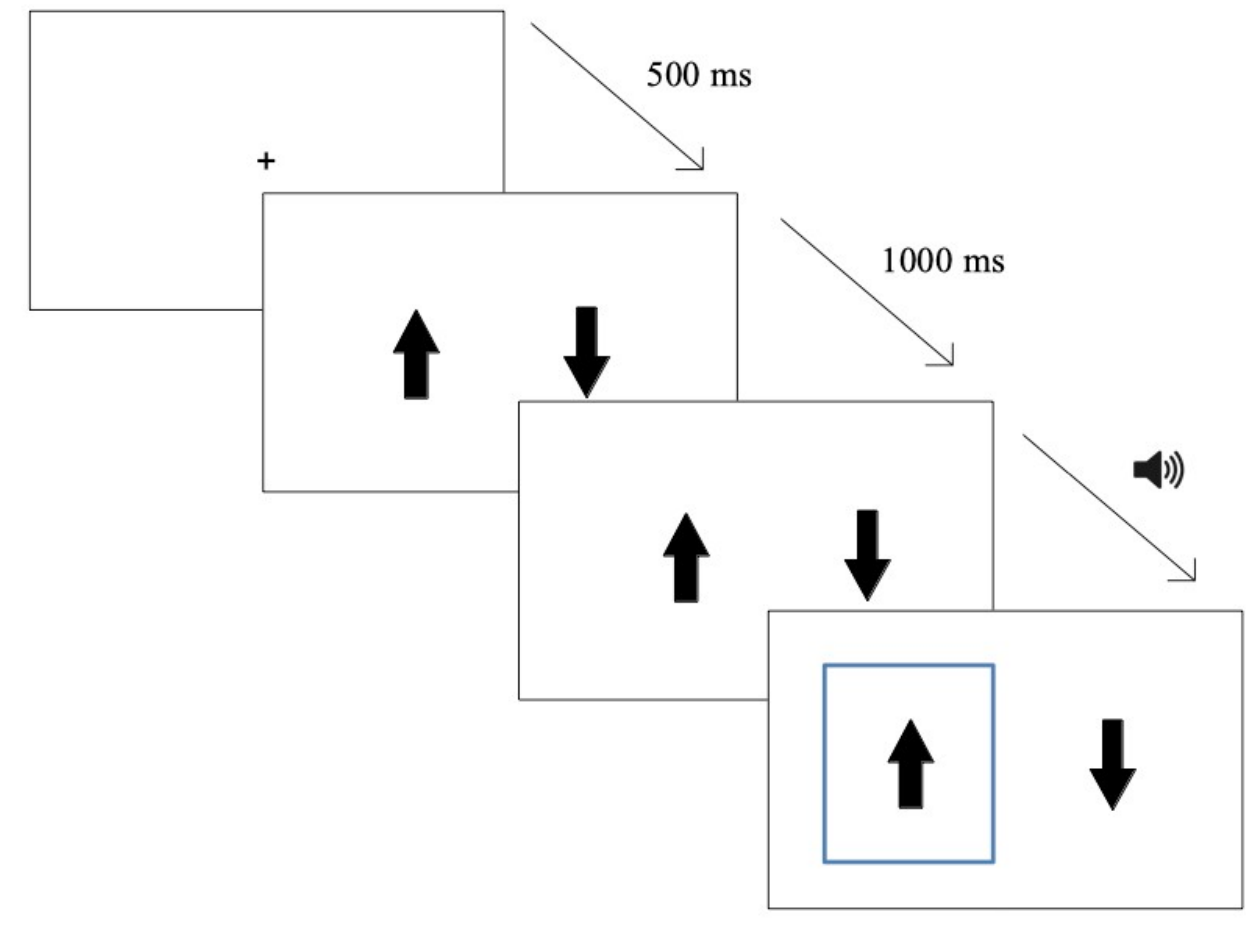


Figure 3: Sample trial of the tone anticipation task

Visuospatial anticipation task

In the visuospatial anticipation task, participants saw a car moving from one side to the other on the computer screen. The car disappeared behind a mountain, and participants had to press the spacebar when they anticipated the car would reappear on the other side of the mountain, marked with a checkered flag. There were four practice trials. In the first two practice trials, participants saw the car's position as feedback upon pressing the spacebar, to learn if they had calculated correctly; in the last two practice trials, they did not receive any feedback, just like in the

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

experimental trials. In the experimental trials, the trial would automatically finish upon the space bar press. There was a fixation cross for 250 ms between trials. Figure 4 shows a trial of the task.

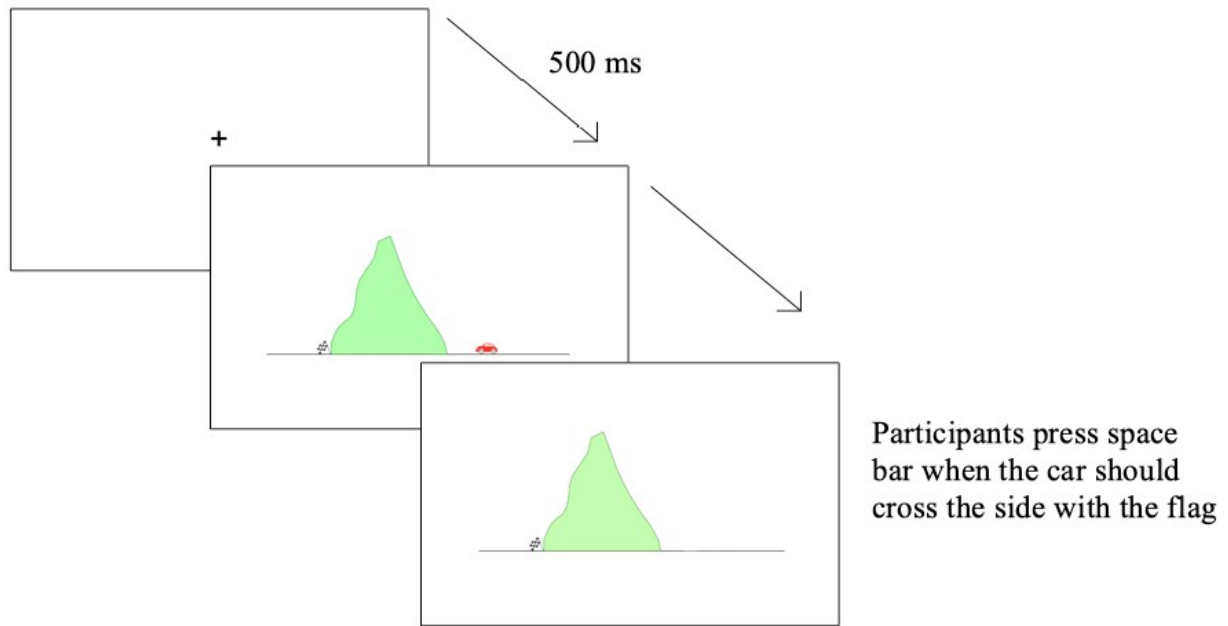


Figure 4: Sample trial of the visuospatial anticipation task

Visuospatial WM task

The Corsi-blocks task consisted of recreation of flashing square sequences previously seen. In this task participants completed 2 practice sets, and then the experimental section began. For both phases, a series of squares on the screen would flash red for a second. After the last square in each sequence turned white, participants needed to recreate the sequence they had just seen by clicking with the mouse on the squares that had flashed red in the same order they had flashed. Once they had clicked the same number of squares as in the original sequence, a fixation cross appeared for 500 ms in the center of the screen, and then the next sequence started (see Figure 5 for a sample trial). The sequences started with three squares flashing and ended with nine squares flashing. For each sequence length, there were three trials.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

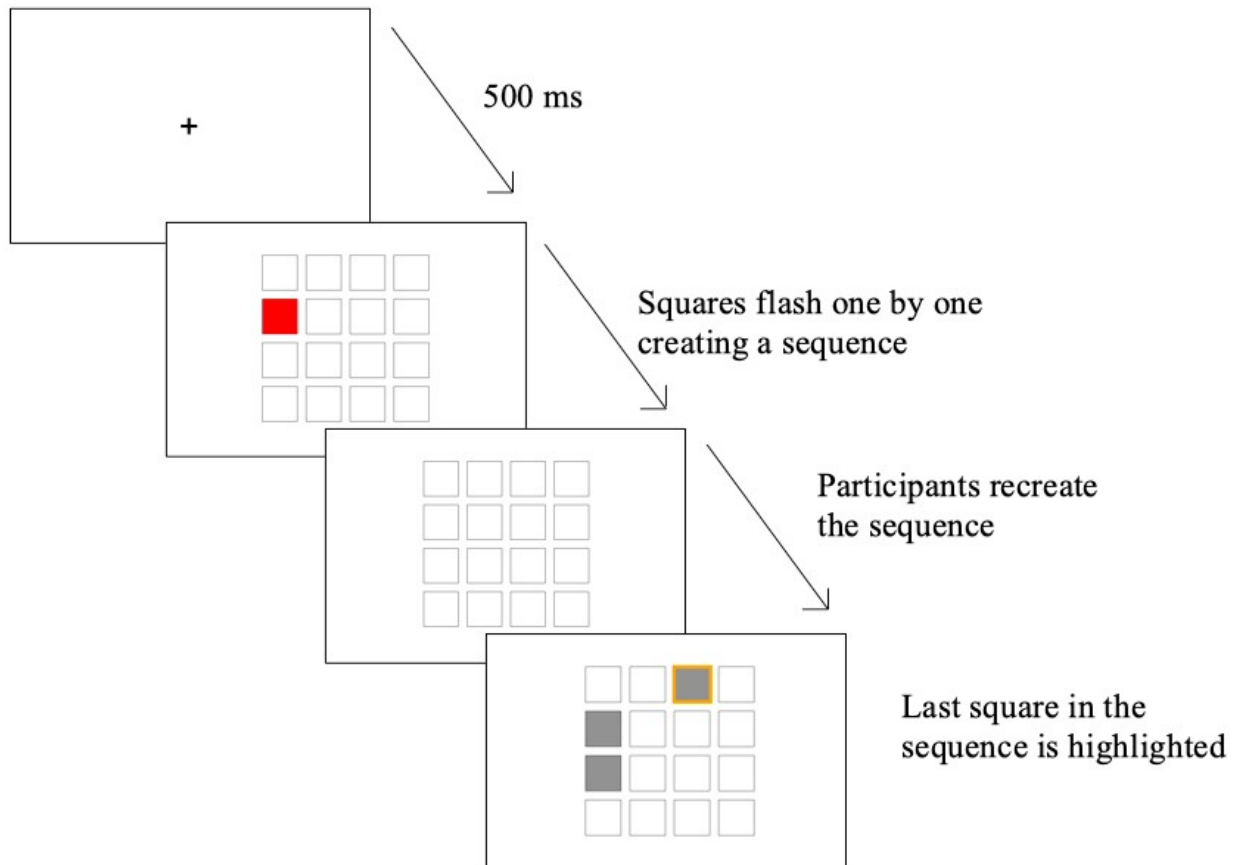


Figure 5.: Sample trial of the Corsi-blocks tapping task

Verbal WM task

The OSpan task was divided into practice and experimental trials. For each trial, participants first heard a word in their L1 and then heard a simple equation, like $2+2=5$, also in their L1. During the equation, 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 equation was correct or not. After each equation, they saw a fixation point for 500 ms and another pair of word-equation 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 paper the

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

words they had heard in the order they were presented. 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. Figure 6 shows a sample trial.

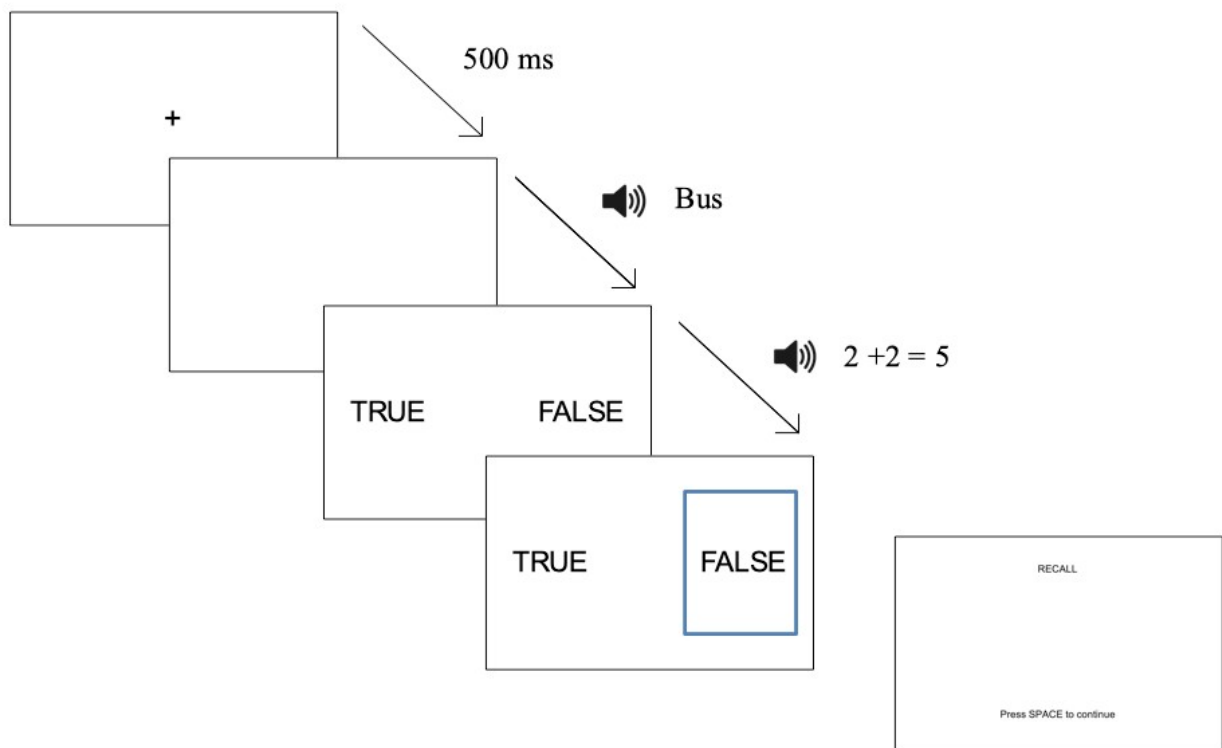


Figure 6: Sample trial of the OSpan

Vocabulary test Finally, a vocabulary multiple-choice test evaluated participants knowledge of the eye-tracking task words. For each word, they had to select the closer equivalent in their L1 from multiple choices. If they did not know what the word in Spanish meant, they had an option to mark that that was the case. Participants were instructed not to guess the answers if they did not know what a word meant.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

4.5. Scoring*Proficiency test*

Each question in the proficiency test was worth one point. Each question answered correctly would thus add one point up. Questions answered wrongly did not deduct points. Since there were 56 questions, the maximum possible score was 56, and the minimum was 0. Only participants who got at least 25 points were recruited for the study.

Visual world paradigm

Participants' key presses were considered accurate if they pressed the key corresponding to the verb in the sentence, and inaccurate if they pressed the other verb. Only the sentences with accurate responses were included in the statistical analyses. In the statistical analyses, proportion and count of fixations on the verbs over time in the sentence were analyzed. There were several moments in the sentence of special interest, namely, target onset, onset of the first vowel, onset of the code in the first syllable, onset of the second syllable, and offset of the verb. 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.

Pitch anticipation task

Participants' key presses were considered accurate if they pressed the key corresponding to the direction of the pitch change, and inaccurate if they pressed the key for the other arrow. Only the accurate trials were included in the statistical analyses. Given that participants were primed that a higher pitch to the base indicated a still higher following note, and a lower pitch was followed by a yet lower tone, the closer the key presses were to the onset of the cueing tone, the better the

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

anticipation was deemed. That is, the shorter the reaction time in pressing the response key, the better. Times were averages for the trials in each melody.

Rhythm anticipation task

Following Pagliarini (2016), key presses happening 150 ms after the beginning of the tap-along beat were discarded for the statistical analyses as they were considered reaction to the second beat. For valid timings, the closer the key presses were to the start of the second beat, the better the anticipation. Times were averaged for the trials in each condition.

Visuospatial anticipation task

Key presses were stored taken as referent 0 the ms in which the car was meant to reappear from behind the mountain. Key press timings could thus be negative if they happened before, or positive if they happened afterwards. The closer the key press timing was to 0, the better the visuospatial movement anticipation was deemed to be. Key press timings were averaged for trials in each condition. Trials where the participant took too long to respond and the car should have “left” the screen were discarded.

Ospar

Several measures were taken in this task: for the mathematical problems, if participants pressed TRUE or FALSE correctly, and how long it took them to respond; for the words, if they had written all words and if they had, if they were in the correct order. Given that speakers of different languages have different average spans, processing speed in the mathematical problems was the measure taken to compare WM across L1 groups.

Corsi-blocks tapping task

Two measures were taken in this task: if the correct squares had been tapped regardless of the

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

order, and if the correct squares had been tapped in the same order as the original sequence. For the purpose of this project, only the latter score was analyzed. In other words, only those sequences that had been exactly recreated were counted. The total number of correct sequences was added up for each participant, and that was considered their Corsi score.

4.6. Statistical analyses

Statistical analyses were conducted on R (Team & others, 2013) using the packages *lme4* (Bates, Mächler, Bolker, & Walker, 2014) and *multcomp* (Hothorn et al., 2016). The empirical logit transformation was applied to binary responses (fixations on target or distractor; Barr, 2008). The bins of 10 ms were run through independent t-tests to find out whether participants were anticipating the correct verbal tense upon hearing the lexical stress or lack thereof. The bins of 50 ms were used to 1) model a GLMM to observe how the different factors considered (L1 transfer, L2 proficiency and WM) mediated the anticipatory ability; and 2) to model a growth curve analysis (GCA, Mirman, 2016) to analyze the evolution of the gaze fixation pattern over time as suprasegmental and segmental information became available. The GCA 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 linguistic and tone anticipation tasks, only accurate trials were included. For the rhythm anticipation task, deviation time from target beat onset was averaged across conditions and across the test when the key-presses happened within 150 ms after the start of the tap-along beat. For the movement anticipation task, deviation time from the ms when the car should reappear was

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

averaged across conditions and across the test. Reaction time was averaged across conditions and across the test. For the WM tests, number of correct trials out of all trials were the score used as reference. For the OSpan, reaction time in pressing TRUE or FALSE for the mathematical problems was also averaged across trials and used as measure of processing speed.

The proficiency and the two WM scores were analyzed as:

- 1) Proficiency determining groups and WM used as homogeneity measure.
- 2) Proficiency and WM scores as continuous scales to observe how changes in these three measures affect language processing and anticipation.

5. The studies

5.1. Study 1 – Linguistic anticipation

Study 1 investigated the role of language experience (L1 transfer, L2 proficiency) and WM on adults' ability to use stress cues to predict verb suffixes during spoken word recognition. Previous research shows that adult L2 learners transfer L1 prosodic information when perceiving the L2 are able to transfer and extrapolate prosody encoding abilities from their L1 to their L2 (Krishnan, Gandour, & Bidelman, 2010). Furthermore, L2 learners use L2 acoustic information to make predictions between words (Perdomo & Kaan, 2019) and within words (e.g., Roll & Horne, 2015; Sagarra & Casillas, 2018).

Particularly relevant to the present study, Sagarra and Casillas (2018) investigated use of lexical stress to predict verb suffixes in native and non-native speakers. Spanish monolinguals and beginning and advanced English learners of Spanish completed a visual-world paradigm with sentences containing Spanish verbs in the present and the preterit tenses. As a reminder, lexical stress is contrastive in English and Spanish, but the acoustic correlates are different in each

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

language. They found that advanced English learners of Spanish could use Spanish lexical stress to predict verb tense information. Intermediate speakers could still not use that connection. The ability to generate this prediction was not mediated by WM. The English speakers in Sagarra and Casillas (2018)'s study might have selected to transfer function knowledge from all the information encoded along with lexical stress in English. It is not possible to confirm that hypothesis because there was no population with which to compare that might have transferred other information, like Mandarin L1 speakers could do with acoustic knowledge. L2 proficiency conditioned the English speakers' ability to anticipate morphosyntax in Spanish. In the case that Mandarin speakers also anticipate, it is possible their proficiency also conditions their ability to generate the correct predictions, and therefore, only advanced speakers are able to predict verb tense when cued through lexical stress.

Lastly, WM is the cognitive skill to store temporarily and process incoming information so complex cognitive actions are executed (Baddeley, 2007). Variability in WM have been found to be one of the possible factors mediating L2 anticipation (Huettig & Mani, 2016 found effects; Otten & Van Berkum, 2009 found none; Sagarra & Casillas, 2018). The specific role of WM on L2 anticipation or how it interacts with other factors is not clear. In order to clarify these issue, WM has so been included.

The research question for Study 1 was whether Spanish monolinguals, and intermediate and advanced Mandarin and English learners of Spanish use lexical stress to anticipate verbal suffixes in Spanish. In the case that they do so, whether their prediction abilities are mediated by verbal WM. The hypotheses are found in Section 3. The findings of Study 1 will inform the models SLM, PAM-L2 and L2LP of L2 phonology acquisition by expanding their theoretical tenets to suprasegmental information, as well as cognitive models of SLA.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

5.2. Study 2 – Auditory anticipation: pitch, rhythm, and morphosyntactic anticipation

Study 2 examined whether speech anticipation is language-specific or it relies on more general auditory mechanisms also shared by other cognitive skills related to audition, in native and non-native speakers. This study also explores whether WM has any impact on the sharing of the mechanisms. Lozano-Argüelles et al. (2019) found that practice can lead to transfer of auditory processing abilities across linguistic domains. WM capacities have been shown to be associated across the auditory and visuospatial domains (Kane et al., 2004), such that lasting improvement in the auditory area, for example, has effects in the visual domain (Bergman Nutley et al., 2014). In particular, this study focuses on shared mechanisms of language with two auditory phenomena: rhythm and pitch. Rhythm is a pattern of recurrent time intervals that usually occur periodically (Berlyne, 1971). A listener needs to anticipate when the next beat or event signaling the end of an interval and beginning of the next one is coming in order to move or act synchronously. Rhythm abilities have been linked positively to L2 prosody processing (Cason et al., 2019). Pitch is the frequency associated to a sound wave so it sounds high or low during perception (Klapuri, 2006). For pitch, previous findings point towards a positive relationship between musical abilities and prosodic abilities regarding absolute pitch (Ngo et al., 2016), and out-of-key tunes violate melodic prediction in musicians and non-musicians in Western music at least (e.g., Sherwin & Sajda, 2013). There is therefore the possibility that rhythmic, pitch, and linguistic anticipation based on prosody are correlated. The research question for Study 2 was whether linguistic prediction of word morphology is associated with auditory prediction in Spanish monolinguals, and intermediate and advanced Chinese and English learners of Spanish. If so, how WM, L1 transfer and L2 proficiency mediate this relationship. The hypotheses are found in Section 3. Spanish monolinguals and intermediate and advanced Mandarin and English

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

learners of Spanish completed a linguistic prediction task and two non-linguistic auditory tasks: a pitch task and a rhythm task. The findings of Study 2 will provide insight into how independent the language anticipatory function is in human cognition, or how it relies on common processing mechanisms that also underlie information prediction in other domains, namely, pitch and rhythm.

5.3. Study 3 – Linguistic and non-linguistic visuospatial anticipation

Study 3 explored whether visuospatial capacities affect linguistic anticipation in native and non-native speakers, and how WM influences that relationship. The link between linguistic and visuospatial cognitive systems is not a new matter for research. Several frameworks have been proposed (e.g. Barrouillet, Bernardin, & Camos, 2004; Baddeley, 1986, 1996, 2012; Baddeley & Hitch, 1974; Cowan, 1999) trying to capture how these systems may be interrelated modalities. Indeed, visual and auditory-verbal binding WM in children is positively associated with their word recognition skills (Wang, Allen, Lee, & Hsieh, 2015). More specifically, visual attention span is a significant predictor of reading fluency at both beginning and advanced stages of literacy and can also predict orthographic knowledge and spelling performance in Dutch children (Van Den Boer, Van Bergen, & Jong, 2015). Space representation and processing also affect linguistic performance in atypical populations (e.g., Bochynska et al., 2020; Landau & Hoffman, 2005). However, there is no research focusing on how space information processing affects other types of information processing. The research question for Study 3 was whether linguistic prediction of word morphology is associated with visuospatial prediction in Spanish monolinguals, and intermediate and advanced Chinese and English learners of Spanish. In that were the case, how WM, L1 transfer and L2 proficiency mediate this relationship. The hypotheses are found in Section 3. Spanish monolinguals and intermediate and advanced

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Mandarin and English learners of Spanish completed a linguistic prediction task, a non-linguistic visuospatial task, a verbal WM task, and a visuospatial WM task. The findings of Study 3 will clarify how anticipation in different cognition modalities are connected, and whether different processing and anticipatory mechanisms are domain specific or underpinned by common cognitive resources to different domains, namely, auditory and visuospatial.

6. Conclusion

The goal of this dissertation was to examine the role of language experience (L1 transfer, L2 proficiency) (Study 1), non-linguistic auditory prediction (Study 2), and visuospatial prediction (Study 3), on L1 and L2 linguistic prediction of word endings based on prosodic cues. In addition, this dissertation explored the mediation of verbal and visuospatial WM morphosyntactic anticipation based on lexical stress in the L1 and the L2. Spanish monolinguals and intermediate and advanced Mandarin and English learners of Spanish completed a linguistic anticipation task, a pitch anticipation task, a rhythm anticipation task, a visuospatial anticipation task, a verbal WM task, and a visuospatial anticipation task. The linguistic anticipation task, a visual-world paradigm, tested the participants' ability to predict verb tense suffixes in L2 Spanish based on the stressed or unstressed first syllable of the verb. In this task, the L1 English speakers were hypothesized to transfer lexical stress function (Sagarra & Casillas, 2018), and L1 Mandarin speakers were hypothesized to transfer acoustic correlate knowledge (Li et al., 2017). Both transfers were expected to be as costly, and their effects only visible at higher levels of proficiency. Therefore, only L2 speakers at higher proficiencies and monolinguals would be able to generate the correct predictions, but the L2 speakers would not reach a target-like performance (Perdomo & Kaan, 2019). Verbal WM was expected to foster both types of transfer (Huettig &

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION (Mani, 2016).

Across non-linguistic domains, auditory predictive abilities were hypothesized to be correlated positively with linguistic predictive abilities, given that there is already some evidence of rhythm and prosody perception (Cason et al., 2019), and pitch in music and suprasegmental perception (Chua & Brunt, 2014), but visuospatial predictive abilities were hypothesized to not be associated with linguistic predictive abilities. L2 proficiency and L1 transfer were not expected to mediate associations between language and other non-linguistic anticipation abilities. WM was expected to account for individual differences in anticipation, but only in the non-linguistic anticipation tasks.

Results confirming these hypotheses would confirm that different cognitive domains in the auditory modality can influence speech anticipation, and thus that anticipation relies at least partially on domain-general cognitive mechanisms. These results would also confirm, however, that the underlying anticipatory mechanisms are only common within modality, but not shared across modalities, and therefore better anticipatory abilities in other modalities do not affect linguistic prediction.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

References

- Alcaro, A., & Panksepp, J. (2011). The seeking mind: Primal neuro-affective substrates for appetitive incentive states and their pathological dynamics in addictions and depression. *Neuroscience & Biobehavioral Reviews*, 35(9), 1805–1820.
- Allopenna, P. D., Magnuson, J. S., & Tanenhaus, M. K. (1998). Tracking the time course of spoken word recognition using eye movements: Evidence for continuous mapping models. *Journal of Memory and Language*, 38(4), 419–439.
- Altmann, G. T., & Kamide, Y. (1999). Incremental interpretation at verbs: Restricting the domain of subsequent reference. *Cognition*, 73(3), 247–264.
- Altmann, G. T., & Kamide, Y. (2007). The real-time mediation of visual attention by language and world knowledge: Linking anticipatory (and other) eye movements to linguistic processing. *Journal of Memory and Language*, 57(4), 502–518.
- Anvari, S. H., Trainor, L. J., Woodside, J., & Levy, B. A. (2002). Relations among musical skills, phonological processing, and early reading ability in preschool children. *Journal of Experimental Child Psychology*, 83(2), 111–130.
- Appel, H. M., & Cocroft, R. (2014). Plants respond to leaf vibrations caused by insect herbivore chewing. *Oecologia*, 175(4), 1257–1266.
- Baddeley, A. (1986). Working memory (vol. 11). Oxford: Oxford University Press, Clarendon Press.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Baddeley, A. (1996). Exploring the central executive. *The Quarterly Journal of Experimental Psychology Section A*, 49(1), 5–28.

Baddeley, A. (2007). *Working memory, thought, and action* (Vol. 45). OUP Oxford.

Baddeley, A. (2012). Working memory: Theories, models, and controversies. *Annual Review of Psychology*, 63, 1–29.

Baddeley, A. D., & Hitch, G. (1974). Working memory. *Psychology of Learning and Motivation*.
[https://doi.org/https://doi.org/10.1016/S0079-7421\(08\)60452-1](https://doi.org/https://doi.org/10.1016/S0079-7421(08)60452-1)

Baddeley, A., & Wilson, B. (1988). Frontal amnesia and the dysexecutive syndrome. *Brain and Cognition*, 7(2), 212–230.

Barr, D. J. (2008). Analyzing ‘visual world’ eyetracking data using multilevel logistic regression. *Journal of Memory and Language*, 59(4), 457–474.

Barrouillet, P., Bernardin, S., & Camos, V. (2004). Time constraints and resource sharing in adults’ working memory spans. *Journal of Experimental Psychology: General*, 133(1), 83.

Bartlett, N. R., & Bartlett, S. C. (1959). Synchronization of a motor response with an anticipated sensory event. *Psychological Review*, 66(4), 203.

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2014). Fitting linear mixed-effects models using lme4. *arXiv Preprint arXiv:1406.5823*.

Beatty-Martí'nez, A. L., Navarro-Torres, C. A., Dussias, P. E., Bajo, M. T., Guzzardo Tamargo, R. E., & Kroll, J. F. (2019). Interactional context mediates the consequences of

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

bilingualism for language and cognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*.

Beckman, M. E. (1986). *Stress and non-stress accent* (Vol. 7). Walter de Gruyter.

Bennett, S. J., & Barnes, G. R. (2004). Predictive smooth ocular pursuit during the transient disappearance of a visual target. *Journal of Neurophysiology*, 92(1), 578–590.

Bennett, S. J., & Barnes, G. R. (2005). Timing the anticipatory recovery in smooth ocular pursuit during the transient disappearance of a visual target. *Experimental Brain Research*, 163(2), 198–203.

Bennett, S. J., & Barnes, G. R. (2006). Combined smooth and saccadic ocular pursuit during the transient occlusion of a moving visual object. *Experimental Brain Research*, 168(3), 313–321.

Benton, A. L. (1977). The amusias. In *Music and the brain* (pp. 378–397). Elsevier.

Bergman Nutley, S., Darki, F., & Klingberg, T. (2014). Music practice is associated with development of working memory during childhood and adolescence. *Frontiers in Human Neuroscience*, 7, 926.

Berlyne, D. E. (1971). Aesthetics and psychobiology.

Berthelsen, S. G., Horne, M., Brännström, K. J., Shtyrov, Y., & Roll, M. (2018). Neural processing of morphosyntactic tonal cues in second-language learners. *Journal of Neurolinguistics*, 45, 60–78.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Best, C. T. (1995). Learning to perceive the sound pattern of english. *Advances in Infancy Research*, 9, 217–217.

Best, C. T., & Tyler, M. D. (2007). Nonnative and second-language speech perception: Commonalities and complementarities. In O.-S. Bohn & M. J. Munro (Eds.), *Language experience in second language speech learning: In honor of James Emil Flege* (pp. 13–34). Amsterdam, The Netherlands: John Benjamins.

Bhatara, A., Yeung, H. H., & Nazzi, T. (2015). Foreign language learning in french speakers is associated with rhythm perception, but not with melody perception. *Journal of Experimental Psychology: Human Perception and Performance*, 41(2), 277.

Bidelman, G. M., Hutka, S., & Moreno, S. (2013). Tone language speakers and musicians share enhanced perceptual and cognitive abilities for musical pitch: Evidence for bidirectionality between the domains of language and music. *PloS One*, 8(4).

Bochynska, A., Vulchanova, M., Vulchanov, V., & Landau, B. (2020). Spatial language difficulties reflect the structure of intact spatial representation: Evidence from high-functioning autism. *Cognitive Psychology*, 116, 101249.

Borowsky, A., Horrey, W. J., Liang, Y., Garabet, A., Simmons, L., & Fisher, D. L. (2016). The effects of brief visual interruption tasks on drivers' ability to resume their visual search for a pre-cued hazard. *Accident Analysis & Prevention*, 93, 207–216.

Brennan, J. R., & Hale, J. T. (2019). Hierarchical structure guides rapid linguistic predictions during naturalistic listening. *PloS One*, 14(1).

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Bybee, J. (2006). From usage to grammar: The mind's response to repetition. *Language*, 82(4),

711–733. Retrieved from <http://www.jstor.org/stable/4490266>

Carpenter, P. A., & Just, M. A. (1977). Reading comprehension as eyes see it. *Cognitive Processes in Comprehension*, 109–139.

Carr, K. W., White-Schwoch, T., Tierney, A. T., Strait, D. L., & Kraus, N. (2014). Beat synchronization predicts neural speech encoding and reading readiness in preschoolers. *Proceedings of the National Academy of Sciences*, 111(40), 14559–14564.

Cason, N., Marmursztejn, M., D'Imperio, M., & Schön, D. (2019). Rhythmic abilities correlate with l2 prosody imitation abilities in typologically different languages. *Language and Speech*, 0023830919826334.

Cason, N., & Schön, D. (2012). Rhythmic priming enhances the phonological processing of speech. *Neuropsychologia*, 50(11), 2652–2658.

Chan, R. K., & Leung, J. H. (2019). WHY are lexical tones difficult to learn?: INSIGHTS from the incidental learning of tone-segment connections. *Studies in Second Language Acquisition*, 1–27.

Chao, Y. R. (1968). A grammar of spoken chinese.

Chen, H. C. (2013). Chinese learners' acquisition of english word stress and factors affecting stress assignment. *Linguistics and Education*, 24(4), 545–555.

Cheung, H. (1996). Nonword span as a unique predictor of second-language vocabulary language. *Developmental Psychology*, 32(5), 867.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Child, S., Oakhill, J., & Garnham, A. (2020). Tracking your emotions: An eye-tracking study on

reader's engagement with perspective during text comprehension. *Quarterly Journal of*

Experimental Psychology, 1747021820905561.

Chomsky, N. (1986). *Knowledge of language: Its nature, origin, and use*. Greenwood Publishing Group.

Chua, A. J., & Brunt, J. (2014). Effect of musical experience on tonal language perception. In *Proceedings of meetings on acoustics 167ASA* (Vol. 21, p. 060009). Acoustical Society of America.

Colantoni, L., Steele, J., Escudero, P., & Neyra, P. R. E. (2015). *Second language speech*. Cambridge University Press.

Colley, I. D., Keller, P. E., & Halpern, A. R. (2018a). Working memory and auditory imagery predict sensorimotor synchronisation with expressively timed music. *Quarterly Journal of Experimental Psychology*, 71(8), 1781–1796.

Colley, I. D., Varlet, M., MacRitchie, J., & Keller, P. E. (2018b). The influence of visual cues on temporal anticipation and movement synchronization with musical sequences. *Acta Psychologica*, 191, 190–200.

Cooper, N., Cutler, A., & Wales, R. (2002). Constraints of lexical stress on lexical access in english: Evidence from native and non-native listeners. *Language and Speech*, 45(3), 207–228.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

- Cooper, R. M. (1974). The control of eye fixation by the meaning of spoken language: A new methodology for the real-time investigation of speech perception, memory, and language processing. *Cognitive Psychology*.
- Correia, S., Frota, S., Butler, J., & Vigário, M. (2013). Word stress perception in european portuguese. In *INTERSPEECH* (pp. 267–271).
- Cowan, N. (1999). An embedded-processes model of working memory. *Models of Working Memory: Mechanisms of Active Maintenance and Executive Control*, 20, 506.
- Cowan, N. (2016). *Working memory capacity: Classic edition*. Psychology press.
- Crawford, L. E., Regier, T., & Huttenlocher, J. (2000). Linguistic and non-linguistic spatial categorization. *Cognition*, 75(3), 209–235.
- Cuetos, F., Mitchell, D. C., & Corley, M. M. (1996). Language processing in spanish. In (pp. 145–187). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.
- Cutler, A. (1986). Forbear is a homophone: Lexical prosody does not constrain lexical access. *Language and Speech*, 29(3), 201–220.
- Dagerman, K. S., MacDonald, M. C., & Harm, M. W. (2006). Aging and the use of context in ambiguity resolution: Complex changes from simple slowing. *Cognitive Science*, 30(2), 311–345.
- Dahan, D., Swingle, D., Tanenhaus, M. K., & Magnuson, J. S. (2000). Linguistic gender and spoken-word recognition in french. *Journal of Memory and Language*, 42(4), 465–480.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Davidson, M. C., Amso, D., Anderson, L. C., & Diamond, A. (2006). Development of cognitive

control and executive functions from 4 to 13 years: Evidence from manipulations of

memory, inhibition, and task switching. *Neuropsychologia*, 44(11), 2037–2078.

Degé, F., & Schwarzer, G. (2011). The effect of a music program on phonological awareness in preschoolers. *Frontiers in Psychology*, 2, 124.

De Luca, C. R., & Leventer, R. J. (2010). Developmental trajectories of executive functions across the lifespan. In *Executive functions and the frontal lobes* (pp. 57–90). Psychology Press.

Desimone, R., & Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual Review of Neuroscience*, 18(1), 193–222.

Deutsch, D., Dooley, K., Henthorn, T., & Head, B. (2009). Absolute pitch among students in an american music conservatory: Association with tone language fluency. *The Journal of the Acoustical Society of America*, 125(4), 2398–2403.

Dijkgraaf, A., Hartsuiker, R. J., & Duyck, W. (2017). Predicting upcoming information in native-language and non-native-language auditory word recognition. *Bilingualism: Language and Cognition*, 20(5), 917–930.

Dilley, L. C. (2005). *The phonetics and phonology of tonal systems* (PhD thesis). Massachusetts Institute of Technology.

Duchowski, A. T. (2007). Eye tracking methodology. *Theory and Practice*, 328(614), 2–3.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Duma, G. M., Mento, G., Manari, T., Martinelli, M., & Tressoldi, P. (2017). Driving with

intuition: A preregistered study about the eeg anticipation of simulated random car

accidents. *PloS One*, 12(1).

Dupoux, E., Sebastián-Gallés, N., Navarrete, E., & Peperkamp, S. (2008). Persistent stress

“deafness”: The case of french learners of spanish. *Cognition*, 106(2), 682–706.

Duranovic, M., Dedeic, M., & Gavrić, M. (2015). Dyslexia and visual-spatial talents. *Current*

Psychology, 34(2), 207–222.

Dussias, P. E., Kroff, J. R. V., Tamargo, R. E. G., & Gerfen, C. (2013). When gender and looking

go hand in hand: Grammatical gender processing in l2 spanish. *Studies in Second*

Language Acquisition, 35(2), 353–387.

Engle, R. W. (2002). Working memory capacity as executive attention. *Current Directions in*

Psychological Science, 11(1), 19–23.

Escudero, P. (2005). *Linguistic perception and second language acquisition: Explaining the*

attainment of optimal phonological categorization. Netherlands Graduate School of

Linguistics.

Escudero, P. (2009). Linguistic perception of “similar” l2 sounds. *Phonology in Perception*, 15,

152–190.

Estes, Z., & Barsalou, L. W. (2018). A comprehensive meta-analysis of spatial interference from

linguistic cues: Beyond petrova et al.(2018). *Psychological Science*, 29(9), 1558–1564.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Face, T. L. (2006). Cognitive factors in the perception of spanish stress placement: Implications for a model of speech perception. *Linguistics*, 44(6), 1237–1267.

Farran, E. K., Atkinson, L., & Broadbent, H. (2016). Impaired spatial category representations in williams syndrome; an investigation of the mechanistic contributions of non-verbal cognition and spatial language performance. *Frontiers in Psychology*, 7, 1868.

Federmeier, K. D., & Kutas, M. (2019). What’s “left”? Hemispheric sensitivity to predictability and congruity during sentence reading by older adults. *Neuropsychologia*, 133, 107173.

Fischer, B. (1992). Saccadic reaction time: Implications for reading, dyslexia, and visual cognition. In *Eye movements and visual cognition* (pp. 31–45). Springer.

Flege, J. E. (1995). Second language speech learning: Theory, findings, and problems. In W. Strange (Ed.), *Speech perception and linguistic experience issues in cross-language research* (pp. 229–273). Timonium, MD: York Press.

Fodor, J. A. (1983). *The modularity of mind*. MIT press.

Foote, R. (2011). Integrated knowledge of agreement in early and late english–spanish bilinguals. *Applied Psycholinguistics*, 32(1), 187–220.

Fraisse, P. (2013). Psychology of music. In D. Deutsch (Ed.). Elsevier.

Fraisse, P., Pichot, P., & Clairouin, G. (1949). Les aptitudes rythmiques. Etude comparée des oligophrenes et des enfants normaux. *Journal de Psychologie Normale et Pathologique*.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Fraisse, P., & Repp, B. H. (2012). Anticipation of rhythmic stimuli: Speed of establishment and precision of synchronization (1966). *Psychomusicology: Music, Mind, and Brain*, 22(1),

84.

Friedrich, M., & Friederici, A. D. (2005). Phonotactic knowledge and lexical-semantic processing in one-year-olds: Brain responses to words and nonsense words in picture contexts. *Journal of Cognitive Neuroscience*, 17(11), 1785–1802.

Fry, D. B. (1955). Duration and intensity as physical correlates of linguistic stress. *The Journal of the Acoustical Society of America*, 27(4), 765–768.

Fry, D. B. (1958). Experiments in the perception of stress. *Language and Speech*, 1(2), 126–152.

Fry, D. B. (1965). The dependence of stress judgments on vowel formant structure. In *Phonetic sciences* (pp. 306–311). Karger Publishers.

Gambi, C., Gorrie, F., Pickering, M. J., & Rabagliati, H. (2018). The development of linguistic prediction: Predictions of sound and meaning in 2-to 5-year-olds. *Journal of Experimental Child Psychology*, 173, 351–370.

Gandour, J. T., & Fromkin, V. (1978). The perception of tone in tone: A linguistic survey.

Gathercole, S. E., & Baddeley, A. D. (1990). Phonological memory deficits in language disordered children: Is there a causal connection? *Journal of Memory and Language*, 29(3), 336–360.

Gathercole, S. E., Hitch, G. J., Martin, A. J., & others. (1997). Phonological short-term memory and new word learning in children. *Developmental Psychology*, 33(6), 966.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Gathercole, S. E., Willis, C. S., Emslie, H., & Baddeley, A. D. (1992). Phonological memory and vocabulary development during the early school years: A longitudinal study.

Developmental Psychology, 28(5), 887.

George, E. M., & Coch, D. (2011). Music training and working memory: An erp study.

Neuropsychologia, 49(5), 1083–1094.

Ghaffarvand Mokari, P., & Werner, S. (2018). Perceptual training of second-language vowels:

Does musical ability play a role? *Journal of Psycholinguistic Research*, 47(1), 95–112.

Giovagnoli, G., Vicari, S., Tomassetti, S., & Menghini, D. (2016). The role of visual-spatial

abilities in dyslexia: Age differences in children's reading? *Frontiers in Psychology*, 7, 1997.

Gordon, M., & Roettger, T. (2017). Acoustic correlates of word stress: A cross-linguistic survey.

Linguistics Vanguard, 3(1).

Grabe, E., & Low, E. L. (2002). Durational variability in speech and the rhythm class hypothesis.

Papers in Laboratory Phonology, 7(515-546).

Grey, S., Cox, J. G., Serafini, E. J., & Sanz, C. (2015). The role of individual differences in the

study abroad context: Cognitive capacity and language development during short-term intensive language exposure. *The Modern Language Journal*, 99(1), 137–157.

Grüter, T., & Rohde, H. (2013). L2 processing is affected by rage: Evidence from reference

resolution. In *The 12th conference on generative approaches to second language acquisition (gasla)*.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

- Grüter, T., Rohde, H., & Schafer, A. (2014). The role of discourse-level expectations in non-native speakers' referential choices. In *Proceedings of the annual boston university conference on language development*.
- Grüter, T., Takeda, A., Rohde, H., & Schafer, A. J. (2016). L2 listeners show anticipatory looks to upcoming discourse referents. In *Poster presented at the 41st annual boston university conference on language development, boston university* (pp. 4–6).
- Hasson, U., Egidi, G., Marelli, M., & Willems, R. M. (2018). Grounding the neurobiology of language in first principles: The necessity of non-language-centric explanations for language comprehension. *Cognition*, 180, 135–157.
- Hawthorne, K., & Gerken, L. (2014). From pauses to clauses: Prosody facilitates learning of syntactic constituency. *Cognition*, 133(2), 420–428.
- Hed, A., Schremm, A., Horne, M., & Roll, M. (2019). Neural correlates of second language acquisition of tone-grammar associations. *The Mental Lexicon*, 14(1), 98–123.
- Hopp, H. (2013). Grammatical gender in adult l2 acquisition: Relations between lexical and syntactic variability. *Second Language Research*, 29(1), 33–56.
- Hopp, H. (2015). Semantics and morphosyntax in predictive l2 sentence processing. *International Review of Applied Linguistics in Language Teaching*, 53(3), 277–306.
- Hopp, H. (2016). Learning (not) to predict: Grammatical gender processing in second language acquisition. *Second Language Research*, 32(2), 277–307.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Hothorn, T., Bretz, F., Westfall, P., Heiberger, R. M., Schuetzenmeister, A., Scheibe, S., &

Hothorn, M. T. (2016). Package “multcomp”. *Simultaneous Inference in General Parametric Models. Project for Statistical Computing, Vienna, Austria.*

Hu, J., Gao, S., Ma, W., & Yao, D. (2012). Dissociation of tone and vowel processing in mandarin idioms. *Psychophysiology*, 49(9), 1179–1190.

Hualde, J. I. (2005). *The sounds of spanish with audio cd*. Cambridge University Press.

Hualde, J. I., & Kim, J. Y. (2015). The acquisition of spanish lexical stress by korean learners. In *ICPhS*.

Huetting, F., & Mani, N. (2016). Is prediction necessary to understand language? Probably not. *Language, Cognition and Neuroscience*, 31(1), 19–31.

Huetting, F., & McQueen, J. M. (2007). The tug of war between phonological, semantic and shape information in language-mediated visual search. *Journal of Memory and Language*, 57(4), 460–482.

Huetting, F., Rommers, J., & Meyer, A. S. (2011). Using the visual world paradigm to study language processing: A review and critical evaluation. *Acta Psychologica*, 137(2), 151–171.

Huttenlocher, J., Hedges, L. V., & Duncan, S. (1991). Categories and particulars: Prototype effects in estimating spatial location. *Psychological Review*, 98(3), 352.

Ito, A. (2016). Prediction during native and non-native language comprehension: The role of mediating factors.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Iversen, J. R., Patel, A. D., Nicodemus, B., & Emmorey, K. (2015). Synchronization to auditory and visual rhythms in hearing and deaf individuals. *Cognition*, 134, 232–244.

Jentschke, S., Friederici, A. D., & Koelsch, S. (2014). Neural correlates of music-syntactic processing in two-year old children. *Developmental Cognitive Neuroscience*, 9, 200–208.

Jones, K. L., & Smith, D. W. (1975). The williams elfin facies syndrome: A new perspective. *The Journal of Pediatrics*, 86(5), 718–723.

Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review*, 99(1), 122.

Kamide, Y., Altmann, G. T., & Haywood, S. L. (2003). The time-course of prediction in incremental sentence processing: Evidence from anticipatory eye movements. *Journal of Memory and Language*, 49(1), 133–156.

Kamin, L. (1969). Predictability, surprise, attention and cognition. *BA Campbell, RM Church* New York: Appleton-Century-Crofts.

Kane, M. J., Hambrick, D. Z., Tuholski, S. W., Wilhelm, O., Payne, T. W., & Engle, R. W. (2004). The generality of working memory capacity: A latent-variable approach to verbal and visuospatial memory span and reasoning. *Journal of Experimental Psychology: General*, 133(2), 189.

Katz, L., & Frost, R. (1992). The reading process is different for different orthographies: The orthographic depth hypothesis. *ADVANCES IN PSYCHOLOGY-AMSTERDAM-*, 94, 67–67.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

- Kim, A. E., Oines, L., & Miyake, A. (2018). Individual differences in verbal working memory underlie a tradeoff between semantic and structural processing difficulty during language comprehension: An erp investigation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 44(3), 406.
- Kjelgaard, M. M., & Speer, S. R. (1999). Prosodic facilitation and interference in the resolution of temporary syntactic closure ambiguity. *Journal of Memory and Language*, 40(2), 153–194.
- Klapuri, A. (2006). Introduction to music transcription. In *Signal processing methods for music transcription* (pp. 3–20). Springer.
- Koelsch, S., & Siebel, W. A. (2005). Towards a neural basis of music perception. *Trends in Cognitive Sciences*, 9(12), 578–584.
- Krishnan, A., Gandour, J. T., & Bidelman, G. M. (2010). The effects of tone language experience on pitch processing in the brainstem. *Journal of Neurolinguistics*, 23(1), 81–95.
- Lagrois, M.-É., Palmer, C., & Peretz, I. (2019). Poor synchronization to musical beat generalizes to speech. *Brain Sciences*, 9(7), 157.
- Laing, E., & Jarrold, C. (2007). Comprehension of spatial language in williams syndrome: Evidence for impaired spatial representation of verbal descriptions. *Clinical Linguistics & Phonetics*, 21(9), 689–704.
- Landau, B., & Hoffman, J. E. (2005). Parallels between spatial cognition and spatial language: Evidence from williams syndrome. *Journal of Memory and Language*, 53(2), 163–185.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

- Lebedeva, G. C., & Kuhl, P. K. (2010). Sing that tune: Infants' perception of melody and lyrics and the facilitation of phonetic recognition in songs. *Infant Behavior and Development*, 33(4), 419–430.
- Lee, G., Shin, D.-J., & Garcia, M. T. M. (2019). Perception of lexical stress and sentence focus by korean-speaking and spanish-speaking l2 learners of english. *Language Sciences*, 72, 36–49.
- Lee, Y.-s., Lu, M.-j., & Ko, H.-p. (2007). Effects of skill training on working memory capacity. *Learning and Instruction*, 17(3), 336–344.
- Levy, R. (2008). Expectation-based syntactic comprehension. *Cognition*, 106(3), 1126–1177.
- Lew-Williams, C., & Fernald, A. (2010). Real-time processing of gender-marked articles by native and non-native spanish speakers. *Journal of Memory and Language*, 63(4), 447–464.
- Li, J. J., & Grigos, M. (2018). The effect of l1 prosody in the perception and production of non-native lexical stress. In (pp. 898–902). <https://doi.org/10.21437/SpeechProsody.2018-181>
- Li, X., To, C. K. S., & Ng, M. L. (2017). Effects of l1 tone on perception of l2 tone-a study of mandarin tone learning by native cantonese children. *Bilingualism: Language and Cognition*, 20(3), 549–560.
- Liberman, I. Y., Liberman, A. M., Mattingly, I., & Shankweiler, D. (1980). Orthography and the beginning reader. *Orthography, Reading, and Dyslexia*, 137–153.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Liburd, T. (2014). *Investigating prediction in l2 morpho-syntax: A visual world study* (PhD thesis). University of Pittsburgh.

Lin, H. 林., & Wang, Q. 王倩. (2007). Mandarin rhythm: An acoustic study. *Journal of Chinese Language and Computing*, 17(3), 127–140.

Linck, J. A., Osthus, P., Koeth, J. T., & Bunting, M. F. (2014). Working memory and second language comprehension and production: A meta-analysis. *Psychon. Bull. Rev.*, 21(4), 861–883.

Linzen, T., & Jaeger, T. F. (2016). Uncertainty and expectation in sentence processing: Evidence from subcategorization distributions. *Cognitive Science*, 40(6), 1382–1411.

Lord, G. (2007). The role of the lexicon in learning second language stress patterns. *Applied Language Learning*, 17(1/2), 1.

Loui, P., & Wessel, D. (2007). Harmonic expectation and affect in western music: Effects of attention and training. *Perception & Psychophysics*, 69(7), 1084–1092.

Lozano-Argüelles, C., Sagarra, N., & Casillas, J. V. (2019). Slowly but surely: Interpreting facilitates l2 morphological anticipation based on suprasegmental and segmental information. *Bilingualism: Language and Cognition*, 1–11.

Lukács, A., Pleh, C., & Racsmany, M. (2007). Spatial language in williams syndrome: Evidence for a special interaction? *Journal of Child Language*, 34(2), 311–343.

Ma, S. M. (2016). Working memory in spanish-english and chinese-english bilinguals. *Psychology and Behavioral Sciences*, 5(4), 104–112.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Mackintosh, N. J. (1975). A theory of attention: Variations in the associability of stimuli with reinforcement. *Psychological Review*, 82(4), 276.

Magne, C., Schön, D., & Besson, M. (2006). Musician children detect pitch violations in both music and language better than nonmusician children: Behavioral and electrophysiological approaches. *Journal of Cognitive Neuroscience*, 18(2), 199–211.

Malins, J. G., & Joanisse, M. F. (2010). The roles of tonal and segmental information in mandarin spoken word recognition: An eyetracking study. *Journal of Memory and Language*, 62(4), 407–420.

Marques, C., Moreno, S., Lui's Castro, S., & Besson, M. (2007). Musicians detect pitch violation in a foreign language better than nonmusicians: Behavioral and electrophysiological evidence. *Journal of Cognitive Neuroscience*, 19(9), 1453–1463.

Martin, J. G. (1972). Rhythmic (hierarchical) versus serial structure in speech and other behavior.

Martí'nez-Castilla, P., & Sotillo, M. (2014). Pitch processing in children with williams syndrome: Relationships between music and prosody skills. *Brain Sciences*, 4(2), 376–395.

Marull, C. (2017). Second language processing efficiency: Experience and cognitive effects on l2 morphosyntactic integration and anticipation. In *BUCLD 41: Proceedings of the 41st boston university conference on language development* (pp. 466–480). Cascadilla Press Somerville, MA.

Milner, B. (1971). Interhemispheric differences in the localization of psychological processes in man. *British Medical Bulletin*.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Mirman, D. (2016). *Growth curve analysis and visualization using r*. CRC press.

Mitsugi, S., & Macwhinney, B. (2016). The use of case marking for predictive processing in second language japanese. *Bilingualism: Language and Cognition*, 19(1), 19–35.

Miyake, Y., Onishi, Y., & Poppel, E. (2004). Two types of anticipation in synchronization tapping. *Acta Neurobiologiae Experimentalis*, 64(3), 415–426.

Mok, P. (2009). On the syllable-timing of cantonese and beijing mandarin. *Chinese Journal of Phonetics*, 2, 148–154.

Morando, A., Victor, T., & Dozza, M. (2016). Drivers anticipate lead-vehicle conflicts during automated longitudinal control: Sensory cues capture driver attention and promote appropriate and timely responses. *Accident Analysis & Prevention*, 97, 206–219.

Morrison, S. J., & Demorest, S. M. (2009). Cultural constraints on music perception and cognition. *Progress in Brain Research*, 178, 67–77.

Musacchia, G., Sams, M., Skoe, E., & Kraus, N. (2007). Musicians have enhanced subcortical auditory and audiovisual processing of speech and music. *Proceedings of the National Academy of Sciences*, 104(40), 15894–15898.

Nakamoto, H., & Mori, S. (2012). Experts in fast-ball sports reduce anticipation timing cost by developing inhibitory control. *Brain and Cognition*, 80(1), 23–32.

Nakamura, C., Arai, M., & Mazuka, R. (2012). Immediate use of prosody and context in predicting a syntactic structure. *Cognition*, 125(2), 317–323.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Nakano, H., Saron, C., & Swaab, T. Y. (2010). Speech and span: Working memory capacity

impacts the use of animacy but not of world knowledge during spoken sentence

comprehension. *Journal of Cognitive Neuroscience*, 22(12), 2886–2898.

Ngo, M. K., Vu, K.-P. L., & Strybel, T. Z. (2016). Effects of music and tonal language

experience on relative pitch performance. *The American Journal of Psychology*, 129(2),

125–134.

Nozaradan, S., Peretz, I., & Keller, P. E. (2016). Individual differences in rhythmic cortical

entrainment correlate with predictive behavior in sensorimotor synchronization. *Scientific*

Reports, 6, 20612.

Nuria Sagarra, N. R., Cristina Sanz. (n.d.). Eye-tracking reveals study abroad benefits on l2

morphosyntactic processing. Second Language Research Forum. Columbia University.

Orban de Xivry, J.-J., Bennett, S. J., Lefèvre, P., & Barnes, G. R. (2006). Evidence for synergy

between saccades and smooth pursuit during transient target disappearance. *Journal of*

Neurophysiology, 95(1), 418–427.

Ortega-Llebaria, M. (2006). Phonetic cues to stress and accent in spanish. In *Selected*

proceedings of the 2nd conference on laboratory approaches to spanish phonetics and

phonology (pp. 104–118). Cascadilla Proceedings Project Somerville, MA.

Ortega-Llebaria, M., Gu, H., & Fan, J. (2013). English speakers' perception of spanish lexical

stress: Context-driven l2 stress perception. *Journal of Phonetics*, 41(3-4), 186–197.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

- Ortega-Llebaria, M., & Prieto, P. (2007). Disentangling stress from accent in spanish: Production patterns of the stress contrast in deaccented syllables. *Amsterdam Studies in the Theory and History of Linguistic Science Series 4*, 282, 155.
- Ortega-Llebaria, M., & Prieto, P. (2009). Perception of word stress in castilian spanish. *Phonetics and Phonology: Interactions and Interrelations*, 306, 35.
- Otten, M., & Van Berkum, J. J. (2009). Does working memory capacity affect the ability to predict upcoming words in discourse? *Brain Research*, 1291, 92–101.
- Pagliarini, E. (2016). Predictive timing in developmental dyslexia: A new hypothesis. Anticipatory skills across language and motor domains.
- Pakulak, E., & Neville, H. J. (2010). Proficiency differences in syntactic processing of monolingual native speakers indexed by event-related potentials. *Journal of Cognitive Neuroscience*, 22(12), 2728–2744.
- Pan, Y., Lin, B., Zhao, Y., & Soto, D. (2014). Working memory biasing of visual perception without awareness. *Attention, Perception, & Psychophysics*, 76(7), 2051–2062.
- Papagno, C., Valentine, T., & Baddeley, A. (1991). Phonological short-term memory and foreign-language vocabulary learning. *Journal of Memory and Language*, 30(3), 331–347.
- Patel, A. D., Wong, M., Foxton, J., Lochy, A., & Peretz, I. (2008). Speech intonation perception deficits in musical tone deafness (congenital amusia). *Music Perception: An Interdisciplinary Journal*, 25(4), 357–368.
- Pearce, J. (2005). Selected observations on amusia. *European Neurology*, 54(3), 145–148.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Perdomo, M., & Kaan, E. (2019). Prosodic cues in second-language speech processing: A visual world eye-tracking study. *Second Language Research*, 0267658319879196.

Persici, V., Stucchi, N., & Arosio, F. (2019). Rhythmic and morphosyntactic predictions: The anticipation abilities of italian children with developmental dyslexia.

Phillips, C. E., Jarrold, C., Baddeley, A. D., Grant, J., & Karmiloff-Smith, A. (2004). Comprehension of spatial language terms in williams syndrome: Evidence for an interaction between domains of strength and weakness. *Cortex*, 40(1), 85–101.

Phillips-Silver, J., Toiviainen, P., Gosselin, N., & Peretz, I. (2013). Amusic does not mean unmusical: Beat perception and synchronization ability despite pitch deafness. *Cognitive Neuropsychology*, 30(5), 311–331.

Pozzan, L., Gleitman, L. R., & Trueswell, J. C. (2016). Semantic ambiguity and syntactic bootstrapping: The case of conjoined-subject intransitive sentences. *Language Learning and Development*, 12(1), 14–41.

Rehrig, G. L. (2017). *Acoustic correlates of syntax in sentence production and comprehension* (PhD thesis). Rutgers University-School of Graduate Studies.

Roden, I., Grube, D., Bongard, S., & Kreutz, G. (2014). Does music training enhance working memory performance? Findings from a quasi-experimental longitudinal study. *Psychology of Music*, 42(2), 284–298.

Roll, M., & Horne, M. (2015). A neurolinguistic study of south swedish word accents: Electrical brain potentials in nouns and verbs, 38(2), 149–162.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Roll, M., Horne, M., & Lindgren, M. (2010). Word accents and morphology—erps of swedish word processing. *Brain Research*, 1330, 114–123.

Roll, M., Horne, M., & Lindgren, M. (2011). Activating without inhibiting: Left-edge boundary tones and syntactic processing. *Journal of Cognitive Neuroscience*, 23(5), 1170–1179.

Roll, M., Söderström, P., & Horne, M. (2013). Word-stem tones cue suffixes in the brain. *Brain Research*, 1520, 116–120.

Ryskin, R. A., Qi, Z., Duff, M. C., & Brown-Schmidt, S. (2017). Verb biases are shaped through lifelong learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 43(5), 781.

Ryskin, R., Levy, R. P., & Fedorenko, E. (2020). Do domain-general executive resources play a role in linguistic prediction? Re-evaluation of the evidence and a path forward. *Neuropsychologia*, 136, 107258.

Sagarra, N. (2017). Longitudinal effects of working memory on l2 grammar and reading abilities. *Second Language Research*, 33(3), 341–363.

Sagarra, N., & Casillas, J. V. (2018). Suprasegmental information cues morphological anticipation during l1/l2 lexical access. *Journal of Second Language Studies*, 1(1), 31–59.

Sagarra, N., & Herschensohn, J. (2010). The role of proficiency and working memory in gender and number agreement processing in l1 and l2 spanish. *Lingua*, 120(8), 2022–2039.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Salimpoor, V. N., Zald, D. H., Zatorre, R. J., Dagher, A., & McIntosh, A. R. (2015). Predictions

and the brain: How musical sounds become rewarding. *Trends in Cognitive Sciences*,

19(2), 86–91.

Salverda, A. P., Kleinschmidt, D., & Tanenhaus, M. K. (2014). Immediate effects of anticipatory

coarticulation in spoken-word recognition. *Journal of Memory and Language*, 71(1), 145–

163.

Sammler, D., Novembre, G., Koelsch, S., & Keller, P. E. (2013). Syntax in a pianist's hand: ERP

signatures of “embodied” syntax processing in music. *Cortex*, 49(5), 1325–1339.

Sanz, C., Lin, H.-J., Lado, B., Stafford, C. A., & Bowden, H. W. (2016). One size fits all?

Learning conditions and working memory capacity in ab initio language development.

Applied Linguistics, 37(5), 669–692.

Saslow, M. (1967). Effects of components of displacement-step stimuli upon latency for saccadic

eye movement. *Josa*, 57(8), 1024–1029.

Schmalz, X., Marinus, E., Coltheart, M., & Castles, A. (2015). Getting to the bottom of

orthographic depth. *Psychonomic Bulletin & Review*, 22(6), 1614–1629.

Schremm, A., Söderström, P., Horne, M., & Roll, M. (2016). Implicit acquisition of tone-suffix

connections in l2 learners of swedish. *The Mental Lexicon*, 11(1), 55–75.

Schwab, S., & Dellwo, V. (2016). The use of the odd-one-out task in the study of the perception

of lexical stress in spanish by german-speaking listeners?

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Serafini, E. J., & Sanz, C. (2016). Evidence for the decreasing impact of cognitive ability on

second language development as proficiency increases. *Studies in Second Language*

Acquisition, 38(4), 607–646.

Sereno, J. A., & Lee, H. (2015). The contribution of segmental and tonal information in mandarin

spoken word processing. *Language and Speech*, 58(2), 131–151.

Service, E. (1992). Phonology, working memory, and foreign-language learning. *The Quarterly*

Journal of Experimental Psychology Section A, 45(1), 21–50.

Slevc, L. R., & Miyake, A. (2006). Individual differences in second-language proficiency: Does

musical ability matter? *Psychological Science*, 17(8), 675–681.

Sluijter, A. M., & Van Heuven, V. J. (1996). Spectral balance as an acoustic correlate of

linguistic stress. *The Journal of the Acoustical Society of America*, 100(4), 2471–2485.

Sluijter, A. M., Van Heuven, V. J., & Pacilly, J. J. (1997). Spectral balance as a cue in the

perception of linguistic stress. *The Journal of the Acoustical Society of America*, 101(1),

503–513.

Soto-Faraco, S., Sebastián-Gallés, N., & Cutler, A. (2001). Segmental and suprasegmental cues

for lexical access in spanish. *Journal of Memory and Language*, 45, 412–432.

Söderström, P., Horne, M., & Roll, M. (2015). Using tonal cues to predict inflections. *Working*

Papers 55. 2015 Linguistics Lund University, 91.

Söderström, P., Roll, M., & Horne, M. (2012). Processing morphologically conditioned word

accents. *The Mental Lexicon*, 7(1), 77–89.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

- Stahl, P., Donmez, B., & Jamieson, G. A. (2016). Supporting anticipation in driving through attentional and interpretational in-vehicle displays. *Accident Analysis & Prevention*, *91*, 103–113.
- Staub, A., & Clifton Jr, C. (2006). Syntactic prediction in language comprehension: Evidence from either... Or. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*(2), 425.
- Steen, M. M. van der, Jacoby, N., Fairhurst, M. T., & Keller, P. E. (2015). Sensorimotor synchronization with tempo-changing auditory sequences: Modeling temporal adaptation and anticipation. *Brain Research*, *1626*, 66–87.
- Sun, Y., Lu, X., Ho, H. T., Johnson, B. W., Sammler, D., & Thompson, W. F. (2018). Syntactic processing in music and language: Parallel abnormalities observed in congenital amusia. *NeuroImage: Clinical*, *19*, 640–651.
- Swaminathan, S., Schellenberg, E. G., & Venkatesan, K. (2018). Explaining the association between music training and reading in adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *44*(6), 992.
- System, V. T. (2013). Zeit- und bewegungsantizipation “time and movement anticipation”.
- Tanenhaus, M. K., Spivey-Knowlton, M. J., Eberhard, K. M., & Sedivy, J. C. (1995). Integration of visual and linguistic information in spoken language comprehension. *Science*, *268*(5217), 1632–1634.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

Tang, W., Xiong, W., Zhang, Y.-x., Dong, Q., & Nan, Y. (2016). Musical experience facilitates

lexical tone processing among mandarin speakers: Behavioral and neural evidence.

Neuropsychologia, 91, 247–253.

Tanner, D., & Van Hell, J. G. (2014). ERPs reveal individual differences in morphosyntactic

processing. *Neuropsychologia*, 56, 289–301.

Team, R. C., & others. (2013). R: A language and environment for statistical computing.

Tsukada, K., Xu, H. L., & Rattanasone, N. X. (2015). The perception of mandarin lexical tones

by listeners from different linguistic backgrounds. *Chinese as a Second Language*

Research, 4(2), 141–161.

Unsworth, N., Heitz, R. P., Schrock, J. C., & Engle, R. W. (2005). An automated version of the

operation span task. *Behavior Research Methods*, 37(3), 498–505.

Van Berkum, J. J., Brown, C. M., Zwitserlood, P., Kooijman, V., & Hagoort, P. (2005).

Anticipating upcoming words in discourse: Evidence from erps and reading times.

Journal of Experimental Psychology: Learning, Memory, and Cognition, 31(3), 443.

Van Den Boer, M., Van Bergen, E., & Jong, P. F. de. (2015). The specific relation of visual

attention span with reading and spelling in dutch. *Learning and Individual Differences*, 39,

141–149.

Van Leussen, J.-W., & Escudero, P. (2015). Learning to perceive and recognize a second

language: The L2LP model revised. *Frontiers in Psychology*, 6, 6–12.

<https://doi.org/10.3389/fpsyg.2015.01000>

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

- Vickie, Y. Y., & Andruski, J. E. (2010). A cross-language study of perception of lexical stress in english. *Journal of Psycholinguistic Research*, 39(4), 323–344.
- Vidyasagar, T. R., & Pammer, K. (2010). Dyslexia: A deficit in visuo-spatial attention, not in phonological processing. *Trends in Cognitive Sciences*, 14(2), 57–63.
- Von Károlyi, C., & Winner, E. (2004). Dyslexia and visual spatial talents: Are they connected? In *Students with both gifts and learning disabilities* (pp. 95–117). Springer.
- Wang, S., Allen, R. J., Lee, J. R., & Hsieh, C.-E. (2015). Evaluating the developmental trajectory of the episodic buffer component of working memory and its relation to word recognition in children. *Journal of Experimental Child Psychology*, 133, 16–28.
- Weber, A., Grice, M., & Crocker, M. W. (2006). The role of prosody in the interpretation of structural ambiguities: A study of anticipatory eye movements. *Cognition*, 99(2), B63–B72.
- Wicha, N. Y., Bates, E. A., Moreno, E. M., & Kutas, M. (2003). Potato not pope: Human brain potentials to gender expectation and agreement in spanish spoken sentences. *Neuroscience Letters*, 346(3), 165–168.
- Wiener, S., & Turnbull, R. (2016). Constraints of tones, vowels and consonants on lexical selection in mandarin chinese. *Language and Speech*, 59(1), 59–82.
- Wilson, M., & Lindstrom, S. H. (2011). What the bird's brain tells the bird's eye: The function of descending input to the avian retina. *Visual Neuroscience*, 28(4), 337–350.

L1 AND L2 LINGUISTIC AND NON-LINGUISTIC ANTICIPATION

- Wong, P. C., Skoe, E., Russo, N. M., Dees, T., & Kraus, N. (2007). Musical experience shapes human brainstem encoding of linguistic pitch patterns. *Nature Neuroscience*, *10*(4), 420–422.
- Woodman, G. F., & Luck, S. J. (2004). Visual search is slowed when visuospatial working memory is occupied. *Psychonomic Bulletin & Review*, *11*(2), 269–274.
- Woodman, G. F., Vogel, E. K., & Luck, S. J. (2001). Visual search remains efficient when visual working memory is full. *Psychological Science*, *12*(3), 219–224.
- Wright, M. J., Bishop, D. T., Jackson, R. C., & Abernethy, B. (2010). Functional mri reveals expert-novice differences during sport-related anticipation. *Neuroreport*, *21*(2), 94–98.
- Yang, E. (2017). Bilinguals' working memory (wm) advantage and their dual language practices. *Brain Sciences*, *7*(7), 86.
- Yang, Y., Gryllia, S., Pablos, L., & Cheng, L. L.-S. (2019). Clause type anticipation based on prosody in mandarin. *International Journal of Chinese Linguistics*, *6*(1), 1–26.
- Ye, Z., & Zhou, X. (2008). Involvement of cognitive control in sentence comprehension: Evidence from erps. *Brain Research*, *1203*, 103–115.
- Yu, M., Xu, M., Li, X., Chen, Z., Song, Y., & Liu, J. (2017). The shared neural basis of music and language. *Neuroscience*, *357*, 208–219.
- Zhu, X., & Wang, C. (2015). The oxford handbook of chinese linguistics. In W. S. Wang & C. Sun (Eds.). Oxford University Press.