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Arriba, Abajo, al Centro, pa' Dentro!: An Event-Related Brain Potential Study of Path- and Manner-Sensitivity and Motion Expression

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¡ARRIBA, ABAJO, AL CENTRO, PA' DENTRO!: AN EVENT-RELATED BRAIN POTENTIAL STUDY OF PATH- AND MANNER-SENSITIVITY AND MOTION EXPRESSION

by

SAMANTHA N. EMERSON

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ABSTRACT

Languages can be divided into two types based on how they express motion events. Some languages, like English, tend to express manner of motion in the verb and path of motion outside the verb. Other languages, like Spanish, tend to express path of motion in the verb and only express manner rarely in subordinated or separate clauses. Behavioral research has examined whether these differences in expression lead to crosslinguistic differences in the sensitivity to manner versus path information in cognition; however, these studies have led to inconclusive results. To date, no study has examined the neural correlates associated with either the lexicalization of motion information nor to the sensitivity of motion information processing. As such, the current study examines the event-related potentials (ERPs) associated with the

processing of grammatical but atypical patterns of lexicalization and sensitivity to violations of expectancy for motion expression (congruency with a preceding animation) in adult native speakers of English and Spanish by examining the N400 (marker of semantic expectancy) and the P600 (marker of syntactic congruity that has recently been implicated in certain semantic errors). I predicted that atypical lexicalization patterns would produce larger ERP effects compared to typical patterns, and ERP effects would be larger for motion information to which speakers were more sensitive.

Rather than the traditionally predicted N400 effects to atypical lexicalizations, the results showed greater P600 effects. Similarly, analyses of sensitivity to motion expression violations revealed greater P600—as opposed to N400—amplitudes in response to incongruent compared to congruent motion verbs in both languages as well as both an N400 and P600 effect in path prepositions in English. In contrast, manner expressed outside the verb (gerunds) in both languages and path expressed outside the verb in Spanish (prepositions, adverbs) produced the traditional N400 effect for incongruent compared to congruent expressions. While these results do not provide support for the idea that habitual expression increases sensitivity to that type of information, it does suggest that speakers are sensitive to those lexical patterns. More interestingly, it suggests that the P600 may be sensitive to a broader range of stimuli than previously predicted.

INDEX WORDS: Motion typology, Event-related potentials, P600, N400, Lexicalization, Expectancy

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DEDICATION

I dedicate this dissertation to all of the people who have helped me throughout this process and my graduate career: To Şeyda and Chris for giving me the tools to develop as a researcher and as an intellectual. To Chantal for helping me develop as a teacher. To Wojtek, Valery, Prisma, Maria, Iria, and Hillary for their help in getting the stimuli just right. To Prisma, Maria, Leo, Jamie, and Hillary for going above and beyond the call of duty to collect the data. To Will, Skip, Sharon, and Cyrille for getting me off to a good start. To Julie and Al, as always, for raising me right and trusting in me. And to Ryan for keeping me sane and putting up with me.

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1 BACKGROUND

Languages differ systematically in the way they express different components of a motion event (Talmy, 1985, 2000), and these differences have been shown to influence the way we perceive and categorize such events (Gennari, Sloman, Malt, & Fitch, 2002, Kersten et al., 2010; Lai & Narasimhan, 2015). Most of the earlier work on this topic has focused on behavioral differences in the way speakers of different languages perceive and express motion events, leaving crosslinguistic variation in the neural processing of such events largely unexamined (e.g., event-related brain potentials; ERPs). A neural approach has the potential to expand our knowledge of motion event processing in two important ways: First, it can detect subtle differences in responses to stimuli that may not be present in behavioral data alone. Second, it can capture changes in processing as they unfold over time, particularly compared to behavioral measures (e.g., reaction time, accuracy) that can only capture the end state of event processing. This study aims to examine adult native English versus Spanish speakers' neurophysiological responses to violations of language-specific expression of motion events and their sensitivity to the different components of motion (i.e., manner, path) in their native language using ERPs.

1.1 Crosslinguistic Differences in Motion Expression

According to Talmy (1985, 2000), languages differ in how they describe motion events. The two motion components that most markedly differ between languages are manner (e.g., *run*, *jump*, *roll*) and path (e.g., *into*, *below*, *exit*) of motion. Speakers of English typically express manner in the verb, followed by a path satellite (i.e., manner-verb construction; see example 1a). Speakers of Spanish, on the other hand, typically express path in the verb, optionally followed by

an adjunct manner expression or a subordinate manner clause (i.e., path-verb construction; see example 1b; Naigles, Eisenberg, Kako, Highter, & McGraw, 1998; Özçalışkan, 2004, 2005; Özçalışkan & Slobin, 1999, 2003; Slobin, 2004; see examples 2a-2b;)

(1a) The dog **runs** <u>into</u> the house

(1b) El perro <u>entra</u> la casa (**corriendo/rápidamente**)

'The dog <u>enters</u> the house (**running**/**quickly**)'

Talmy's (1985, 2000) typology divides languages into two types based on which construction is preferred by native speakers of each language[1]. Languages like English, German, and Russian that tend to prefer the manner-verb construction are called satellite-framed languages (*S-languages*) while languages like Spanish, Turkish, and Greek that tend to use the path-verb construction are called verb-framed languages (*V-languages*).

The difference in preferred sentence construction between the two language types results in a large discrepancy in the frequency of manner expression between the two languages as well as in the number of different types of manner words speakers produce in each language. The preference for the manner-verb construction (i.e., manner in the verb, path in a satellite) by S-language speakers enables them to express manner more easily than speakers of V-languages. This ease of expression in S-languages results in a greater variety of manner words that capture a broader and more fine-grained set of distinctions (Özçalışkan, 2005; Özçalışkan, Lucero, &

[1] More recently researchers have begun to move away from this binary division of languages based on motion expression. Slobin (2004) suggested the addition of a third category called "equipollently-framed" languages for languages such as Mandarin Chinese in which both manner and path can be expressed succinctly and with equal significance in a serial-verb construction. Alternatively, he suggested that, rather than categorizing languages, it might be more appropriate to place languages on a cline of manner salience with high-manner-salient languages readily encoding manner in either the main verb, a serial-verb construction, a morpheme associated with the verb, a preverb, or an ideophone and with low-manner-salient languages encoding manner through some other subordinated means. The two languages discussed here represent classic exemplars of an S-language (English) and a V-language (Spanish) and easily fall into the high the and low ends of the manner-salience cline, respectively. As such, the current study leaves open the question of neural correlates of motion expression within equipollently-framed languages and across the spectrum of manner-salience.

Goldin-Meadow, 2016; Özçalışkan & Slobin, 1999; Slobin, 2004). For instance, English speakers can express variations on jumping by using many different verbs including *jump*, *hop*, *skip*, *leap*, *bound*, *bounce*, *pop*, *bob*, *vault*, and *spring* while Spanish speakers have only three words to express variations on jumping—*brincar* 'jump', *saltar* 'jump', and *botar* 'bounce'. These language-specific preferences in the *expression* of motion information, in turn, may create different expectancies for how motion information should be lexicalized in one's language.

1.2 Effects of Variation in Motion Expression on Cognitive Processes

Proponents of the theory of linguistic relativity (Sapir, 1929; Whorf, 1956) would suggest that given the aforementioned patterns of expression, speakers of S-languages (e.g., English) would be more attuned to manner information than speakers of V-languages (e.g., Spanish), thus showing a between-language difference. At the same time, researchers have differed in their between-language predictions for path with some arguing that V-language speakers should be more sensitive to path than S-language speakers while others suggest that there should be no difference in sensitivity between the two groups. The predictions for the effect of language on cognition become even more complex when considering within-language differences (i.e., differences between manner and path for a given language) with some suggesting that S-language speakers should be more sensitive to manner than path, others suggesting that they should be more sensitive to path than manner, and others still saying there should be no differences.

One hypothesis—which I will call the "salient verb hypothesis"—is that speakers should be more sensitive to information that is habitually encoded in the verb as it holds a privileged position in a sentence (Papafragou, Massey, & Gleitman, 2002). As such, speakers should

preferentially attend to information that is typically encoded in the verb (Finkbeiner, Nicol, Greth, & Nakamura, 2002; Papafragou et al., 2002). Accordingly, it would follow that S-language speakers would be more sensitive to manner than path, and V-language speakers would be more sensitive to path than manner (within-language type variability); and S-language speakers would be more sensitive to manner than V-language speakers, and V-language speakers would be more sensitive to path than S-language speakers (between-language type variability). Because this theory places more weight on the verb, it would also suggest that these patterns would be stronger for violations of motion information in the verb than in motion elements outside the verb.

A second hypothesis—which I will call the “encodability hypothesis”—is that speakers should be more sensitive to information that is more easily encoded at the clausal level within their language (Gennari et al., 2002). As aforementioned, S-language speakers prefer manner-verb constructions, in which both manner and path are expressed tightly within the same clause, but V-language speakers prefer path-verb constructions, in which path is expressed within the main clause but manner requires the addition of an optional element, typically a subordinate clause. Accordingly, it would follow that S-language speakers would be equally sensitive to path and manner information (given that both are typically encoded in a single clause) while V-language speakers would be more sensitive to path than manner (as manner is typically expressed in an additional clause subordinate to the main clause that encodes path). Between language types, S-language speakers would be more sensitive to manner information compared to V-language speakers. In contrast, speakers of both languages would be equally sensitive to path information given that path is encoded in both languages (either inside or outside the verb). Unlike the salient verb hypothesis, this hypothesis places equal weight on the various elements

encoding motion (i.e., verb, outside the verb) suggesting that these effects should be equivalent regardless of where the manner or path information is lexicalized within the sentence.

A final hypothesis—which I will call the "path universal hypothesis"—is based on Talmy's proposal that path constitutes the core component for any motion event; it is also expressed habitually in both V- and S-languages (Talmy, 2000). As the core component of motion, path may consequently be more salient to all speakers than manner of motion (Kersten et al., 2010). Accordingly, it would follow that all speakers—regardless of language type—would show greater sensitivity to path than manner. Despite this within-language type prediction, this theory does not make any specific between-language predictions about the how path and manner should compare. Thus this prediction would still allow for variability between speakers of V- and S-languages in their sensitivity to either manner or path information. For example, this hypothesis does not preclude the possibility that V-language speakers are more sensitive to path information than S-language speakers or vice versa despite their overall higher preference for path when compared to manner. (See Table 1.1 for a summary of the three hypotheses.)

Table 1.1 *Summary of predictions for sensitivity to path and manner information within each language type and between different language types*

	Salient Verb	**Encodability**	**Path Universal**
Within Language			
V-Language	Path > Manner	Path > Manner	Path > Manner
S-Language	Manner > Path	Path = Manner	Path > Manner
Between Languages			
Path	V-Language > S-Language	V-Language = S-Language	–
Manner	S-Language > V-Language	S-Language > V-Language	–

Previous research has attempted to tease apart these possibilities, using several methodological paradigms, which have included similarity judgment tasks (e.g., Gennari et al., 2002; Papafragou et al., 2002), categorization tasks (e.g., Kersten et al., 2010), word learning (e.g., Emerson, Özçalışkan, & Frishkoff, 2016), and recognition memory (e.g., Gennari et al., 2002; Papafragou et al., 2002); the overarching findings across different studies are presented below.

1.2.1 Similarity Judgment Tasks

The most common technique has been the similarity judgment task in which a participant is shown a target motion event and asked to choose which of two alternative events is most similar to the target event. One alternative preserves manner information but alters path (i.e., same-manner), while the other preserves path information and alters manner (i.e., same-path).[2] However, results in this paradigm have been sharply divided between studies in which participants were asked to verbalize the target events before making their choice between the same-manner and same-path alternatives and those studies that did not require such verbalization. The results from studies without an initial verbal manipulation are described presently before returning to the results of those studies that did use verbal manipulations later.

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[2] Note that while this technique is useful for comparing the relative sensitivity of path to manner within a language, what it contrasts between languages is the manner versus path *bias* rather than making a direct comparison of the manner sensitivity between languages and path sensitivity between languages. For example, if speakers of two different languages both show path-biases (i.e., a preference to choose same-path items over same-manner items), the between-language contrasts can only compare the *strength of the path biases* (i.e., a between-language comparison of their within-language preference for path over manner). However, knowing the strength of the within-language preference for path over manner does not provide any information about how the salience of manner information, in its own right, might compare between two languages. In this scenario, it is still possible that one group of speakers may find manner information more salient than the other group of speakers. Yet, if the salience of the individual manners in the trials is still weaker than the salience of the path in the opposing alternative event, the participant will necessarily choose the path event, thereby masking any between-language differences in manner salience. Consequently, the forced-choice design prevents the comparison of manner and path *individually* between languages. As such, all between-language comparisons in this paradigm should be thought of as comparing biases rather than separate comparisons of manner and path sensitivity as described in the two "Between Languages" rows of Table 1.1.

For studies in which the participants **did not verbalize** the target event prior to making a decision, within-language comparisons of path and manner and between-language comparisons of biases have led to results that are highly variable and often contradictory. For example, within-language findings for English (an S-language) were inconclusive: two studies (Finkbeiner et al., 2002; Loucks & Pederson, 2010) found evidence of a manner bias (i.e., a preference to choose more same-manner than same-path events), one study found a path bias (Cardini, 2010), and three found no strong bias for either manner or path (Finkbeiner et al., 2002; Loucks & Pederson, 2010; Papafragou et al., 2002). Similarly, within language-findings for V-languages (for example Spanish and Japanese) also showed contradictory results, including either a path bias (Spanish: Bohnemeyer, Eisenbeiss, & Narasimhan, 2006), manner bias (Spanish: Loucks & Pederson, 2010; Japanese: Bohnemeyer et al., 2006; Finkbeiner et al., 2002), and no bias for either manner or path (Spanish: Finkbeiner et al., 2002; Japanese: Loucks & Pederson, 2010). In fact, a comprehensive survey of 17 different languages showed that the within-language biases for S-language speakers tended to lean towards weak manner biases while V-language speakers showed a range from strong manner to weak path biases (Bohnemeyer et al., 2006).

Between-language comparisons using similarity judgment tasks also yielded similar inconclusive results. Most studies showed the same within-language bias in speakers of both language types (i.e., both groups showed either a manner-bias, a path-bias, or no bias) and the strengths of the biases did not differ between languages (Cardini, 2010; Gennari et al., 2002; Loucks & Pederson, 2010; Papafragou et al., 2002). Only two studies have shown between-language differences using the similarity judgment paradigm without verbalizations: One study by Finkbeiner et al. (2002) found a stronger manner bias in speakers of an S-language (English)

than in either Japanese or Spanish speakers—both of which are V-languages. While this between-language outcome would be predicted by all three of the aforementioned hypotheses, this same study also found that Japanese speakers chose same-manner significantly more often than chance—a within-language prediction not made by any of the hypotheses. The second study was Bohnemeyer et al. (2006), which found multiple between-language differences across 17 languages where the preference for choosing the same manner videos ranging from 43% of the trials (Jalonke and Yikatek; V-languages) to 85% of trials (Polish; S-language). The study provided some support for the salient verb hypothesis for S-languages in that all showed at least a slight preference to choose the same manner video over path, but this preference was barely present in one of the S-languages (i.e., Tiriyo), in which speakers chose same manner videos in only 52% of trials. The variability was even greater between the 12 V-languages with the number of same-manner choices ranging from 43% (i.e., Jalonke and Yikatek) to 78% (i.e., French) of the trials. Thus, it did not appear that the variability in biases across the 17 languages studied varied according to their language type as predicted by the theory of linguistic relativity (Sapir, 1929; Slobin, 1996; Whorf, 1956).

The inconclusive results in similarity judgment studies without verbalization might suggest that the results may be an outcome of the experimental design of each study, particularly the stimuli used to capture within versus between-language differences. In fact, both Finkbeiner et al. (2002) and Loucks and Pederson (2010) found that the within-language biases for manner or path were highly sensitive to the particular demands of the task. Loucks and Pederson (2010) also suggested that the similarity judgment tasks may suffer from key methodological shortcomings. In particular, they suggest that it is unclear what strategy participants may be using to determine "similarity" between two events and that the forced-choice design may

encourage participants to engage in a strategy that might not correspond to the strategies they would use under more natural settings.

In contrast to the conflicting results found in the previously described studies, similarity judgment studies in which **participants verbalized events** showed more consistent results. Gennari et al. (2002) found that after describing the target stimuli, English speakers (S-language) showed no within-language bias (i.e., chose the same-manner and same-path alternatives with equal frequency) while Spanish speakers (V-language) showed a within-language path bias (i.e., chose same-path alternatives more often than same-manner). A similar study by Lai and Narasimhan (2015) examined Spanish-English bilinguals. In this study, participants were asked to repeat sentences describing both the manner and path of the target motion event in either English or Spanish. Similar to the results of Gennari et al., Lai and Narasimhan found that speakers who repeated English sentences showed no within-language bias for either path or manner while speakers who repeated Spanish sentences demonstrated a path bias. Looking at between-language differences, the biases (or lack thereof) evident within each language showed significant between-language differences in both studies.

The pattern of results from these two studies supports the encodability hypothesis, namely that S-language speakers—who encode manner and path within the same clause—should show no biases in motion sensitivity while V-language speakers—who encode path in the main clause with manner in an optional subordinate clause that is typically not expressed—should show a path-bias. Importantly, this pattern of results was also found in the Lai and Narasimhan (2015) study despite speakers being exposed to the same motion information in the verbal descriptions (i.e., all statements included both path and manner descriptions). This suggests that, at least in terms of similarity judgments the key factor in motion sensitivity is how the

information is habitually encoded rather than what information is actually expressed during the presentation of the stimulus. In other words, the lack of manner in habitual expression in Spanish led to a decrease in Spanish speakers' manner-biases despite the actual presence of manner in the descriptions they were repeating (as in the Lai and Narasimhan study).

One potential reason why verbalization led to more consistent findings across these studies could be that it provided participants with an explicit strategy for structuring their thoughts about the target event. Thus, in response to Loucks and Pederson's (2010) critique of the similarity judgment paradigm, the use of language during the task may have given speakers a convenient way to operationally define similarity (e.g., events that have more linguistic elements in common). This linguistic strategy is also in line with Slobin's (1996) Thinking for Speaking hypothesis which suggests that the process of verbalizing (or interpreting someone else's verbalization of) an event influences a speaker's conceptualization of that event to be more consistent with the language the speaker is using to describe it.

On the whole, while similarity judgment tasks without verbal manipulations resulted in contradictory results, studies with verbalization showed clear differences between the strength of manner and path preferences between speakers, suggesting that speakers are more sensitive to elements that are more easily encoded at the clause level within their language (i.e., encodability hypothesis). These conclusions should be considered tentative, however, given that they are based on two studies, both of which used English and Spanish as their representative S- and V-languages, respectively.

1.2.2 Categorization/Word Learning Tasks

A second approach to examine sensitivity to manner and path information involves the use of learning tasks in which participants are asked to classify motion exemplars into groups as examples of a new word or new category. One such experiment by Kersten et al. (2010) asked Spanish (V-language) and English (S-language) speakers to classify bug-like animations that varied in a number of physical aspects as well as in the manner and path with which they moved. Participants had to learn to classify the creatures by either the manner or path of motion into groups labeled by a pseudo-verb, a pseudo-noun, or a group numeral (i.e., 'Specie 1' through 'Specie 4'). English speakers showed greater accuracy in categorization than Spanish speakers when the relevant categorization feature was manner, but not path, suggesting a between-language difference in categorization for manner, regardless of the label. Labels, however, were shown to affect within-language contrasts. When motions were labeled with a pseudo-verb or pseudo-noun (but not with a numeral), both English and Spanish speakers demonstrated quicker learning and higher accuracy for classification when the relevant categorization feature was path than when it was manner. When labels consisted of specie numerals, Spanish speakers again showed greater accuracy at labeling path than manner events; but no differences were observed between the two tasks for English speakers.

The results of the Kersten et al. study are partially consistent with the hypothesis that speakers are more sensitive to elements that are easily encoded within their language at the clausal level (encodability hypothesis) but only when the motion events are labeled with numerals as opposed to pseudo-verbs or pseudo-nouns. In particular, the encodability hypothesis makes the between-language prediction that speakers of English (the V-language) would perform better on categorizing manner than speakers of Spanish (the V-language) but would show no

between-language differences in categorizing path. However, the hypothesis also makes the within-language prediction that Spanish speakers would be able to classify path items better than manner items while English speakers would classify manner and path items equally well—a prediction partially supported by Kersten et al. study when the events were labeled with numerals. In contrast, Kersten et al. found that when the events were labeled with pseudo-verbs or pseudo-nouns, all speakers were able to classify path items better than manner items, which in turn, supports the hypothesis that all speakers—regardless of language—are more sensitive to path information than to manner information (path universal hypothesis). Because this theory makes only within-language predictions, it is not incompatible with the between-language results found by Kersten et al. It is unclear why the presence of a pseudo-word might trigger this difference, but the salient verb hypothesis, which emphasizes the role of the verb in the sentence, might suggest that the presence of a verb—or another privileged element such as a noun—could have an impact on how speakers processed the motion information. In contrast to the salient verb hypothesis, this biased English speakers towards the path rather than manner information.

A second study by Emerson et al. (2016) examined the effect of manner versus path sensitivity in learning novel words. In this study we asked speakers of English to learn pseudo-words that described motion animations that varied in either path or manner. Participants were told that these pseudo-words were from a new language but were not told what part of speech the words belonged to. Similar to the pseudo-word experiment of Kersten et al. (2010), Emerson et al. found that English (S-language) speakers learned new words referring to path better than the ones referring to manner, thus providing additional support for the hypothesis that all speakers may be more sensitive to path than manner information (path universal hypothesis) particularly when a salient word label (e.g., a pseudo-word) is present.

Putting the two studies together, within-language results support the path universal hypothesis that suggests that all speakers should be more sensitive to path compared to manner. This hypothesis, however, leaves open the question of between-language comparisons. While Emerson et al. (2016) lacked a between-language comparison group, the results from between-language comparisons in Kersten et al. (2010) support for the encodability hypothesis: Stimuli that differed in manner of motion were categorized more quickly and accurately by speakers of a language (English) in which manner is more easily and frequently encoded compared to a language in which it is not (Spanish); there were also no differences between English and Spanish for path, which is equally encodable in both languages. In line with the similarity judgment tasks, these results also suggest that the presentation of linguistic stimuli—whether it be real or pseudo-language presented by the experimenters or real language elicited from the participants—mediate the cognitive biases involved with processing the motion events.

1.2.3 Recognition Memory Tasks

A final paradigm used to examine motion sensitivity to manner versus path was to study recognition memory for various motion events after a delay in time. With this paradigm Papafragou et al. (2002), Gennari et al. (2002), and Loucks and Pederson (2010) looked at V-language (English) and S-language (Greek, Spanish, and Japanese, respectively) speakers' ability to recall motion events in visual scenes after a delay period. First looking at between-language differences, none of these studies found any differences between the two language groups' ability to discriminate motion events they had previously seen from the ones that were altered in either manner information or in path information. Turning next to within-language differences, while not statistically tested, both V- and S-language speaking participants in the Papafragou et

al. (2002) study performed slightly better at identifying path alterations than manner alterations after verbalizing the to-be-remembered events. This possibly suggests better memory for path than manner information. Similarly, both V- (Spanish) and S-language (English) speaking participants in the Gennari et al. (2002) study produced a larger—though again, not statistically tested—number of false alarms to videos that were altered in manner than to those that were altered in path but only if they had previously verbalized the event. Importantly, this was a pattern that was not evident if the participants were not asked to verbalize the event or asked to repeat nonsense syllables (Gennari et al., 2002). Loucks and Pederson (2010) also found a tendency for better memory for path than for manner information in participants who had not verbalized the events—but without a significant difference. These studies thus provide tentative (but not statistically-tested) support for the path universal hypothesis that all speakers—V-language or S-language—are more sensitive to path information than manner information.

Altogether the results from these previous studies, using one of the three common paradigms (i.e., similarity judgment tasks, categorization and word learning tasks, and recognition memory tasks), suggest a complex relationship between motion expression and sensitivity to path and manner information. Results from the similarity judgment task experiments in which the target stimuli were verbally described and from the within-language contrasts made in word learning and categorization tasks (but not the between-language contrasts) lend support to the encodability hypothesis, which states that sensitivity to motion information follows a pattern akin to its expression at the clausal level. On the other hand, patterns of results in recognition memory studies with verbalizations (albeit not tested statistically) and from the within-language contrasts for word learning and categorization tasks support the path universal hypothesis that all speakers are more sensitive to path information

than to manner information. To date, no strong support has been found for the hypothesis that sensitivity is heightened for information encoded in the verb as suggested in the salient verb hypothesis. At the same time, partial support comes from the similarity judgment tasks without verbalization (Bohnemeyer et al.,2006) which showed that across the four S-languages studied, speakers tended to have a moderate to strong manner-bias. Yet, as aforementioned, these results have proven difficult to replicate and are likely largely dependent on task demands. Despite the lack of clear evidence, the salient verb hypothesis has played a significant role in the formulation of numerous studies examining linguistic relativity within the domain of motion and therefore is also included in our study.

As such, behavioral research has begun to uncover patterns concerning the nature of motion event expression and conceptualization; however, further research and more sensitive techniques are still needed to provide more definitive answers on the relationship between motion expression and cognition. In particular, the tasks described here measure accuracy (i.e., memory, categorization, and word learning tasks) and subjective judgments (i.e., similarity judgment task), which can only assess the end-state of a process. However, prior to making a decision in a task, a participant goes through a series of cognitive operations, which may be difficult to measure at the behavioral level. As such, neural measures can provide information on the subtle differences in the ongoing processing of stimuli that occur prior to a behavioral response. To date no study has examined the neural correlates of motion lexicalization nor to the crosslinguistic sensitivity to path and manner information that result from these various lexicalization preferences. Consequently, the second aim of this study is to examine crosslinguistic sensitivity to motion processing using a novel event-related brain potential (ERP) paradigm.

1.3 Event-Related Brain Potentials

Electroencephalography (EEG) is a noninvasive neural recording technique that involves the placement of electrodes on the scalp in order to record brain activity in response to external or internal events and is particularly useful for measuring the unfolding of neural cognitive processes over time. The continuous stream of electrical activity in the EEG is then segmented into epochs approximately one second long that are time-locked to the presentation of target stimuli. Trials of the same condition are then averaged together to form ERPs. It is assumed that any activity not related to the information processing operations associated with the target stimuli will vary randomly between trials and will thus average to zero across trials. The remaining activity after this averaging process consequently represents neural activity that is time-locked to the onset of that particular event and reflects the underlying processing of the stimuli. This technique gives ERPs a high level of temporal precision and enables the measurement of changes in the processing of stimuli as they occur to a precision of milliseconds after the onset of the stimulus.

Of particular relevance to the processing of linguistic stimuli are the ERP components known as the N400 and the P600. The N400 is a negative component with a centroparietal scalp distribution that peaks in amplitude approximately 400ms after the onset of a semantically incongruent stimulus (Kutas & Hillyard, 1980). Kutas and Federmeier (2000, 2011) have suggested that the N400 ERP component reflects the online integration of meaningful stimuli and that this process integrates all available—linguistic and nonlinguistic—information as it becomes available in order to make predictions about upcoming information. Typically, this anticipatory procedure eases the processing load; however, when an unexpected stimulus is encountered, more energy must be exerted (exhibited as an increased amplitude in the N400) in

an attempt to integrate the incongruent information. This makes the amplitude of the N400 a good index of a participant's expectancy for a particular stimulus within a given context, with larger amplitudes indexing a larger degree of violation to expectations. The P600 is a positively deflecting component with a centroparietal scalp distribution that usually occurs between 500 and 800ms after the presentation of a syntactic error and has been suggested to reflect the reanalysis of linguistic stimuli in an attempt to reconcile the meaning of the critical word with the rest of the sentence (Osterhout & Holcomb, 1992). Similar to the N400, greater energy (i.e., larger positive amplitudes for the P600) must be exerted when trying to interpret and reconcile the syntactically anomalous or ambiguous (e.g., in a garden-path sentence) information. However, more recent evidence has blurred the line between this semantic/N400 and syntactic/P600 distinction with the emergence of evidence for P600 effects in response to certain types of semantic errors (Kuperberg, 2007).

1.3.1 N400

In the traditional N400 paradigm, participants either hear or see sentences in which one word is semantically congruent or incongruent with the rest of the sentence. For example, the participant might hear the sentence '*I like to take my coffee with milk and...*' followed by the word '*sugar*' or '*socks*'. The amplitude of the N400 is typically larger to the incongruent word (e.g., 'socks') than it is to the congruent word (e.g., 'sugar'; Kutas & Van Petten, 1988).

More recent work has shown that the amplitude of the N400 can also be sensitive to several factors other than semantic congruency. These include the factors related to expectancy such as usage frequency of the word in a language (Halgren & Smith, 1987; Rugg, 1990; Van Petten, 2014; Van Petten & Kutas, 1990, 1991; Young & Rugg, 1992) as well as the repetition of

the word in an experimental task (Rugg, 1985, 1990; Halgren & Smith, 1987; Young & Rugg, 1992)—both of which lead to decreases in N400 amplitude. In contrast, factors related to meaningfulness—such as larger orthographic neighborhoods (Holcomb, Grainger, & O'Rourke, 2002; Laszlo & Federmeier, 2011; Van Petten, 2014), concreteness (Kounios & Holcomb, 1994; Van Petten, 2014), and words that elicit a greater range of diversity in responses on free-association tasks (Laszlo & Federmeier, 2011; Van Petten, 2014)—lead to increases in N400 amplitudes. In fact, even nonlinguistic stimuli can elicit an N400 effect in similar contexts. Gestures (Özyürek, Willems, Kita, & Hagoort, 2007; Wu & Coulson, 2005), photographs (McPherson & Holcomb, 1999; Proverbio & Riva, 2009), drawings (Holcomb & McPherson, 1994; Willems, Özyürek, & Hagoort, 2008), faces (Bobes, Valdés-Sosa, & Olivares, 1994; Voss & Paller, 2006), videos of actions and motions (Amoruso et al., 2014; Sitnikova, Holcomb, Kiyonaga, & Kuperberg, 2008), nonlinguistic sounds (Chao, Nielsen-Bohlman, & Knight, 1995; Van Petten & Rheinfelder, 1995), and even odors (Grigor, Van Toller, Behan, & Richardson, 1999; Sarfarazi, Cave, Richardson, Behan, & Sedgwick, 1999) have all been shown to elicit larger N400s in situations in which they violate a particular expectation.

Another factor that has been found to have a major impact on the amplitude of the N400 is the *larger context in which the stimulus is presented*[3]. For example, when words are presented in pairs or lists, target words that are semantically related to a preceding word (prime) elicit smaller N400s than words that are semantically unrelated demonstrating that the prime has activated related representations (Bentin, McCarthy, & Wood, 1985; Brown & Hagoort, 1993;

[3] While paradigms assessing congruency and context have a high degree of overlap, the two paradigms have notable differences. In particular, congruency typically refers to whether or not the target stimulus is in some way erroneous with respect to the surrounding information. For example, the term '*socks*' in the sentence '*I like to take my coffee with milk and socks'* (Kutas & Van Petten, 1988) would be considered incongruent because coffee would generally not be drunk with socks. In contrast, context refers to a broader concept in which the target stimulus is unexpected given the preceding information but does not necessarily have to be erroneous. For example, when a target stimulus does not match the theme of a preceding list of stimuli, it would be unexpected given the context of the previous stimuli; however, it would not be considered erroneous.

Kutas, 1993; Kutas & Hillyard, 1989; Rugg, 1985). When presented in a sentential context, the cloze probability of a word (i.e., a measurement of the number of people who chose that particular word as the best completion to a sentence fragment) is a strong predictor of the N400 amplitude that it will produce (Kretzschmar, Schlesewsky, & Staub, 2015; Kutas & Hillyard, 1984). Furthermore, congruous, open-class words that appear later in the sentence—and as such have more context—elicit smaller N400s than words that appear earlier in the sentence (e.g., the word 'keys' versus the word 'car' in the sentence 'He couldn't start the *car* because he had forgotten his *keys*'; Payne, Lee, & Federmeier, 2015; Van Petten & Kutas, 1990, 1991). Similarly, when otherwise nonsensical sentences are given some sort of global context either through the use of an informative title (St. George, Mannes, & Hoffman, 1994) or through the preceding discourse (Nieuwland & van Berkum, 2006; van Berkum, 2009), the N400 will also be reduced. Even nonlinguistic stimuli can provide a context for a word stimulus that will evoke an N400, such as pictures (Wilkinson, Stutzman, & Seisler, 2015), meaningful actions (van Elk, van Schie, & Bekkering, 2008), gestures (Kelly, Kravitz, & Hopkins, 2004; Wu & Coulson, 2005), and nonlinguistic sounds (Van Petten & Rheinfelder, 1995). Thus, larger N400s can be elicited in situations in which the stimulus is locally congruent (e.g., within the sentence) but is somehow incongruent within the larger context.

1.3.2 P600

Another relevant ERP component is the P600. This component is a positive deflection with a centroparietal scalp distribution that usually occurs between 500 and 800ms after the presentation of a syntactic anomaly (Osterhout & Holcomb, 1992). For example grammatical errors such as the word 'throw' in the sentence '*The spoilt child <u>throw</u> the toy to the ground*'

produced a larger P600 component compared to the syntactically correct word ‘throws’ (Hagoort, Brown, & Groothusen, 1993). Additionally, sentences with syntactic constructions that lead the reader to parse the sentence one way often elicit a P600 effect when a critical word appears that forces the reader to reevaluate their parsing of the sentence (i.e., garden-path effect). For example the phrase ‘was lying’ in the ambiguous sentence ‘*The lawyer charged the defendant was lying*' produced a larger P600 amplitude than the same phrase than in the less ambiguous sentence ‘*The lawyer charged that the defendant was lying*' (Osterhout, Holcomb, & Swinney, 1994).

More recently it has been suggested that, rather than being sensitive to only the syntax of linguistic stimuli, this component may instead index a more domain-general processing mechanism that is related to the cost of integrating the violating item into a larger structure (Christiansen, Conway, & Onnis, 2012). For example Christiansen et al. (2012) found that after a brief training period on a miniature grammar for nonwords paired with graphical symbols, tokens that did not conform to the grammar elicited a P600 effect that was similar to those that were elicited by violations to number agreement between a noun and verb. Similarly, Patel, Gibson, Ratner, Besson, and Holcomb (1998) found that chords in a musical phrase that were out of key based on the norms of Western European music produced a P600 effect that was nearly identical to those produced by a garden path sentence.

While the P600 has traditionally been studied with respect to syntax and the structure of organized systems more broadly, more recently this component has been found in response to semantic irregularities. Sentences that contain a mismatch between an inanimate object and some action expressed by the verb are one type of stimulus that elicits such a response (Hoeks, Stowe, & Doedens, 2004; Kim & Osterhout, 2005; Kuperberg, Caplan, Sitnikova, Eddy, &

Holcomb, 2006; Kuperberg, Kreher, Sitnikova, Caplan, & Holcomb, 2007; Kuperberg, Sitnikova, Caplan, & Holcomb, 2003; Paczynski, Kreher, Ditman, Holcomb, & Kuperberg, 2006; Weckerly & Kutas, 1999). For example, the verb *eat* with the inanimate subject *eggs* in the sentence "*Every morning at breakfast the eggs would <u>eat</u>...*" elicited a P600 effect whereas the verb *plant* with the animate subject *boys* in the sentence "*Every morning at breakfast the boys would <u>plant</u>...*" elicited an N400 effect (Kuperberg et al., 2003). Thus so called 'semantic-thematic' violations (i.e., violations to the thematic role of a particular noun in relation to particular verb, regardless of the syntactic construction of the sentence; Kuperberg, 2007) to animacy may elicit P600 effects instead of the traditionally expected N400.

Other studies have elicited a P600 effect when the critical anomalous word was semantically associated with the context of the sentence, regardless of animacy (Friederici & Frisch, 2000; Kolk, Chwilla, van Herten, & Oor, 2003; Kuperberg, Ditman, Kreher, & Goldberg, 2008; van Herten, Chwilla, & Kolk, 2006). For example, van Herten et al. (2006) found that verbs that had a stronger semantic association with other words in the sentence such as the word *pruned* in the sentence "*John saw that the elephants the trees <u>pruned</u>...*" (high semantic association between 'trees' and 'pruning') elicited a P600 effect whereas completing the sentence with the word *caressed* (low semantic association) instead elicited an N400 component instead.

Incongruities within more global contexts have also been shown to affect the elicitation of the P600, though in different ways: On the one hand, Nieuwland and Van Berkum (2005) presented the sentence "*the woman told the <u>suitcase</u> that she thought [a man] looked really trendy*" either before or after a story that leads to a situation in which a woman might talk to an inanimate suitcase. When the sentence was preceded by a story to contextualize the action, the

noun *suitcase* elicited a P600; however, when the sentence preceded the context, *suitcase* elicited an N400 instead. Thus, an anomalous word that was congruent with the preceding context elicited a P600 instead of an N400. In contrast, Vissers, Kolk, van de Meerendonk, and Chwilla (2008) established a context for their sentences by displaying two shapes in relationship to one another (e.g., a square above a triangle). Sentences that contained a preposition that mismatched the locations of the preceding image such as *above* or *behind* in the sentences "*The triangle stands above the square*" or "*The triangle stands behind the square*" elicited a P600 effect. Thus, Vissers et al. found a P600 effect in response to words that were incongruent with a preceding context.

1.3.3 Application of ERPs to Motion Expression Expectancy and Sensitivity

As stated previously, no study to date has attempted to use ERPs to examine motion events in the domain of either cognitive sensitivity or linguistic expression. However, recent evidence suggests that one or both of these components may be used to index these processes.

1.3.3.1 N400

The N400 has several regularities that may be beneficial in the examination of motion expression: First, although traditionally associated with semantic violations of a sentential context, the N400 is also elicited by a variety of other factors related to word expectancy (e.g., Van Petten, 2014). Thus, it is possible that the encoding of a motion component in an unexpected—albeit grammatical—element may also elicit an N400. For example, in V-languages, such as Spanish, the path of motion is typically expressed in the verb. As such, a speaker may find the use of the verb to express manner unexpected, thereby eliciting a larger N400. Furthermore, once the speaker is aware of the type of sentence construction (i.e., manner-

verb construction or path-verb construction), other expectancies for the remainder of the sentence may also be established. In particular, if a manner-verb construction is in place, in both English and Spanish, a path satellite is also typically expressed. However, in a path-verb construction, the addition of manner information is optional. As such, speakers may have a greater expectancy for the expression of a path in a manner-verb construction than for manner in a path-verb construction, eliciting a larger N400 effect in the latter condition than in the former. Consequently, the N400 may be a useful tool to answer the question of whether or not speakers have an expectancy for motion events to be expressed using the same sentence constructions (i.e., manner-verb or path verb) that are preferentially expressed in that language.

Second, the N400 is sensitive, not only to the local context, but also to more global contexts (e.g., St. George et al., 1994; van Berkum, 2009). This means that even if a stimulus is coherent within a sentence, it can elicit a larger N400 if it contradicts some previously established context. Thus, if a motion component violates a more global expectation, it will elicit an N400 effect even if it is locally congruent. For example, the word ‘run’ in the sentence ‘He runs across the bridge’ is congruent within the local context of the sentence. However, if from a larger context (e.g., from preceding discourse), the speaker has established an expectancy that the actor should be walking in this scenario, the word ‘run’ should elicit a larger N400 than the word ‘walk’.

Third, the global context for a particular word does not need to be linguistic per se (e.g., van Elk et al., 2008; Wilkinson et al., 2015). As such, the global context used to establish expectancies for motion sentences does not need to be verbal but, instead, can involve the viewing of an actual motion event. This means that expectancies for motion expressions can be

established without the use of potentially biasing verbal descriptions (e.g., use of video stimuli instead).

Finally, on the basis of the second and third points stated above, it stands to reason that motion expressions that contain a violation to either the manner or path information established by a global context (i.e., a video of a motion event) will elicit larger N400s than motion expressions that are congruent with those same global expectations. However, if speakers of typologically distinct languages have different sensitivities to the processing of manner and path information based on their habitual expression of motion events, violations in motion expression (i.e., a path or manner word that is incongruent with the global context established by a video of a motion event) should show differences in N400 amplitudes. Thus, N400 comparisons between congruent and incongruent expressions of the different components of a particular motion event may aid in answering the question of whether speakers of different languages show differences in path- and manner-sensitivity.

1.3.3.2 P600

While the N400 has traditionally been associated with semantic processing, certain semantic violations have been shown to elicit P600 effects either in addition to or instead of the N400. In particular, these stimuli typically involved violations to animacy, the anomalous word was semantically associated to the expected word, or the word interacted with a larger global context (i.e., a preceding story or picture). As such, it is possible that motion expressions may also elicit semantic P600 effects for several reasons.

First, Kuperberg et al. (2007) suggested that the semantic P600 may be sensitive to what they call ‘semantic-thematic’ relationships between a verb and its preceding noun phrase argument, particularly between the thematic roles of inanimate objects with particular verbs.

However, they suggest there may be other types of semantic constraints that are related to syntactic structures that could also elicit semantic P600 effects. Given that speakers of typologically distinct languages have strong preferences to express motion using either manner- or path-verb constructions, there is reason to believe that the *lexico-semantic* (i.e., expectations surrounding how certain types of information are typically lexicalized) expectancies associated with motion expression preferences may also be a special case that could elicit P600 effects.

Second, motion violations could be constructed in one of two ways: (1) lexico-semantic violations in which it is anticipated that a word will connote either manner or path information based on its part of speech, but the other type of information is expressed instead or (2) violations to context in which a specific motion word is expected based on the preceding discourse or some other cue, but another word—which may connote either a different motion within the same type or a different type instead—is expressed. In both of these cases the violating critical word would still be a form of motion and thus would be semantically associated with the expected word.

Finally, previous studies have found that manipulating the preceding context for the critical word may influence the amplitude of the P600 effect (Nieuwland & Van Berkum, 2005; Vissers et al., 2008). As such, a semantic P600 might be elicited by motion words that are lexically unexpected but congruent with the preceding video (in line with Nieuwland & Van Berkum, 2005) or by any incongruent word (in line with Vissers et al., 2008).

1.4 Current Study

The current experiment focused on ERPs—the N400 and P600—with speakers of English (S-language) and Spanish (V-language) and addressed two main questions: **First, do**

speakers expect motion events to be verbally expressed in ways that are consistent with the typical lexicalization patterns of the events in their language? For speakers of English, these language-specific patterns involve the use of the manner-verb construction (i.e., manner verb followed by a path satellite; e.g., '*he* ***runs*** *across the bridge*') while for Spanish speakers the patterns involve the use of the path-verb construction (path verb followed by a manner adjunct; e.g., '*he crosses the bridge* ***running***'). Furthermore, it asks how strongly speakers expect additional motion information after a construction type has been established by the verb? In other words, regardless of a speaker's preference for path- or manner-verb constructions, how strongly do they expect a path expression after a manner verb or a manner expression after a path verb? **Second, do speakers of these two languages show crosslinguistic differences in their sensitivity to path and manner information as measured by violations of expectations established by the target motion event serving as a global context?** And if so, do these sensitivities interact with the lexicalization of that information (i.e., within the verb or linguistic elements outside the verb)?

With respect to the first question, if speakers have developed expectations about how motion events should be expressed, differences should appear in response to the verb of each sentence (i.e., the point at which the two sentence constructions diverge). While the manner-verb construction constitutes the preferred pattern among English speakers and the path-verb construction among Spanish speakers, both types of constructions are grammatical in either language. Thus, the current study examines speakers' expectations for the type of sentence constructions that are most frequently used to express motion events in their native language. It is expected that, in line with speakers' rates of expression, English speakers should show larger

N400 effects in response to the verbs in path-verb sentences than to the verbs in manner-verb sentences—a pattern that we expect to be reversed for Spanish speakers.

Furthermore, once the sentence construction type is known, this may establish expectancies for the rest of the sentence. In the case of the manner-verb construction, the verb is almost always followed by a path satellite; however, in path-verb constructions the inclusion of the manner is optional. As such, it is expected that ERPs for speakers of both languages will be sensitive to the optional manner information in the path-verb constructions compared to the more standard expression of path in the manner-verb constructions.

Concerning the second question, larger ERP amplitudes—both N400 (e.g., Wilkinson et al., 2015) and P600 (e.g., Vissers et al., 2008)—have been seen in response to violations of semantic expectancy based on global context (e.g., based on a previously seen image) even when the statements are locally coherent (e.g., within the sentence). Thus, it was predicted that sentences where either the manner or the path information violated the expectations established by a preceding video would elicit larger ERP amplitudes than sentences that describe the preceding video accurately (i.e., congruency). Furthermore, if speakers' languages predispose them to be more sensitive to manner or path information, congruency should interact with motion type (i.e., manner or path), such that incongruent words of one motion type elicit larger ERP amplitudes than incongruent words of the other motion type.

Sensitivity to manner and path incongruities could follow one of three different patterns: (1) According to the salient verb hypothesis, *within-languages*, Spanish speakers will show larger amplitudes in response to path violations than to manner violations while English speakers show the opposite pattern of within-language results. *Between-languages*, path violations will produce larger amplitudes in Spanish speakers than English speakers and vice versa for manner

violations. (2) According to the encodability hypothesis, *within-languages,* Spanish speakers would show larger amplitudes in response to path violations than to manner violations (identical to the within-language prediction made in the previous hypothesis), but English speakers would show similar amplitudes between manner violations and path violations. *Between languages*, manner violations would elicit larger amplitudes for English speakers than Spanish speakers; however, for path violations amplitudes should be similar between English and Spanish speakers. (3) Finally, according to the path universal hypothesis, *within-languages*, all speakers will show larger amplitudes in response to path violations than manner violations, but this hypothesis makes no between-language predictions. Additionally, if the verb plays a privileged role in the interpretation of a sentence (Papafragou et al., 2002), violations may be larger for information expressed within the verb compared to violations expressed outside of the verb.

Overall the study aimed to provide a neural measure of sensitivity to manner and path information in speakers of a V-language and an S-language as well as to establish whether speakers expect motion events to be expressed in the same types of constructions that they typically use in expressing such events verbally. This is also first study to apply an ERP paradigm to identify the neural processes associated with manner- and path lexicalization and sensitivity in motion expression.

2 METHODS

2.1 Participants

The participants included 23 English-speaking (M_{age} = 26.04, SD_{age} = 10.87; 12 males; 0 left-handed, 1 ambidextrous) and 22 Spanish-speaking (M_{age} = 22.17, SD_{age} = 7.11; 4 males; 0 left-handed, 2 ambidextrous) adults. While bilingualism was not an exclusion factor for the

English-speaking group, none reported Spanish as one of their native languages. All participants were recruited from an urban university in the Southeastern United States, and as such, all Spanish speakers also had a high level of proficiency in English. One native Spanish-speaking participant was excluded due to technical errors bringing the total number of Spanish speaking participants to 21. Participants received either a small monetary compensation or course credit for their participation. The participants had no known neurological or language disorders and all had normal or corrected to normal vision.

2.2 Stimuli

2.2.1 Video Stimuli

Thirty-two animated video stimuli were created consisting of a character (a male figure named Felix/Félix) moving in relation to a landmark (i.e., an arched bridge; see Figure 2.1). Each video contained one of eight manners and one of four paths. The eight manners included *walk*, *run*, *jump*, *fly*, *crawl*, *roll*, *limp*, and *slide*. The four paths included *up*/*ascend* (character moves from the base of the bridge to the apex), *down*/*descend* (character moves from the apex of the bridge to the base), *towards*/*approach* (character moves from the right side of the screen towards the base of the bridge), and *across*/*cross* (character moves right to left across the bridge). See Appendices A and B for a full description of all 32 videos.

2.2.2 Linguistic Stimuli

During the ERP task, each of the 32 videos was accompanied by one of six possible sentence types that varied in congruency (congruent, incongruent) and in sentence construction (path-verb construction, manner-verb construction; Table 2.1). Congruent sentences accurately

described both the path and manner of the preceding video. Incongruent sentences either accurately described the manner in the video while describing a different path (path-incongruent) or accurately described the path in the video while describing a different manner (manner-incongruent). Participants saw a total of 256 sentences: Half of these sentences were congruent with the preceding video (one set of 64 distinct sentences repeated twice), and the other half were incongruent with either the path (n = 64) or the manner (n = 64) depicted in the video, thus resulting in equal number of sentences (i.e., 128 congruent, 128 incongruent) that either matched or mismatched the motion event in the video. The order in which trials were presented was randomized between participants.

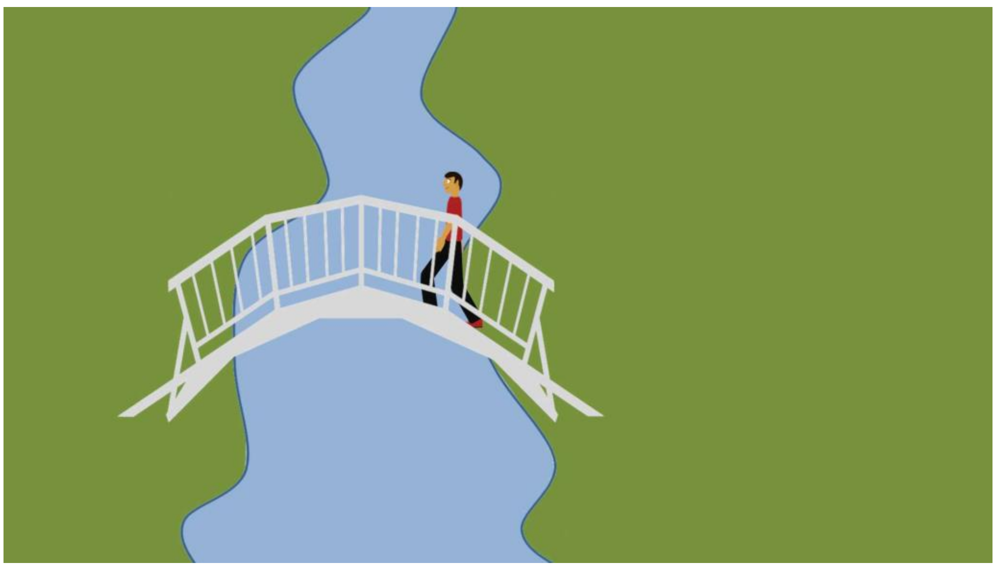

Figure 2.1 *Sample screenshot from a video stimulus.*

Table 2.1 *Sample verbal descriptions for the two types of sentence constructions in the two congruency conditions for walking up a bridge.*

	Manner-Verb Construction	**Path-Verb Construction**
Congruent	*Felix **walks** <u>up</u> the bridge*	*Felix <u>ascends</u> the bridge **walking***
Manner Incongruent	*Felix **runs** <u>up</u> the bridge*	*Felix <u>ascends</u> the bridge **running***
Path Incongruent	*Felix **walks** <u>down</u> the bridge*	*Felix <u>descends</u> the bridge **walking***

Manner information is in bold and path information is underlined

Half of the sentences had a manner-verb construction and half had a path-verb construction (see Appendix A and B for a full list of manner-verb and path-verb constructions, respectively). Manner-verb sentences included a subject, manner verb, and a path preposition along with a landmark (e.g., '*He walks up the bridge*'/'*Camina el puente arriba*') while path-verb sentences included a subject, path verb, landmark, and a manner gerund (e.g., '*He ascends the bridge walking*'/'*Sube el puente caminando*').

Translations between English and Spanish expressions were confirmed by native speakers in each language. Importantly, the translation of a sentence in one language did not always result in the same number of words or constituent orders in the other language. For example, due to various language-specific lexical requirements, the translations of the concepts expressed as 'approaches', 'slides', and 'across' in English (which all require a single word to expressed as '*approaches*', '*slides*', and '*across*' in English (which all require a single word to express in English) require two to three words to express in Spanish ('*llega a*', '*se desliza*', and '*a través del*', respectively). To ensure that participants received comparable amounts of information during each ERP measurement, all sentences were divided into four parts that were presented on four separate screens: subject (i.e., '*Felix*'/'*Félix*'), main verb (e.g., manner: '*walks*'/'*camina*'; path: '*ascends*'/'*sube*'), subordinate motion (e.g., manner: '*walking*'/'*caminando*'; path: '*up*'/'*arriba*'), and landmark (e.g., 't*he bridge*'/'*el puente*').

Similarly, in the linguistic stimuli used for the present study, the two languages differ in their ordering of manner-verb but not path-verb constructions. More specifically, the path-verb sentence construction (Appendix B) for both the English and Spanish sentences are in the order of subject, main verb, landmark, and then subordinate verb (e.g., '*Felix ascends the bridge walking*'/'*Félix sube el puente caminando*'). However, for English sentences, the manner-verb

construction (Appendix A) follows the order of subject, main manner verb, subordinate path (i.e., preposition), and then landmark (e.g., '*Felix walks up the bridge*'). For Spanish, by contrast, half of the manner-verb sentences follow the same construction of English manner-verb sentences (e.g., '*Félix camina hacia el puente*': '*Felix walks toward the bridge*') while half follow the pattern of the path-verb constructions (e.g., '*Félix sube el puente caminando*': '*Felix walks up the bridge*') due to the constraints in the lexicalization of motion in Spanish.

As outlined in Table 2.1, each of the 32 videos was associated with six different sentences. Half of the sentences contained a manner-verb construction and half contained a path-verb construction. Additionally, half were congruent and half were incongruent with the video. Because there were two types of incongruent sentences (manner-incongruent, path-incongruent), each congruent sentence was repeated twice during the testing phase of the ERP experiment to yield an equal number of congruent and incongruent sentences. As such, each video was repeated eight times: four times with a congruent sentence, twice with a path-incongruent sentence, and twice with a manner-incongruent sentence. Half of the sentences used a path-verb construction and the rest used a manner-verb construction. This procedure yielded a total of 256 trials per participant that were divided into four equal blocks of 64 randomized trials.

Previous research has shown that the amplitude of the N400 can be modulated by the frequency of stimulus (Halgren & Smith, 1987; Rugg, 1990; Van Petten, 2014; Van Petten & Kutas, 1990, 1991; Young & Rugg, 1992). Given the language-specific construction preferences in each language, motion lexicalization and word frequency are inherently confounded. For example, the manner-verb construction preference in English speakers leads manner verbs and path prepositions to have a higher word frequency than path verbs. In order to better control for the effects of word frequency on the ERP amplitudes, word frequencies were calculated for all of

the target motion words in both languages and used as a random factor (i.e., control variable) in the linear mixed model (LMM) analysis. Lemma frequencies (i.e., each base word and all of the resulting inflections) were obtained from the Corpus of Contemporary American English (COCA; Davies, 2008) for English and the Corpus del Español (Davies, 2016) for Spanish and were converted into frequency per million words based on the total number of words contained within each corpus at the time of the search (COCA: 533,788,932; Corpus del Español: 2,100,761,288). The full list of word frequencies are listed in Appendix C. Because gerunds were not reliably marked as nouns in the Corpus del Español and produced very few hits in COCA, the frequencies associated with the lemma searches for the verbs were used instead. As such the word frequencies for manner verbs and manner expression outside the verb are identical in Appendix C and are not listed twice. For analyses, all frequencies were mean centered across all frequencies. Both the raw and mean centered frequencies are listed in Appendix C.

2.3 Procedure

Participants completed a demographic questionnaire, a language assessment, and the main ERP task using the stimuli outlined above.

2.3.1 Demographic Questionnaire & Language Assessment

Participants first completed a demographic questionnaire aimed at providing information on speakers' background, language history, and basic demographic information including sex, age, and language experiences (see Appendix D for the demographic questionnaire).

Next, each speaker's language comprehension abilities were measured using the Oral Comprehension and Passage Comprehension subtests of the Woodcock-Muñoz Language

Survey (WMLS; Woodcock, Muñoz-Sandoval, Ruef, & Alvarado, 2005a, 2005b). WMLS is a standardized assessment designed to evaluate an individual's listening, speaking, reading, writing, and comprehension proficiencies in English and Spanish. English speakers received the two subtests in English administered by a native speaker of English. Spanish speakers completed the assessments in both Spanish and English; each subtest was administered by a research assistant who was a native speaker of the language being assessed.

2.3.2 ERP Task

Participants were fitted with a 256-electrode HydroCel Geodesic Sensor Net created by Electrical Geodesics Inc. After the net was applied, participants completed a brief training phase designed to familiarize them with the stimuli and procedures followed by a total of 256 test trials divided into four blocks while electroencephalographic (EEG) data were collected.

2.3.2.1 <u>Familiarization</u>

Participants first completed a short five to ten minute familiarization phase in order to become acquainted with the procedure and stimuli. They were told that they would view the videos one at a time and then read a sentence describing each video. They were also told that sentences would either accurately describe (congruent condition) or not accurately describe the preceding video (incongruent condition) and that their task will be to press one button if the sentence matched the preceding video and another button if any part of the sentence mismatched the video.

Next, participants were told that each video contained one of four types of paths. The following screens then displayed each of the four paths (i.e., *up*, *down*, *across*, and *towards*), one at a time. Each path was represented by a static image of an arrow indicating a direction in

relation to the landmark along with the path verb and preposition listed on the screen (e.g., 'ASCEND' 'UP' + arrow stretching from the base of the bridge to the apex; see Figure 2.2a). Participants were informed that the labels listed on each screen were the correct descriptions of the paths. Next, they were instructed that the videos would contain one of eight different manners. In the following screens, the figure acted out the eight manners (i.e., *walk*, *run*, *jump*, *fly*, *crawl*, *roll*, *limp*, and *slide*), one at a time. Each manner was presented with a dynamic video in which the figure acting out the entire manner with the manner verb listed on the screen (e.g., 'RUN' + figure moving legs and arms as if running; see Figure 2.2b). Participants were informed that the label listed on each screen was the correct description of the each manner. After each path image or manner video the participant had to press a key to move on to the next screen.

Exposure to all the paths and manners with their correct labels ensured that the participants were familiar with the linguistic descriptions of each type of manner and path used in the study prior to the start of the experimental trials.

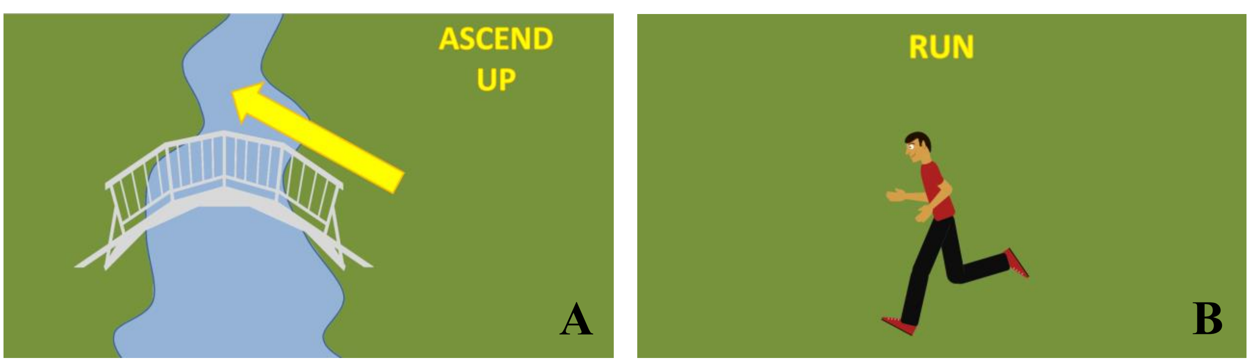

Figure 2.2 *Screenshot of training screens for (a) the path 'ascend' 'up' and (b) the manner 'run'.*

Finally, after seeing all possible paths and manners, participants were informed—via an instructional screen display— that some sentences may sound strange to them and that they

should ignore the sentence construction. They were also reminded that their task was to press one button if the sentence matched the preceding video and another button if any of the information in the sentence mismatched the preceding video. The button associated with matches versus mismatches was counterbalanced between participants. The instructions ended with a screen telling them to wait for the experimenter. The experimenter reiterated the instructions to the participant one more time and prompted them to ask any questions they had.

2.3.2.2 *Testing*

The test trials consisted of the 32 animation videos described previously (see Appendices A and B). Each video was repeated eight times with an accompanying sentence (two congruent manner-verb sentences, two congruent path-verb sentences, one path-incongruent manner-verb sentence, one path-incongruent path-verb sentence, one manner-incongruent manner-verb sentence, and one manner-incongruent path-verb sentence), resulting in a total of 256 test trials divided evenly over four blocks that each took approximately 15 minutes to complete. For each test trial, the participant watched the short animation, read a sentence about the video, and then pressed a button to indicate whether the sentence matched (i.e., congruent) or mismatched (i.e., incongruent) the video. Participants were informed that sentences that match the manner and path depicted in the video should be considered a 'match' (i.e., congruent) while sentences that either differed in manner or in path from the video should be considered a 'mismatch' (i.e., manner incongruent or path incongruent).

Following the presentation of each video, the screen remained blank for a total of 500ms followed by a fixation point (i.e., a '+' symbol) that appeared in the center of the screen for 1500ms. Participants were instructed not to blink during this period and during the presentation of the sentence. The sentence for the video was then provided in the following four screens.

Each of the sentence screens was displayed for 500ms followed by a blank screen for 200ms before the onset of the next screen. Following the completion of the entire sentence for each motion description, participants were presented with a screen that requested a forced-choice response regarding whether the sentence matched or mismatched the preceding video, to which they responded by pressing a button with no time constraints. The screen had the words ‘Match’ and ‘Mismatch’ listed on either side of the screen corresponding to button assigned to that participant to be pressed for that choice (e.g., if the left button corresponded to a match, the word ‘Match’ was presented on the left side of the screen).

Between trials, participants saw a screen telling them to press any button when they were ready to continue. After every 64 trials (i.e., each block), a screen notified participants that they had completed a block and prompted them to take a short break. This allowed participants to set their own pace and take short breaks as needed. After the second block of trials, all of the electrodes were re-wetted to ensure the continuation of a high level of connectivity. Figure 2.3 diagrams the screens from a sample trial.

Event-related brain potentials (ERPs), reaction time, and accuracy were recorded. Electroencephalography (EEG) was recorded using a 256-electrode HydroCel Geodesic Sensor Net created by Electrical Geodesics Inc. (see Figure 2.4) and processed with NetStation. Electrode impedances were kept below 50 kΩ and will be digitized at 250 Hz. EEG was filtered with a 0.1 to 30 Hz bandpass filter and segmented into epochs ranging from 200ms prior to the onset of the stimulus until 700ms post-onset. Because each portion of the sentence was displayed for 500ms and preceded and followed by a 200ms screen, the 200ms prior to the stimulus always corresponded to the presentation of a blank screen, and the 700ms window corresponded to the presentation of stimulus itself as well as the following black screen. As

such, there was no overlap in the presentation of stimuli within each segment. ERPs were time-locked to the onset of each critical word in the trial, baseline-corrected to the 200ms prior to stimulus onset, and average referenced. Any trial that contained ocular artefacts (i.e., blinks or eye movements) or an inaccurate response was excluded from analysis.

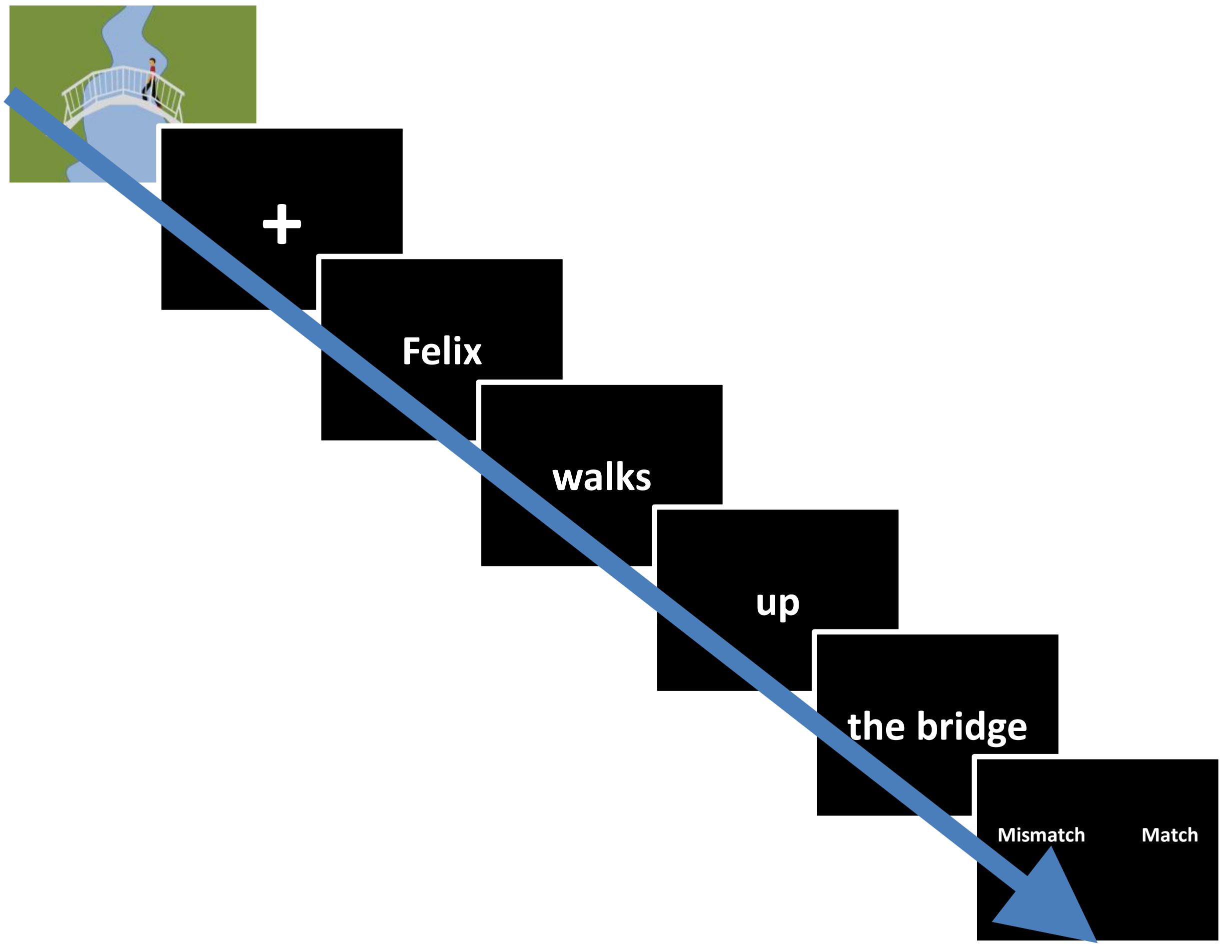

Figure 2.3 *Diagram of stimuli presentation in the primary ERP task. Participants first saw a short animation involving a man performing a manner and a path in relation to a stationary bridge. Following the animation, participants saw a fixation cross for 1500ms. Next, the sentence appeared one to three words at a time, displaying either the subject, main verb, additional motion, or the object. (The order of information displayed in each screen was determined by lexicalization constraints in each language.) Each screen of the sentence was displayed for 500ms followed by a blank screen for 200ms before the presentation of the next screen. Finally, participants saw a screen asking them to indicate whether the sentence matched or mismatched the preceding video. The screen terminated after participants entered a response with the button box.*

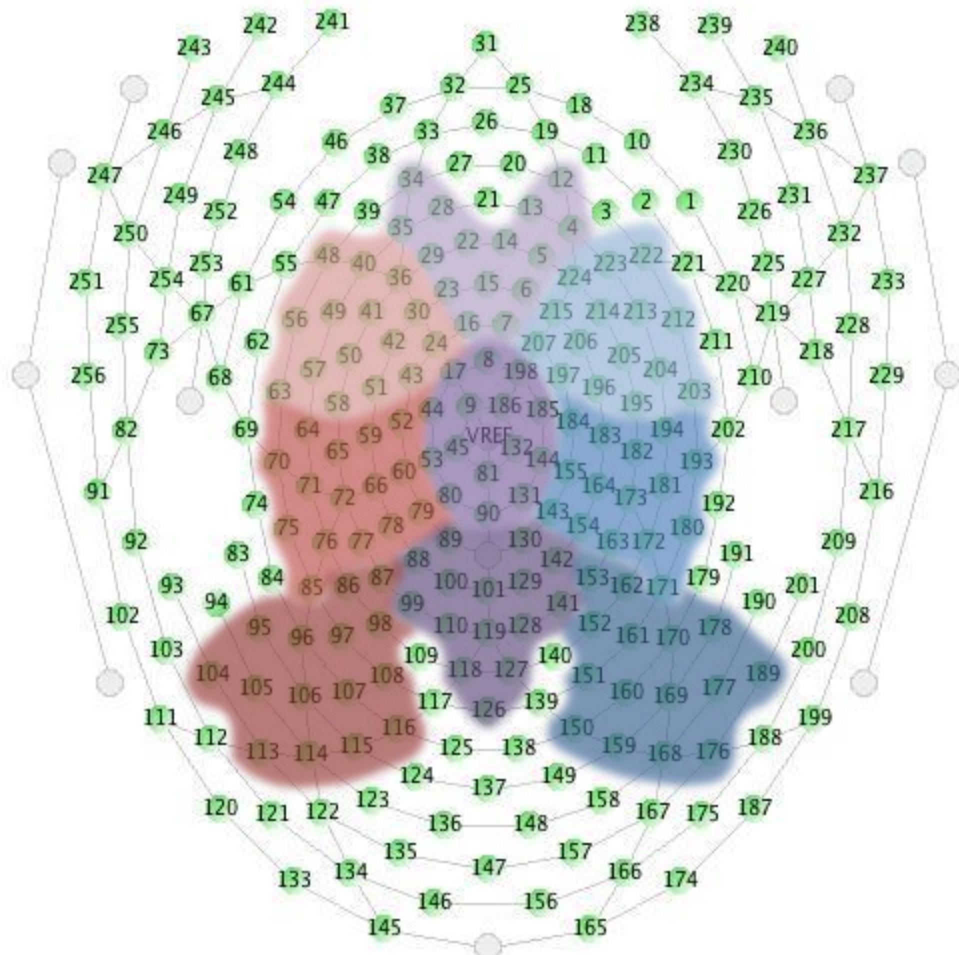

Figure 2.4 *Standard configuration of electrodes in Electrical Geodesics Inc.'s 256-electrode HydroCel Geodesic Sensor Net and the electrodes in the nine regions of interest. The figure is a flattened view from over the head of the participant with eyes at the top of the figure and ears in the blank regions on the left and right side of the figure. The variable laterality is divided into left (red), medial (purple), and right (blue) while the variable antero-posteriority is divided into anterior (light hue; top), central (medium hue), and posterior (dark hue; bottom). Each laterality x antero-posteriority region of interest consisted of 15 electrodes.*

3 ANALYSES

Data were analyzed using Linear Mixed Models (LMMs) using *lmer()* function from the *lme4* library (Bates, Maechler, Bolker, & Walker, 2015) in R (R Core Team, 2017)—a type of analysis that allows for the inclusion of random effects to better account for variance in different baseline levels of performance as well as changes in performance over time on a given item or

by a given participant. The factors included in the models are summarized in Table 3.1. Each analysis proceeded as follows:

(1) First the *maximal model* that was theoretically justified for that dataset (i.e., the model that contained every theoretically justifiable variable) was defined for each analysis.

(2) Then variables were iteratively excluded from the maximal model one at a time and the Akaike information criterion (AIC)[4] was compared for each successive model to find the model with the optimal fit for the data. Variables that did not significantly improve the model fit were excluded from the model until the *optimal model* (i.e., model that contained only the variables that significantly contribute to model fit) was found (Barr, Levy, Scheepers, & Tily, 2013).

(3) After the optimal model for each analysis was found, the highest order interaction (i.e., the interaction containing the most variables) involving unique factors with either MotionType or Congruency that was significant was probed using *post hoc* simple main effects analyses from the *testInteractions()* function of the *phia* library (De Rosario Martínez, 2015). When the highest order interaction for MotionType or Congruency was marginally significant, the probed results were listed in a table but not discussed in the text, and the next highest order interaction that did reach significance was probed as well and discussed. All *post hoc* analyses were adjusted for multiple comparisons using the Holm-Bonferroni method (Holm, 1979).

Importantly, because V-languages preferentially express path verbs and S-languages preferentially express manner verbs, word frequencies were higher for the path verbs in Spanish and for the manner verbs in English. Therefore, to better understand the effects of motion type, both inclusive and exclusive of the effects of word frequency, any model in which MotionType

[4] The AIC is a measure of model fit based on the likelihood function where lower values—relative to other models of the same data—indicate better model fit. Compared to the Bayesian information criterion (BIC), the AIC has a smaller penalty for the number of factors included in the model.

did not contribute to model fit was run again without controlling for WordFreq. The initial inclusion of WordFreq in all models allowed for the examination of the effects of MotionType above and beyond the effects associated with word frequency alone. However, given the integral nature of word frequency with preferred patterns of expression, the exclusion of WordFreq in the cases where MotionType was not significant helped to elucidate whether frequency plays a mediating role in the relationship between motion type with expectancy and sensitivity.

Table 3.1 *Summary of factors for the LMM analyses.*

Factor	**Description**	**Levels**
Fixed Factors		
`MotionType`	Type of information connoted by the target motion word (See Appendices A and B)	Manner, Path
`Congruency`	Congruency of the critical word with preceding video	Incongruent, Congruent
`Language`	Language used in the verbal stimuli and spoken by the participant	English, Spanish
`Block`	Block that the trial occurred in; 64 trials per block	1, 2, 3, 4
`AntPost`	45 electrodes corresponding to the three regions of antero-posteriority across the scalp; interacts with Laterality to produce 9 regions of interest with 15 electrodes each (see Figure 2.5)	Anterior, Central, Posterior
`Laterality`	45 electrodes corresponding to three regions of laterality across the scalp; interacts with AntPost to produce 9 regions of interest with 15 electrodes each (see Figure 2.5)	Left, Middle, Right
Random Factors		
`Block|Subject`	Within-subjects random slopes for Block for each participant	1 to 4 per participant 1 to 44
`Location`	Between-items random intercept for each critical word corresponding to the its presentation order within the sentence (i.e., third or fourth scree); used for expressions outside of the verb only (See Appendices A and B)	3, 4
`WordFreq`	Between-items random intercept for each critical word based on lemma frequency	1.07 to 462.72

	per million words; mean centered across all words for analyses (see Appendix C)
Outcome Measures	
Early Latency	Mean amplitude for the waveform between 200 and 500ms after the onset of the critical word; time window corresponding to the N400
Late Latency	Mean amplitude for the waveform between 500 and 700ms after the onset of the critical word; time window corresponding to the P600

3.1 Lexical Expectancies (Question 1)

The analysis of lexical expectancy was twofold: (1) The first aim was to examine whether speakers of English and Spanish had language-specific *expectancies* for motion events to be lexicalized with either a manner-verb or a path-verb construction. Because manner-verb and path-verb constructions diverge at the point of the verb, speakers will be aware of which construction is being used by the time they have read the verb. In line with typical patterns of expression, it was predicted that English speakers would demonstrate a higher expectancy for manner verbs than path verbs, and Spanish speakers would demonstrate a higher expectancy for path verbs than manner verbs.

(2) The second aim of this analysis was to compare the expectancies for information outside of the verb. Given the more frequent use of path in manner-verb constructions compared to the optional status of manner in path-verb constructions, it was predicted that across languages, speakers should expect path information that is expressed in a preposition in manner-verb sentences (e.g., '*Felix walks up the bridge*') more than they should expect the optional manner gerund in the path-verb sentences (e.g., '*Felix ascends the bridge* ***walking***').

Four separate LMM analyses were conducted to examine expectancy for lexicalization expectancies that focused on either the information expressed within or outside of the verb for ERP amplitudes in the 200 to 500ms time window and the 500 to 700ms time window (see

Figure 3.1). Time windows were chosen to correspond to the typical latencies of the N400 and P600 ERP components, respectively, and were confirmed by visual inspection of the data.

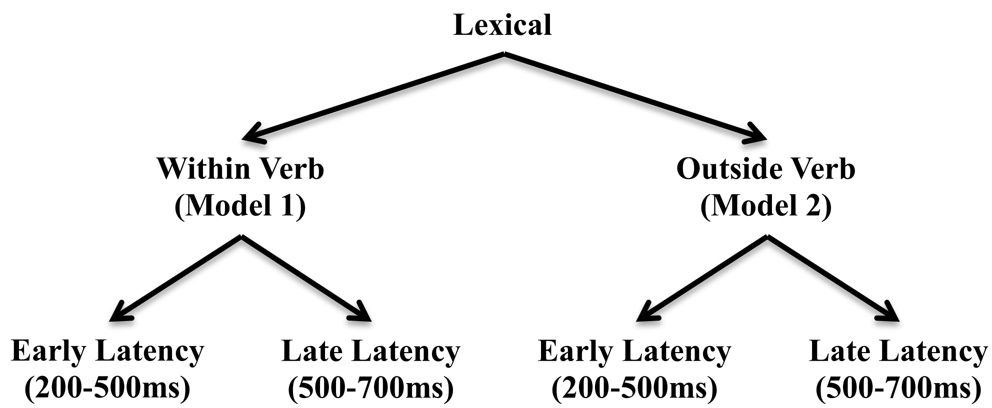

Figure 3.1 *Summary of analyses for lexical expectancy.*

For the analysis of lexical expectancies for the verb, ERPs were time-locked to the onset of all congruent verbs. This included all congruent trials and trials where the motion expression outside the verb was incongruent resulting in a maximum of 192 possible trials per participant. The total number of trials for each condition after the removal of trials with inaccurate responses or ocular artifacts for the lexical expectancies analysis is detailed in Table 3.2, and the maximal model is detailed in Model 1.

```
(1)    Amplitude ~ MotionType * Language * Block * AntPost
       * Laterality + (1 + Block|Subject) + (1|WordFreq)
```

The dependent variable was mean amplitude in either the 200 to 500ms or 500 to 700ms time window time-locked to the onset of the presentation of the verb. The fixed factors included MotionType (manner and path), Language (English and Spanish), Block (1-4), and nine regions of interest (RoIs) dived into two factors: AntPost (anterior, central, and posterior) and Laterality

(left, medial, right; see Figure 2.4 for electrode clusters). Random factors included random slopes for Block within Subjects and random intercepts for WordFreq (see Appendix D).

For the analysis of lexical expectancies for outside of the verb, ERPs were time-locked to the onset of congruent critical words in only the trials that were entirely congruent with the preceding video (maximum of 64 possible trials per participants; Table 3.2) to ensure that no effects from incongruent verbs would carry over into the critical time frame. The maximal model was identical to that of Model 1 with the exceptions that an additional random factor was added for Location as the critical motion word could either occur in the third (i.e., all path expressions outside of the verb in English and the Spanish paths *a través del* and *hacia*) or fourth (i.e., all manner expressions outside of the verb and and the Spanish paths *arriba* and *abajo*) screen. The full model is detailed in Model 2.

```
(2)    Amplitude ~ MotionType * Language * Block * AntPost
       * Laterality + (1 + Block|Subject) + (1|WordFreq) +
       (1|Location)
```

Table 3.2 *Trials per condition for the analyses of lexical expectancies.*

	Verb		**Outside the Verb**	
	Manner (*Max* = 96)	**Path** (*Max* = 96)	**Manner** (*Max* = 64)	**Path** (*Max* = 64)
English (n = 23)				
n	1646	1621	662	1074
%	74.55	73.41	44.97	72.96
M	71.57	70.48	28.78	46.70
SD	21.17	20.20	16.66	14.07
Spanish (n = 21)				
n	1348	1483	633	692
%	66.87	73.56	47.10	51.49
M	64.19	70.62	30.14	32.95
SD	18.93	17.08	18.30	13.44

‘*n*’ total number of trials remaining in analysis across all participants, ‘%’ percentage of maximum number of trials (listed in column headers), ‘*M*’ mean number of trials across

participants, '*SD*' standard deviation of trials across participants

3.2 Motion Sensitivity (Question 2)

The aim of the second set of analyses was to examine whether speakers show heightened sensitivities to manner or path information when it is incongruent with a global context (target motion event). It was predicted that if speakers were more sensitive to one motion type than the other, they would exhibit larger ERP amplitudes in response to the incongruent compared to the congruent motion words labeling the same motion type (i.e., manner or path).

Data were analyzed following the same procedures as for the sentence construction analyses. Two LMMs were conducted to examine the mean ERP amplitudes in the 200 to 500ms and the 500 to 700ms time window time-locked to the presentation of the verb. In order to simplify interpretation of the results, the analyses of manner and path expressions outside of the verb were divided into separate analyses, again focusing on the two different time windows, resulting in a total of four separate LMMs for motion outside of the verb (see Figure 3.2).

For the incongruent conditions, ERPs were time-locked to the onset of the incongruent element (i.e., either manner or path). For half of the congruent sentences, ERPs were time-locked to the onset of the main verb screen. For the other half, ERPs were time-locked to the onset of the screen containing the motion expression outside of the verb (i.e., path preposition or manner gerund). This ensured that there were equal numbers of trials containing congruent and incongruent items within and outside of the verb (i.e., maximum 32 trials per condition). The total number of trials for each condition after the removal of trials with inaccurate responses and ocular artifacts for the motion sensitivity analysis is detailed in Table 3.3.

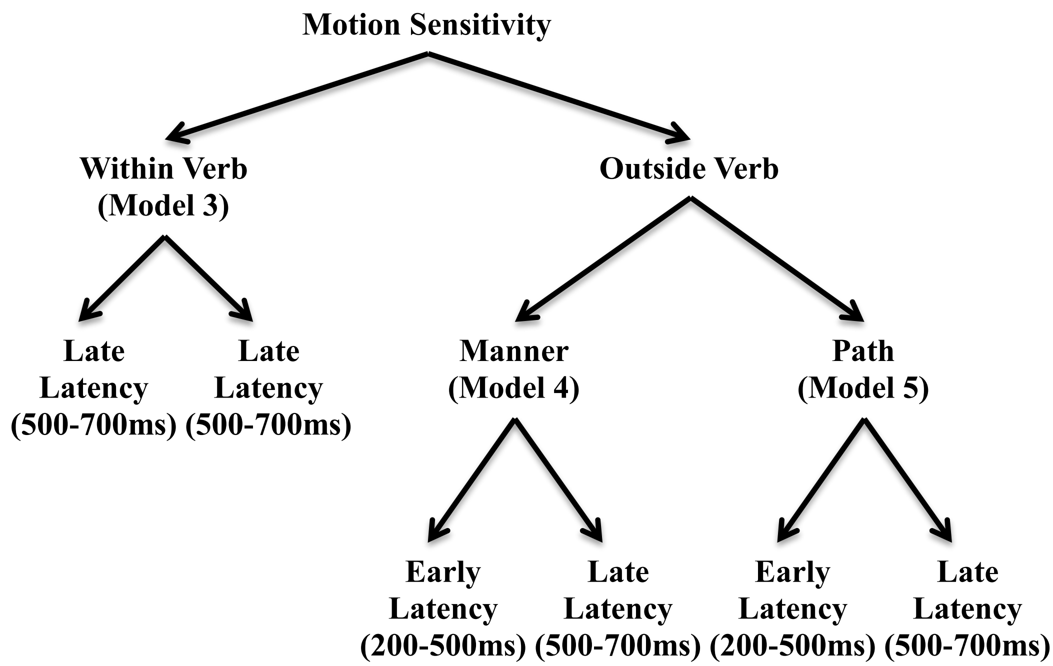

Figure 3.2 *Summary of analyses for motion sensitivity.*

Table 3.3 *Trials per condition for the analyses of motion sensitivity.*

	Verb				**Outside the Verb**			
	Incongruent		**Congruent**		**Incongruent**		**Congruent**	
	Manner	**Path**	**Manner**	**Path**	**Manner**	**Path**	**Manner**	**Path**
English (n = 23)								
n	541	520	545	539	300	557	337	539
%	73.51	70.65	74.05	73.23	40.76	75.68	45.79	73.23
M	23.52	22.61	23.70	23.43	13.04	24.22	14.65	23.43
SD	6.55	7.74	7.60	7.26	9.47	5.44	8.67	7.29
Spanish (n = 21)								
n	499	457	450	495	312	358	305	342
%	74.26	68.01	66.96	73.66	46.43	53.27	45.39	50.89
M	23.76	21.76	21.43	23.57	14.86	17.05	14.52	16.29
SD	6.14	6.54	7.58	5.75	9.17	7.32	9.38	6.81

‘*n*’ total number of trials remaining in analysis across all participants, ‘%’ percentage of maximum number of trials (32 for each condition), ‘*M*’ mean number of trials across participants, ‘*SD*’ standard deviation of trials across participants

The maximal model for the analysis of the verb violations is detailed in Model 3.

```
(3)    Amplitude ~ MotionType * Congruency * Language *
       Block * AntPost * Laterality + (1 + Block|Subject) +
       (1|WordFreq)
```

Model 3 is identical to Model 1 with the notable exception of adding Congruency (congruent or incongruent) as a fixed factor.

The maximal model for motion violations outside of the verb for manner is detailed in Model 4.

```
(4)    Amplitude ~ Congruency * Language * Block * AntPost
       * Laterality + (1 + Block|Subject) + (1|WordFreq)
```

Because path and manner were analyzed separately, MotionType was removed as a fixed factor from the model and instead Congruency was added.

The maximal model for the motion violations outside of the verb for path is detailed in Model 5.

```
(5)    Amplitude ~ Congruency * Language * Block * AntPost
       * Laterality + (1 + Block|Subject) + (1|WordFreq) +
       (1|Location)
```

Unlike manner expressions outside of the verb, which were always displayed in the fourth screen, path expressions outside the verb could be displayed in either the third (i.e., all English paths and *a través del* and *hacia* in Spanish) or fourth (i.e., *arriba* and *abajo* in Spanish) screen. As such, Location was added as a random intercept in the maximal model for these analyses.

4 RESULTS

4.1 Lexical Expectancies (Question 1)

4.1.1 Within the Verb

The grand average waveforms for the lexical analysis of verbs can be seen in Figure 4.1. The optimal model for the mean amplitudes in response to congruent verbs in the 200 to 500ms time window is detailed in Model 6 and summarized in Table 4.1.

```
(6)    Amplitude ~ Language * AntPost * Laterality + (1 +
       Block|Subject) + (1|WordFreq)
```

Table 4.1 *Summary of effects for Model 6 of the mean amplitudes in the 200 to 500ms time window in response to construction expectancy for motion verbs.*

Factor	SumSq	MeanSq	Num*DF*	Den*DF*	F-Value	*p*	
Language	31	30.8	1	45	0.82	.37	
Laterality	1828	914.0	2	54750	24.42	< .001	***
AntPost	34915	17457.7	2	54750	466.39	< .001	***
Language x Laterality	687	343.5	2	54750	9.18	< .001	***
Language x AntPost	6396	3198.0	2	54750	85.43	< .001	***
Laterality x AntPost	8259	2064.9	4	54750	55.16	< .001	***
Language x Laterality x AntPost	761	190.2	4	54750	5.08	< .001	***

‘***’ $p < .001$, ‘**’ $p < .01$, ‘*’ $p < .05$, ‘.’ < .10

MotionType was not found to significantly contribute to the overall model fit. As such, no *post hoc* comparisons were made.

The optimal model for the amplitudes in the 500 to 700ms time window in response to congruent verbs is detailed in Model 7 and summarized in Table 4.2.

```
(7)    Amplitude ~ Language * AntPost * Laterality + (1 +
       Block|Subject) + (1|WordFreq)
```

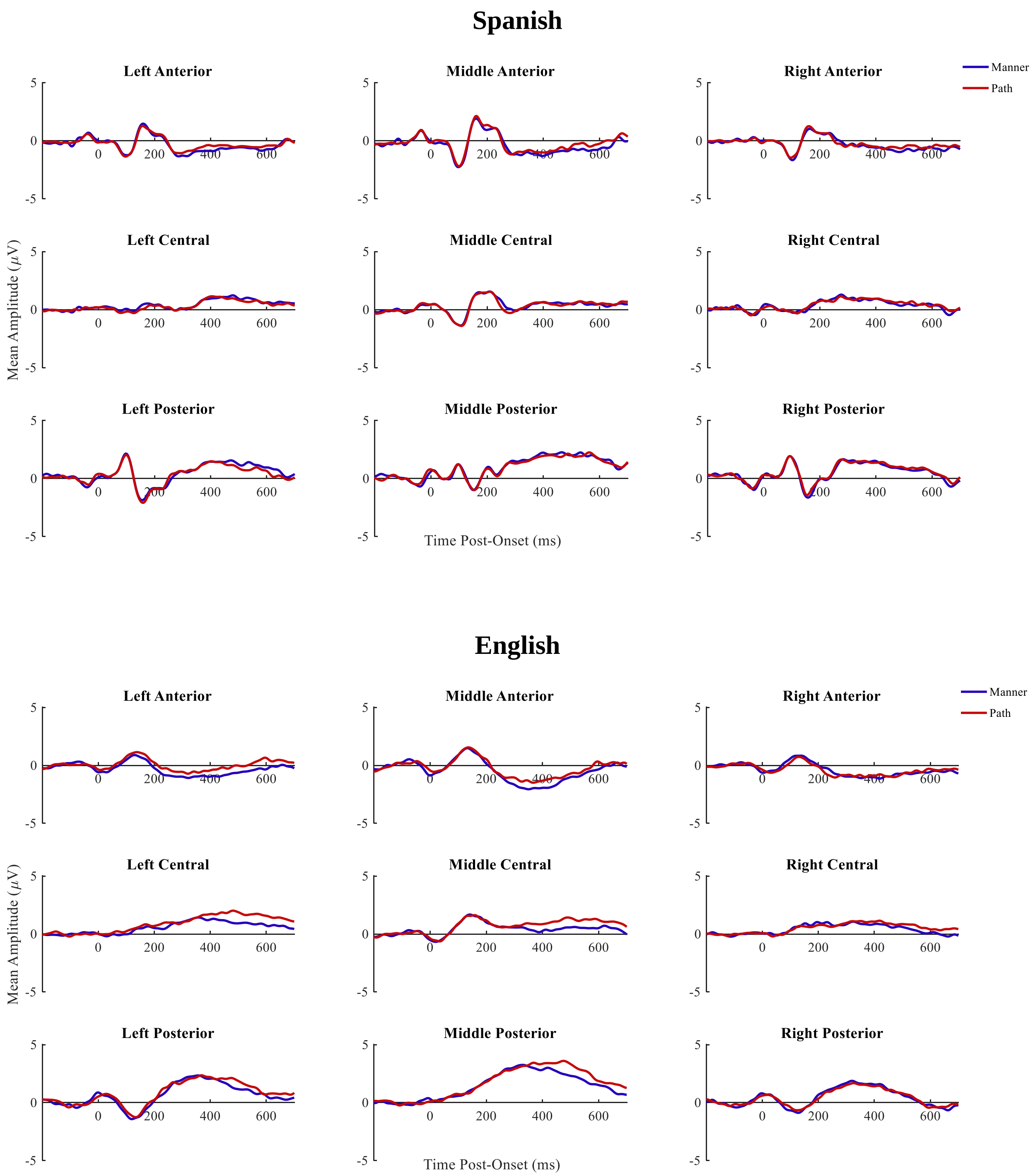

Figure 4.1 *Grand average waveforms for manner (blue) and path (red) verbs across the nine regions of interest for Spanish (upper) and English (lower) speakers.*

Table 4.2 *Summary of effects for Model 7 of the mean amplitudes in the 500 to 700ms time window in response to construction expectancy for verbs.*

Factor	**SumSq**	**MeanSq**	**Num*DF***	**Den*DF***	**F-Value**	***p***	
Language	31	31.1	1	50	0.59	.45	
Laterality	5744	2872.0	2	54751	54.13	< .001	***
AntPost	52840	26420.0	2	54751	497.96	< .001	***
Language x Laterality	722	361.2	2	54751	6.81	.001	**
Language x AntPost	538	269.1	2	54751	5.07	.006	**
Laterality x AntPost	14044	3511.1	4	54751	66.18	< .001	***
Language x Laterality x AntPost	157	39.2	4	54751	0.74	.57	

'***' $p < .001$, '**' $p < .01$, '*' $p < .05$, '.' < .10

Similar to the previous analysis in the earlier time window, the factor MotionType did not significantly contribute to the model fit of Model 7 and no *post hoc* comparisons were made.

The results from these two analyses suggest that there are no differences between speakers' expectancies for manner or path verbs. Given that manner verbs are more frequent in English than path verbs and path verbs than manner verbs in Spanish, these null effects are not surprising when controlling for the effect of word frequency. I therefore removed WordFreq from both models to examine whether word frequency was playing a mediating role in the relationship of MotionType with expectancy.

Consequently, a second analysis was run for the 200 to 500ms time window to examine the effects of MotionType without controlling for WordFreq. The optimal model is detailed in Model 8 and summarized in Table 4.3.

```
(8)    Amplitude ~ MotionType * Language * AntPost *
       Laterality + (1 + Block|Subject)
```

Table 4.3 *Summary of effects for Model 8 of the mean amplitudes in the 200 to 500ms time window in response to construction expectancy for motion verbs without controlling for WordFreq.*

Factor	**SumSq**	**MeanSq**	**Num*DF***	**Den*DF***	**F-Value**	***p***	
Language	47	47.0	1	38	1.25	.27	
MotionType	357	357.5	1	54811	9.54	.002	**
Laterality	1850	925.2	2	54755	24.68	< .001	***
AntPost	34919	17459.6	2	54755	465.75	< .001	***
Language x MotionType	**648**	**647.7**	**1**	**54811**	**17.28**	**< .001**	*****
Language x Laterality	698	349.2	2	54755	9.32	< .001	***
MotionType x Laterality	34	17.2	2	54755	0.46	.63	
Language x AntPost	6373	3186.4	2	54755	85.00	< .001	***
MotionType x AntPost	28	14.2	2	54755	0.38	.68	
Laterality x AntPost	8261	2065.3	4	54755	55.09	< .001	***
Language x MotionType x Laterality	98	48.8	2	54755	1.30	.27	
Language x MotionType x AntPost	58	28.8	2	54755	0.77	.46	
Language x Laterality x AntPost	757	189.4	4	54755	5.05	< .001	***
MotionType x Laterality x AntPost	50	12.5	4	54755	0.33	.86	
Language x MotionType x Laterality x AntPost	19	4.7	4	54755	0.13	.97	

‘***’ $p < .001$, ‘**’ $p < .01$, ‘*’ $p < .05$, ‘.’ < .10

When not controlling for word frequency, the Language x MotionType interaction was significant and simple main effects contrasts (Table 4.4; Figure 4.2) revealed that the amplitudes for path verbs were more positive than manner for English but not for Spanish speakers.

Table 4.4 *Simple main effects analysis for the Language x MotionType interaction of Model 8.*

Language	Manner *M* (*SE*)	Path *M* (*SE*)	Diff	*DF*	ChiSq	*p*	
English	1.56 (0.25)	1.94 (0.25)	-0.38	1	28.47	< .001	***
Spanish	1.38 (0.26)	1.32 (0.26)	0.06	1	0.53	.47	

'***' *p* < .001, '**' *p* < .01, '*' *p* < .05, '.' < .10; *M*: adjusted mean, *SE*: standard error of the link

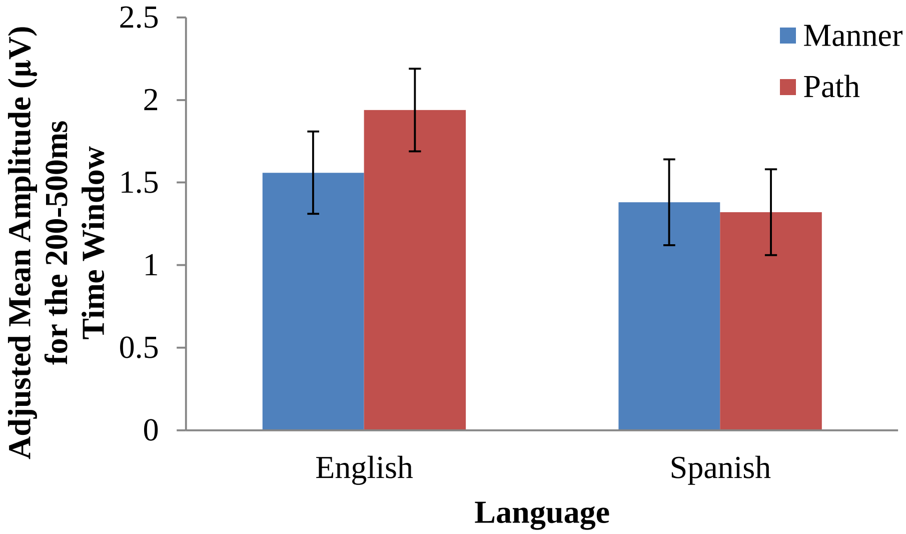

Figure 4.2 *Adjusted mean amplitudes and standard errors of the link for the Language x MotionType interaction of Model 7.*

Similarly, a second analysis was conducted for the 500 to 700ms time window without controlling for the random effects of WordFreq. The new optimal model is detailed in Model 9 and summarized in Table 4.5.

```
(9)     Amplitude ~ MotionType * Language * AntPost *
        Laterality + (1 + Block|Subject)
```

Table 4.5 *Summary of effects for Model 9 of the mean amplitudes in the 500 to 700ms time window in response to construction expectancy for verbs without controlling for WordFreq.*

Factor	SumSq	MeanSq	Num*DF*	Den*DF*	F-Value	*p*
Language	16	15.7	1	38	0.30	.59
MotionType	130	130.3	1	54808	2.45	.12

Laterality	5779	2889.4	2	54755	54.36	< .001	***
AntPost	52923	26461.7	2	54755	497.85	< .001	***
Language x MotionType	**2408**	**2408.1**	**1**	**54808**	**45.31**	**< .001**	*****
Language x Laterality	728	364.1	2	54755	6.85	.001	**
MotionType x Laterality	142	71.1	2	54755	1.34	.26	
Language x AntPost	528	263.8	2	54755	4.96	.007	**
MotionType x AntPost	18	9.0	2	54755	0.17	.84	
Laterality x AntPost	14057	3514.2	4	54755	66.12	< .001	***
Language x MotionType x Laterality	**311**	**155.6**	**2**	**54755**	**2.93**	**.05**	**.**
Language x MotionType x AntPost	145	72.6	2	54755	1.37	.25	
Language x Laterality x AntPost	160	39.9	4	54755	0.75	.56	
MotionType x Laterality x AntPost	71	17.7	4	54755	0.33	.86	
Language x MotionType x Laterality x AntPost	59	14.8	4	54755	0.28	.89	

'***' $p < .001$, '**' $p < .01$, '*' $p < .05$, '.' < .10

When *not* controlling for word frequency, the Language x MotionType x Laterality interaction was marginally significant ($p = .05$) and the Language x MotionType interaction reached significance ($p < .001$). For the sake of comprehensiveness, both interactions were probed (Table 4.6; Figure 4.3). Simple main effect contrasts revealed that, for English, path verbs produced a greater positivity than manner verbs, particularly in the left and middle Laterality RoIs (see Figure 2.4). In contrast, for Spanish, manner verbs produced a greater positivity than path verbs, particularly in the middle Laterality RoI.

***Table 4.6** Simple main effects analysis for the Language x MotionType x Laterality and Language x MotionType interactions of Model 9.*

Language x Laterality	Manner *M* (*SE*)	Path *M* (*SE*)	Diff	*DF*	ChiSq	*p*	
English	1.52 (0.28)	2.04 (0.28)	-0.52	1	37.34	< .001	***
Left	1.48 (0.29)	2.20 (0.29)	-0.72	1	23.92	< .001	***
Middle	1.68 (0.29)	2.35 (0.29)	-0.67	1	20.75	< .001	***
Right	1.39 (0.29)	1.56 (0.29)	-0.17	1	1.33	.25	
Spanish	2.15 (0.29)	1.83 (0.29)	0.32	1	12.37	< .001	***
Left	2.07 (0.31)	1.76 (0.30)	0.31	1	3.84	.15	
Middle	2.77 (0.31)	2.35 (0.30)	0.41	1	6.76	.04	*
Right	1.63 (0.31)	1.38 (0.30)	0.25	1	2.45	.23	

'***' $p < .001$, '**' $p < .01$, '*' $p < .05$, '.' < .10; *M*: adjusted mean, *SE*: standard error of the link

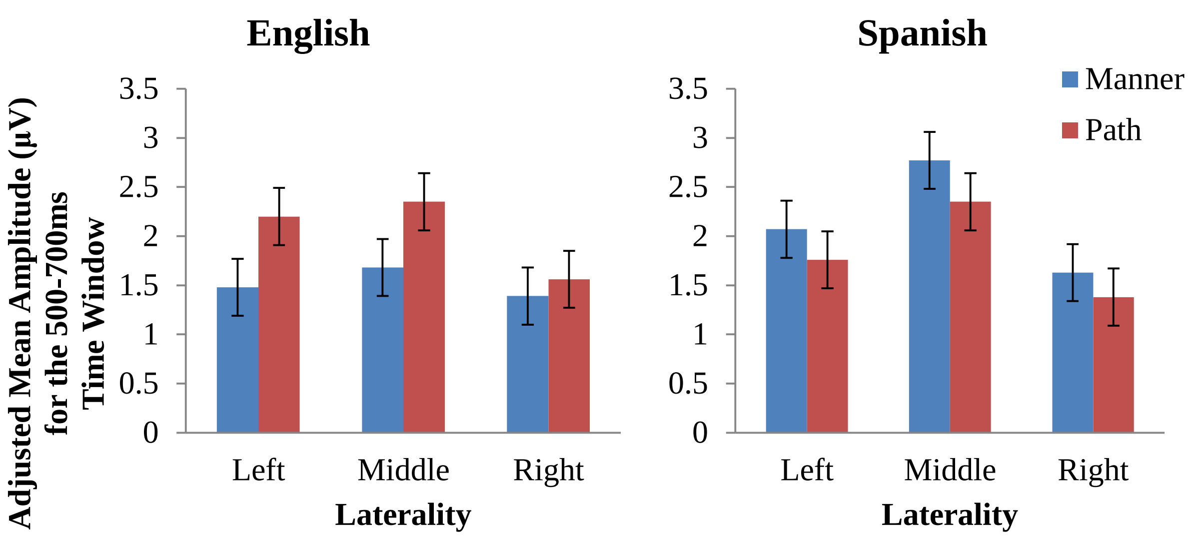

***Figure 4.3** Adjusted mean amplitudes and standard errors of the link for the Language x MotionType x Laterality interaction of Model 9.*

Altogether, analyses of construction expectancy for the verb appear to show a P600 effect for path verbs compared to manner verbs in English and for manner compared to path verbs in Spanish as exhibited by mean amplitudes in the 500 to 700ms time window. The greater positivity to path verbs in the 200 to 500ms time window for English speakers appears to reflect an earlier onset of the P600 for English speakers compared to Spanish speakers who showed no

significant differences in that time window. Importantly, however, when word frequency was controlled for (i.e., random intercepts for WordFreq), these effects disappear suggesting that word frequency plays a mediating role in the relationship between motion type and the P600 for congruent verbs.

4.1.2 Outside the Verb

The grand average waveforms for the lexical analysis of motion expression outside of the verb can be seen in Figure 4.4. The optimal model in response to motion expression outside the verb in the 200 to 500ms time window is detailed in Model and summarized in Table 4.7.

```
(10)   Amplitude ~ MotionType * Language * Block * AntPost
       * Laterality + (1 + Block|Subject) + (1|WordFreq)
```

Table 4.7 *Summary of effects for Model 10 of the mean amplitudes in the 200 to 500ms time window in response to construction expectancy for motion expressions outside of the verb.*

Factor	**SumSq**	**MeanSq**	**Num*DF***	**Den*DF***	**F-Value**	***p***	
Block	1593.22	1593.22	1	40.2	52.33	< .001	***
Language	100.63	100.63	1	48.7	3.30	.08	.
MotionType	348.72	348.72	1	59.5	11.45	.001	**
Laterality	151.94	75.97	2	27364.1	2.50	.08	.
AntPost	1623.55	811.78	2	27364.1	26.66	< .001	***
Block x Language	227.12	227.12	1	40.2	7.46	.009	**
Block x MotionType	4.35	4.35	1	16504.8	0.14	.71	
Language x MotionType	182.00	182.00	1	59.5	5.98	.017	*
Block x Laterality	473.06	236.53	2	27364.1	7.77	< .001	***
Language x Laterality	33.92	16.96	2	27364.1	0.56	.57	
MotionType x Laterality	163.74	81.87	2	27364.1	2.69	.07	.
Block x AntPost	256.21	128.10	2	27364.1	4.21	.015	*
Language x AntPost	59.87	29.93	2	27364.1	0.98	.37	
MotionType x AntPost	73.88	36.94	2	27364.1	1.21	.30	
Laterality x AntPost	97.23	24.31	4	27364.1	0.80	.53	

Block x Language x MotionType	7.72	7.72	1	16504.8	0.25	.61	
Block x Language x Laterality	61.05	30.52	2	27364.1	1.00	.37	
Block x MotionType x Laterality	152.71	76.36	2	27364.1	2.51	.08	.
Language x MotionType x Laterality	120.13	60.07	2	27364.1	1.97	.14	
Block x Language x AntPost	315.53	157.77	2	27364.1	5.18	.006	**
Block x MotionType x AntPost	27.63	13.81	2	27364.1	0.45	.64	
Language x MotionType x AntPost	66.30	33.15	2	27364.1	1.09	.34	
Block x Laterality x AntPost	317.65	79.41	4	27364.1	2.61	.03	*
Language x Laterality x AntPost	50.88	12.72	4	27364.1	0.42	.80	
MotionType x Laterality x AntPost	46.92	11.73	4	27364.1	0.39	.82	
Block x Language x MotionType x Laterality	**228.25**	**114.12**	**2**	**27364.1**	**3.75**	**.02**	*****
Block x Language x MotionType x AntPost	**143.67**	**71.83**	**2**	**27364.1**	**2.36**	**.09**	**.**
Block x Language x Laterality x AntPost	156.99	39.25	4	27364.1	1.29	.27	
Block x MotionType x Laterality x AntPost	34.70	8.68	4	27364.1	0.28	.89	
Language x MotionType x Laterality x AntPost	36.75	9.19	4	27364.1	0.30	.88	
Block x Language x MotionType x Laterality x AntPost	6.83	1.71	4	27364.1	0.06	.99	

‘***’ $p < .001$, ‘**’ $p < .01$, ‘*’ $p < .05$, ‘.’ < .10

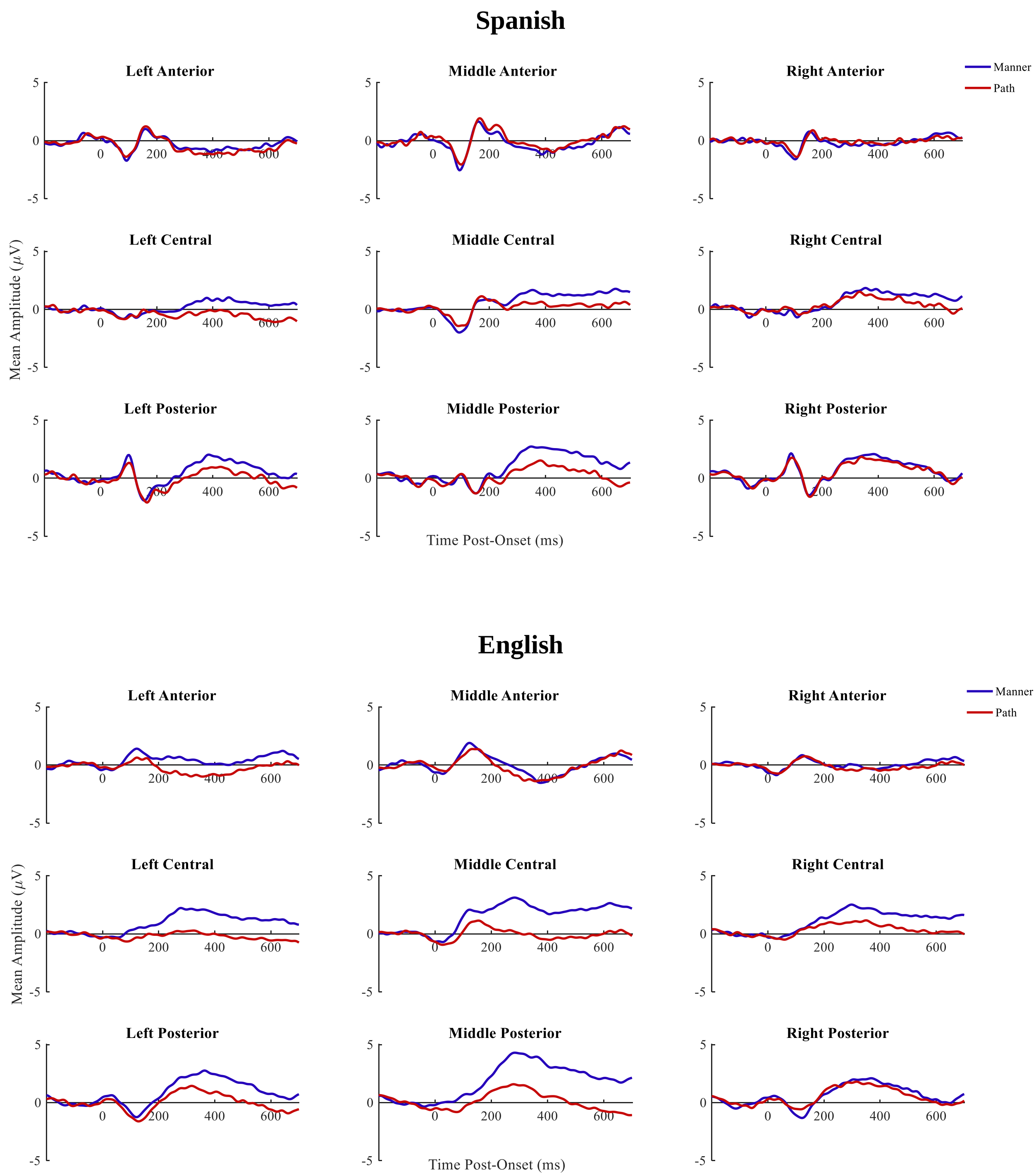

Figure 4.4 *Grand average waveforms for manner (blue) and path (red) expression outside of the verb across the nine regions of interest for Spanish (upper) and English (lower) speakers.*

The Block x Language x MotionType x Laterality interaction was statistically significant and the Block x Language x Motion x AntPost interaction was marginally significant (*p* = .09; Table 4.8; Figure 4.5). Simple main effect contrasts revealed that the expression of manner information outside of the verb in English produced a greater positivity compared to the expression of path information outside the verb. This effect was seen in the in all three hemispheres across all four blocks (with the exception of the right hemisphere in the first block which was only marginally significant (*p* = .06)). For Spanish, no differences were seen between path and manner expressions in the first through third blocks; however, manner elicited a larger positivity compared to path in the left hemisphere in the fourth block. Because the Block x Language x Motion x AntPost interaction failed to reach significance, the results are not discussed here.

Table 4.8 *Simple main effects analysis for the Block x Language x MotionType x Laterality and Block x Language x MotionType x AntPost interactions of Model 10.*

Block x Language x RoI	**Manner *M* (*SE*)**	**Path *M* (*SE*)**	**Diff**	***DF***	**ChiSq**	***p***	
Block 1							
English							
Left	1.25 (0.30)	-0.26 (0.29)	1.51	1	16.72	< .001	***
Middle	1.56 (0.30)	-0.42 (0.29)	1.98	1	28.90	< .001	***
Right	1.27 (0.30)	0.37 (0.29)	0.89	1	5.90	.06	.
Anterior	-0.05 (0.30)	-0.88 (0.29)	0.83	1	5.04	.10	.
Central	1.70 (0.30)	-0.06 (0.29)	1.76	1	22.86	< .001	***
Posterior	2.43 (0.30)	0.64 (0.29)	1.79	1	23.70	< .001	***
Spanish							
Left	0.48 (0.30)	0.66 (0.32)	-0.18	1	0.23	1.00	
Middle	1.45 (0.30)	0.85 (0.32)	0.60	1	2.44	.35	
Right	1.14 (0.30)	1.03 (0.32)	0.11	1	0.08	1.00	
Anterior	0.29 (0.30)	0.29 (0.32)	0.00	1	0.00	1.00	
Central	1.33 (0.30)	1.12 (0.32)	0.21	1	0.31	1.00	
Posterior	1.45 (0.30)	1.14 (0.32)	0.31	1	0.65	1.00	
Block 2							
English							
Left	1.77 (0.24)	0.30 (0.26)	1.47	1	24.12	< .001	***
Middle	2.33 (0.24)	0.31 (0.26)	2.02	1	45.80	< .001	***

Right	1.86 (0.24)	0.95 (0.26)	0.91	1	9.34	.01	**
Anterior	0.40 (0.24)	-0.48 (0.26)	0.89	1	8.76	.01	*
Central	2.58 (0.24)	0.63 (0.26)	1.95	1	42.71	< .001	***
Posterior	2.98 (0.24)	1.41 (0.26)	1.57	1	27.44	< .001	***
Spanish							
Left	0.89 (0.25)	0.69 (0.28)	0.20	1	0.43	1.00	
Middle	1.82 (0.25)	1.48 (0.28)	0.34	1	1.23	.80	
Right	1.11 (0.25)	1.31 (0.28)	-0.20	1	0.42	1.00	
Anterior	0.55 (0.25)	0.75 (0.28)	-0.20	1	0.42	1.00	
Central	1.67 (0.25)	1.53 (0.28)	0.14	1	0.21	1.00	
Posterior	1.60 (0.25)	1.20 (0.28)	0.40	1	1.71	.57	
Block 3							
English							
Left	2.28 (0.26)	0.85 (0.28)	1.43	1	23.09	< .001	***
Middle	3.11 (0.26)	1.04 (0.28)	2.07	1	48.16	< .001	***
Right	2.46 (0.26)	1.52 (0.28)	0.93	1	9.80	.01	**
Anterior	0.86 (0.26)	-0.08 (0.28)	0.94	1	10.03	.01	**
Central	3.47 (0.26)	1.32 (0.28)	2.15	1	51.98	< .001	***
Posterior	3.52 (0.26)	2.18 (0.28)	1.34	1	20.23	< .001	***
Spanish							
Left	1.29 (0.27)	0.71 (0.30)	0.59	1	3.48	.19	
Middle	2.20 (0.27)	2.12 (0.30)	0.09	1	0.08	.78	
Right	1.08 (0.27)	1.59 (0.30)	-0.51	1	2.61	.21	
Anterior	0.81 (0.27)	1.21 (0.30)	-0.40	1	1.61	.41	
Central	2.01 (0.27)	1.95 (0.30)	0.07	1	0.04	.83	
Posterior	1.75 (0.27)	1.26 (0.30)	0.50	1	2.51	.34	
Block 4							
English							
Left	2.80 (0.35)	1.41 (0.34)	1.39	1	14.55	.00	***
Middle	3.88 (0.35)	1.77 (0.34)	2.11	1	33.36	.00	***
Right	3.05 (0.35)	2.10 (0.34)	0.95	1	6.77	.04	*
Anterior	1.32 (0.35)	0.31 (0.34)	1.00	1	7.51	.02	*
Central	4.35 (0.35)	2.01 (0.34)	2.34	1	41.02	< .001	***
Posterior	4.06 (0.35)	2.95 (0.34)	1.11	1	9.28	.01	*
Spanish							
Left	1.70 (0.36)	0.73 (0.37)	0.97	1	5.99	.04	*
Middle	2.58 (0.36)	2.75 (0.37)	-0.17	1	0.18	.67	
Right	1.05 (0.36)	1.87 (0.37)	-0.81	1	4.23	.08	.
Anterior	1.07 (0.36)	1.67 (0.37)	-0.60	1	2.27	.39	
Central	2.35 (0.36)	2.36 (0.37)	-0.01	1	0.00	.98	
Posterior	1.91 (0.36)	1.31 (0.37)	0.59	1	2.23	.39	

‘***’ $p < .001$, ‘**’ $p < .01$, ‘*’ $p < .05$, ‘.’ < .10; *M*: adjusted mean, *SE*: standard error of the link

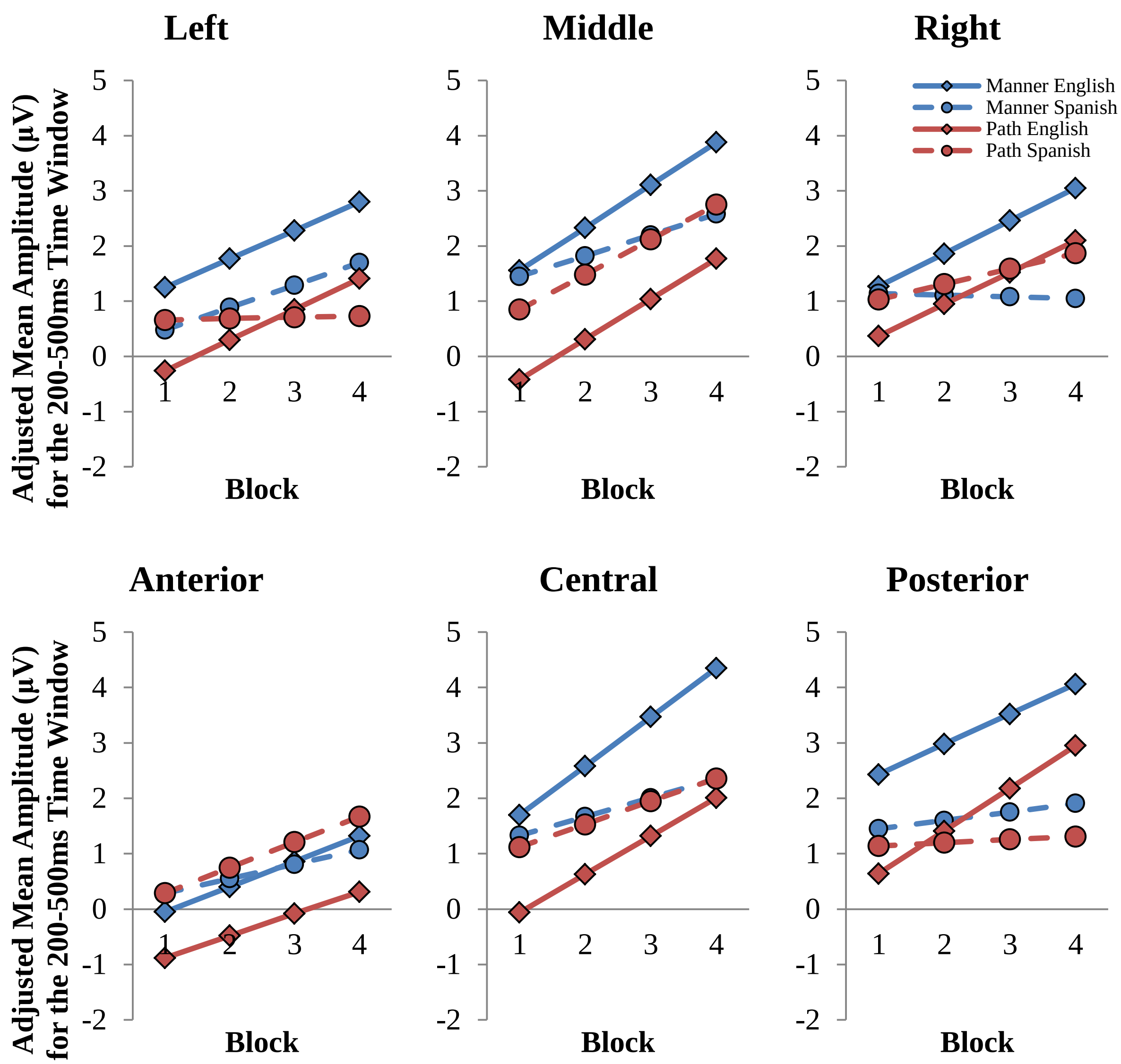

Figure 4.5 *Adjusted mean amplitudes for the Block x Language x MotionType x Laterality (upper row) and Block x Language x MotionType x AntPost (lower row) interactions of Model 10.*

For construction expectancy in the 500 to 700ms time window, the optimal model is detailed in Model 11 and summarized in Table 4.9.

```
(11)    Amplitude ~ MotionType * Language * Block * AntPost
        * Laterality + (1 + Block|Subject) + (1|WordFreq)
```

Table 4.9 *Summary of effects for Model 11 of the mean amplitudes in the 500 to 600ms time window in response to construction expectancy for motion expressions outside of the verb.*

Factor	**SumSq**	**MeanSq**	**Num*DF***	**Den*DF***	**F-Value**	***p***	
Block	1412.9	1412.90	1	36.5	29.52	< .001	***
Language	649.8	649.84	1	40.7	13.58	< .001	***
MotionType	439.3	439.30	1	75.2	9.18	.003	**
Laterality	300.2	150.08	2	27359.7	3.14	.04	*
AntPost	5336.6	2668.28	2	27359.7	55.75	< .001	***
Block x Language	399.1	399.06	1	36.5	8.34	.006	**
Block x MotionType	31.8	31.78	1	17048.3	0.66	.42	
Language x MotionType	29.4	29.43	1	75.2	0.61	.44	
Block x Laterality	984.7	492.35	2	27359.7	10.29	< .001	***
Language x Laterality	271.4	135.70	2	27359.7	2.84	.06	.
MotionType x Laterality	39.0	19.49	2	27359.7	0.41	.67	
Block x AntPost	1973.8	986.88	2	27359.7	20.62	< .001	***
Language x AntPost	52.4	26.20	2	27359.7	0.55	.58	
MotionType x AntPost	387.6	193.78	2	27359.7	4.05	.02	*
Laterality x AntPost	140.3	35.06	4	27359.7	0.73	.57	
Block x Language x MotionType	212.7	212.70	1	17048.3	4.44	.04	*
Block x Language x Laterality	67.9	33.95	2	27359.7	0.71	.49	
Block x MotionType x Laterality	84.6	42.30	2	27359.7	0.88	.41	
Language x MotionType x Laterality	42.9	21.46	2	27359.7	0.45	.64	
Block x Language x AntPost	41.9	20.96	2	27359.7	0.44	.65	
Block x MotionType x AntPost	99.2	49.59	2	27359.7	1.04	.35	
Language x MotionType x AntPost	309.4	154.69	2	27359.7	3.23	.04	*
Block x Laterality x AntPost	248.5	62.14	4	27359.7	1.30	.27	
Language x Laterality x AntPost	241.3	60.33	4	27359.7	1.26	.28	
MotionType x Laterality x AntPost	82.8	20.70	4	27359.7	0.43	.79	

Block x Language x MotionType x Laterality	212.2	106.08	2	27359.7	2.22	.11	
Block x Language x MotionType x AntPost	**288.1**	**144.07**	**2**	**27359.7**	**3.01**	**.05**	*****
Block x Language x Laterality x AntPost	163.8	40.94	4	27359.7	0.86	.49	
Block x MotionType x Laterality x AntPost	67.6	16.90	4	27359.7	0.35	.84	
Language x MotionType x Laterality x AntPost	46.4	11.60	4	27359.7	0.24	.91	
Block x Language x MotionType x Laterality x AntPost	14.5	3.63	4	27359.7	0.08	.99	

‘***’ *p* < .001, ‘**’ *p* < .01, ‘*’ *p* < .05, ‘.’ < .10

The MotionType x Language x Block x AntPost interaction was statistically significant (Table 4.10; Figure 4.6). Simple main effect contrasts revealed that for English speakers, manner expressions outside of the verb produced a larger positivity in the central and posterior RoIs during the first and second blocks and in all three AntPost RoIs in the third and fourth blocks. However, no differences were seen between the manner and path expressions outside the verb in Spanish speakers.

Table 4.10 *Simple main effects analysis for the Block x Language x MotionType x AntPost interactions of Model 11.*

Block x Language x AntPost	**Manner *M* (*SE*)**	**Path *M* (*SE*)**	**Diff**	***DF***	**ChiSq**	***p***	
Block 1							
English							
Anterior	-0.76 (0.40)	-0.89 (0.38)	0.13	1	0.09	1.00	
Central	1.4 (0.40)	-0.28 (0.38)	1.69	1	15.02	< .001	***

Posterior	2.63 (0.40)	0.35 (0.38)	2.28	1	27.51	< .001	***
Spanish							
Anterior	0.69 (0.40)	0.45 (0.41)	0.23	1	0.27	1.00	
Central	2.61 (0.40)	1.83 (0.41)	0.77	1	2.87	.36	
Posterior	2.98 (0.40)	2.34 (0.41)	0.64	1	1.94	.49	
Block 2							
English							
Anterior	0.45 (0.31)	-0.15 (0.33)	0.60	1	3.12	.22	
Central	2.64 (0.31)	0.51 (0.33)	2.13	1	38.98	< .001	***
Posterior	3.03 (0.31)	0.92 (0.33)	2.11	1	38.17	< .001	***
Spanish							
Anterior	1.07 (0.32)	1.09 (0.35)	-0.03	1	0.01	.94	
Central	2.95 (0.32)	2.25 (0.35)	0.70	1	3.91	.19	
Posterior	2.85 (0.32)	2.22 (0.35)	0.64	1	3.23	.22	
Block 3							
English							
Anterior	1.67 (0.34)	0.59 (0.36)	1.08	1	10.07	.006	**
Central	3.88 (0.34)	1.3 (0.36)	2.58	1	57.53	< .001	***
Posterior	3.43 (0.34)	1.5 (0.36)	1.94	1	32.48	< .001	***
Spanish							
Anterior	1.44 (0.36)	1.73 (0.38)	-0.29	1	0.64	.42	
Central	3.29 (0.36)	2.66 (0.38)	0.63	1	3.03	.23	
Posterior	2.73 (0.36)	2.09 (0.38)	0.64	1	3.14	.23	
Block 4							
English							
Anterior	2.89 (0.46)	1.33 (0.45)	1.55	1	12.97	.001	**
Central	5.12 (0.46)	2.1 (0.45)	3.02	1	49.11	< .001	***
Posterior	3.83 (0.46)	2.07 (0.45)	1.76	1	16.71	< .001	***
Spanish							
Anterior	1.82 (0.49)	2.37 (0.49)	-0.55	1	1.36	.52	
Central	3.63 (0.49)	3.07 (0.49)	0.56	1	1.40	.52	
Posterior	2.61 (0.49)	1.96 (0.49)	0.64	1	1.86	.52	

'***' $p < .001$, '**' $p < .01$, '*' $p < .05$, '.' < .10; *M*: adjusted mean, *SE*: standard error of the link

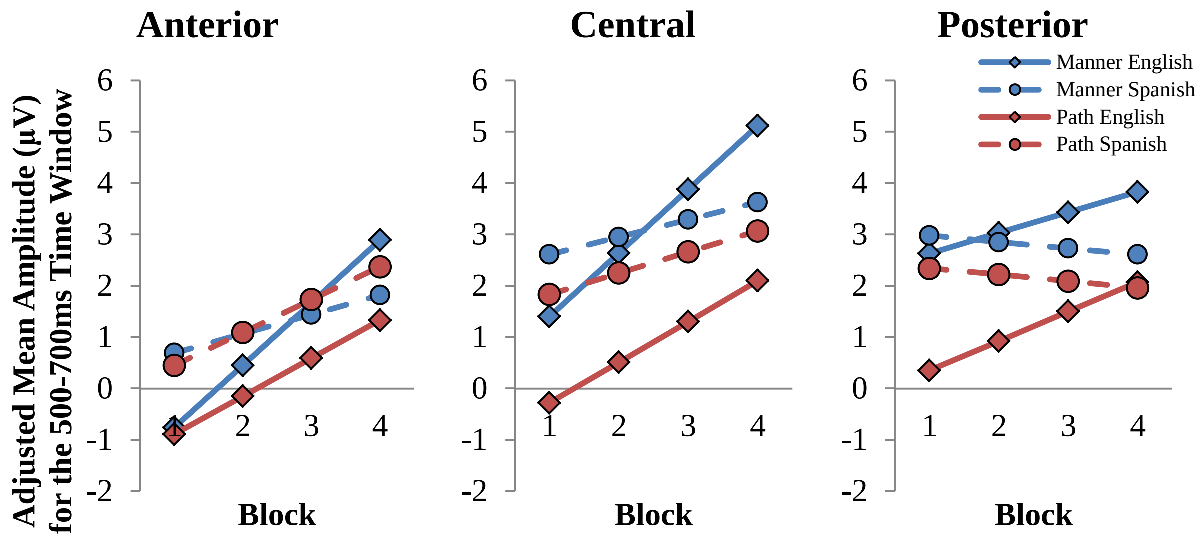

Figure 4.6 *Adjusted mean amplitudes for the Block x Language x MotionType x AntPost interaction of Model 11.*

Altogether, the results for the analyses of construction expectancy for motion expressions outside the verb suggest a P600 effect in English for manner expressions outside the verb compared to path expressions outside the verb and this effect is evident as early as the 200 to 500ms time window. These results are complementary with the results of the construction expectancy analysis for verbs where a larger P600 effect was found for path: English speakers' heightened preference for expressing manner in the verb—as exhibited by lower P600 amplitudes—leads speakers to have lower expectations of finding manner encoded elsewhere in the sentence. In contrast, no significant differences between manner and path expressions outside the verb were seen in Spanish speakers. Thus, while Spanish speakers exhibited a preference to express path in the verb, this did not affect their expectations for path to be expressed elsewhere in the sentence. Unlike the verb construction analysis, these patterns were robust to controls for WordFreq suggesting that the frequency with which these terms were expressed alone cannot account for the differences in expectancy for how motion is lexicalized outside of the verb.

4.2 Motion Sensitivity (Question 2)

4.2.1 Within the Verb

The grand average waveforms for the analysis motion sensitivity within verbs can be seen in Figure 4.7. The optimal model for motion sensitivity in the verb in the 200 to 500ms time window is detailed in Model 12 and in Table 4.11.

```
(12)   Amplitude ~ Congruency * Language * AntPost *
       Laterality + (1 + Block|Subject) + (1|WordFreq)
```

Table 4.11 *Summary of effects for Model 12 of the mean amplitudes in the 200 to 500ms time window in response to sensitivity to motion verbs.*

Factor	**SumSq**	**MeanSq**	**Num*DF***	**Den*DF***	**F-Value**	***p***	
Language	297	296.5	1	51	6.55	.01	*
Congruency	1338	1337.8	1	36241	29.55	< .001	***
Laterality	3553	1776.4	2	36257	39.24	< .001	***
AntPost	39369	19684.6	2	36257	434.81	< .001	***
Language x Congruency	**230**	**230.2**	**1**	**36241**	**5.08**	**.02**	*****
Language x Laterality	1848	924.2	2	36257	20.41	< .001	***
Congruency x Laterality	103	51.5	2	36257	1.14	.32	
Language x AntPost	1389	694.3	2	36257	15.34	< .001	***
Congruency x AntPost	52	26.2	2	36257	0.58	.56	
Laterality x AntPost	9344	2335.9	4	36257	51.60	< .001	***
Language x Congruency x Laterality	5	2.4	2	36257	0.05	.95	
Language x Congruency x AntPost	149	74.4	2	36257	1.64	.19	
Language x Laterality x AntPost	186	46.5	4	36257	1.03	.39	
Congruency x Laterality x AntPost	64	15.9	4	36257	0.35	.84	
Language x Congruency x Laterality x AntPost	76	19	4	36257	0.42	.79	

‘***’ $p < .001$, ‘**’ $p < .01$, ‘*’ $p < .05$, ‘.’ < .10

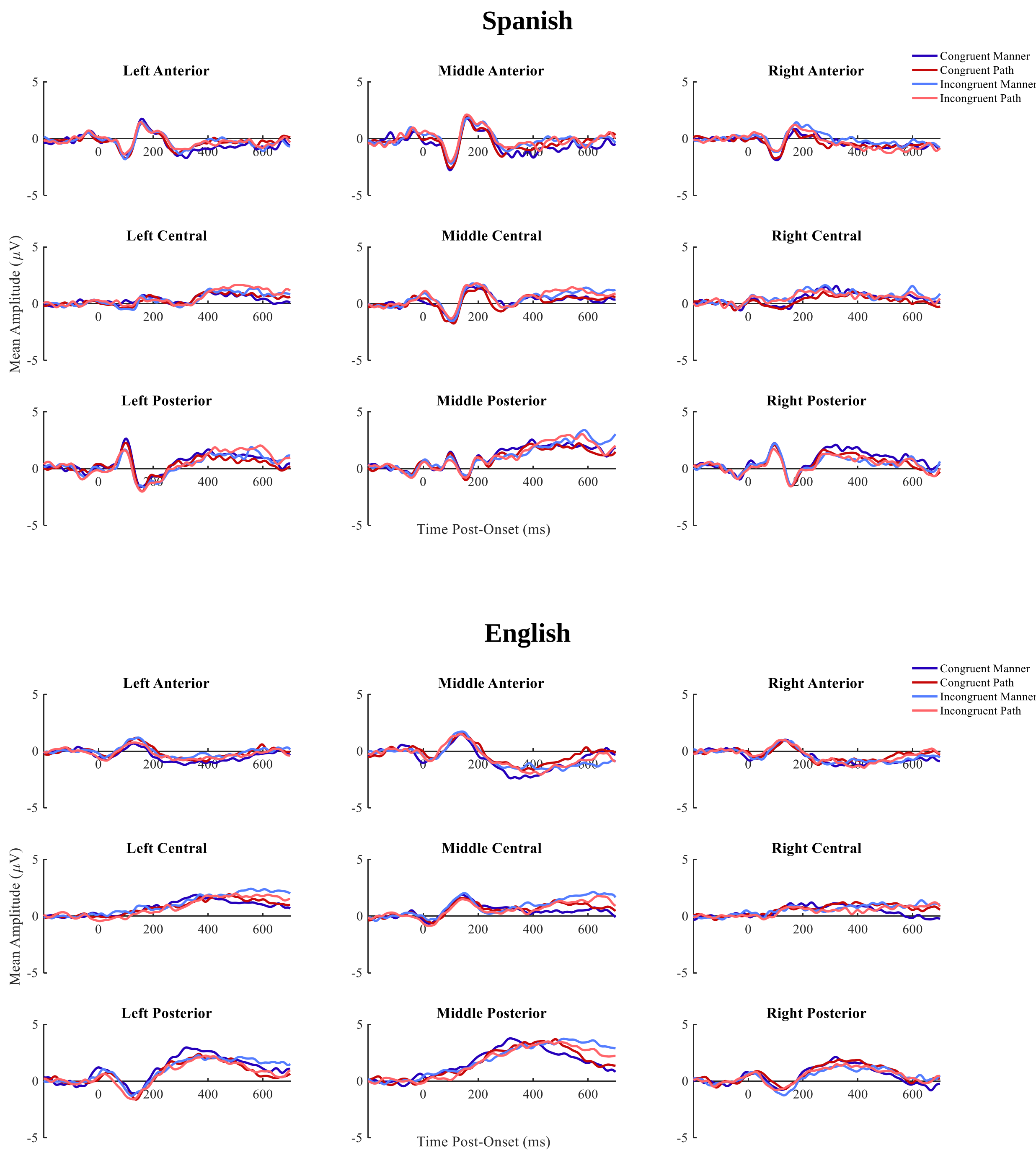

Figure 4.7 *Grand average waveforms for congruent manner (dark blue), congruent path (dark red), incongruent manner (light blue), and incongruent path (light red) verbs across the nine regions of interest for Spanish (upper) and English (lower) speakers.*

The Language x Congruency interaction was statistically significant and simple main effects contrasts (Table 4.12; Figure 4.8) revealed that incongruent verbs elicited a larger positivity than congruent verbs in both English and Spanish.

Table 4.12 *Simple main effects analysis for the Language x Congruency interaction of Model 12.*

Language	**Incongruent** ***M*** **(*SE*)**	**Congruent** ***M*** **(*SE*)**	**Diff**	***DF***	**ChiSq**	***p***	
English	1.57 (0.23)	1.34 (0.23)	0.23	1	5.42	.02	*
Spanish	2.54 (0.23)	1.99 (0.23)	0.55	1	27.75	< .001	***

'***' $p < .001$, '**' $p < .01$, '*' $p < .05$, '.' < .10; *M*: adjusted mean, *SE*: standard error of the link

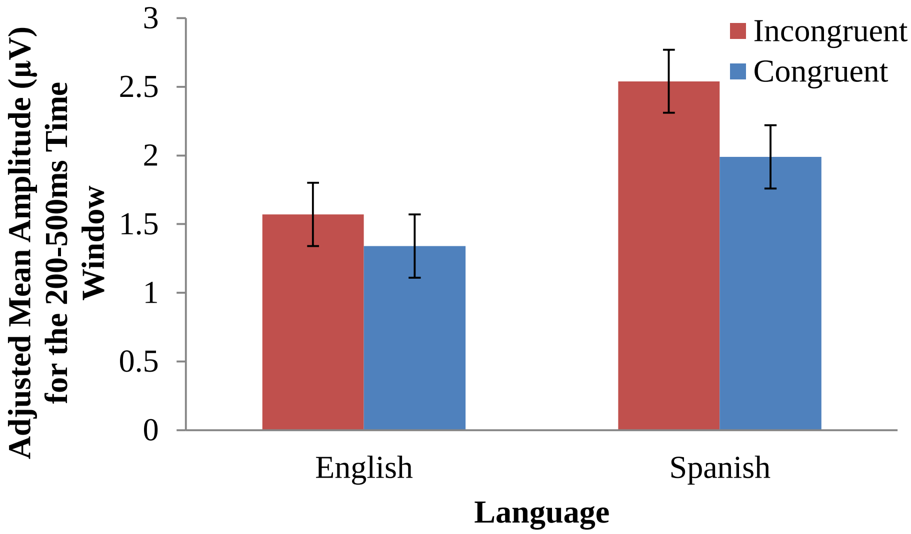

Figure 4.8 *Adjusted mean amplitudes and standard errors of the link for the Language x Congruency interaction of Model 12.*

For the 500 to 700ms time window, the optimal model for motion sensitivity in the verb is detailed in Model 13 and in Table 4.13.

```
(13)    Amplitude ~ Congruency * Language * AntPost *
        Laterality + (1 + Block|Subject) + (1|WordFreq)
```

Table 4.13 *Summary of effects for Model 13 of the mean amplitudes in the 500 to 700ms time window in response to sensitivity to motion verbs.*

Factor	**SumSq**	**MeanSq**	**Num*DF***	**Den*DF***	**F-Value**	***p***	
Language	129.4	129.4	1	44	3.01	0.09	.
Congruency	3144.2	3144.2	1	36326	73.12	< .001	***
Laterality	1651.6	825.8	2	36261	19.20	< .001	***
AntPost	28163.4	14081.7	2	36261	327.47	< .001	***
Language x Congruency	1764.6	1764.6	1	36326	41.04	< .001	***
Language x Laterality	887.6	443.8	2	36261	10.32	< .001	***
Congruency x Laterality	98.9	49.4	2	36261	1.15	0.32	
Language x AntPost	7720.5	3860.2	2	36261	89.77	< .001	***
Congruency x AntPost	253.8	126.9	2	36261	2.95	0.05	.
Laterality x AntPost	8930.2	2232.5	4	36261	51.92	< .001	***
Language x Congruency x Laterality	116.4	58.2	2	36261	1.35	0.26	
Language x Congruency x AntPost	**756.3**	**378.1**	**2**	**36261**	**8.79**	**< .001**	*******
Language x Laterality x AntPost	1447.5	361.9	4	36261	8.42	< .001	***
Congruency x Laterality x AntPost	222.7	55.7	4	36261	1.29	0.27	
Language x Congruency x Laterality x AntPost	261.7	65.4	4	36261	1.52	0.19	

‘***’ $p < .001$, ‘**’ $p < .01$, ‘*’ $p < .05$, ‘.’ < .10

The Language x Congruency x AntPost interaction was statistically significant, and simple main effects contrasts (Table 4.14; Figure 4.9) revealed that congruent verbs produced a greater positivity in all three AntPost RoIs for English speakers and in the anterior AntPost RoI for Spanish speakers.

Table 4.14 *Simple main effects analysis for the Language x Congruency x AntPost interaction of Model 13.*

Language x AntPost	**Incongruent *M* (*SE*)**	**Congruent *M* (*SE*)**	**Diff**	***DF***	**ChiSq**	***p***

English							
Anterior	0.65 (0.28)	0.15 (0.28)	0.50	1	9.24	.01	**
Central	3.65 (0.28)	2.18 (0.28)	1.47	1	80.62	< .001	***
Posterior	4.00 (0.28)	2.84 (0.28)	1.16	1	49.99	< .001	***
Spanish							
Anterior	1.15 (0.29)	0.73 (0.30)	0.42	1	5.81	.05	*
Central	2.19 (0.29)	2.00 (0.30)	0.19	1	1.20	.55	
Posterior	1.64 (0.29)	1.81 (0.30)	-0.16	1	0.87	.55	

'***' $p < .001$, '**' $p < .01$, '*' $p < .05$, '.' < .10; *M*: adjusted mean, *SE*: standard error of the link

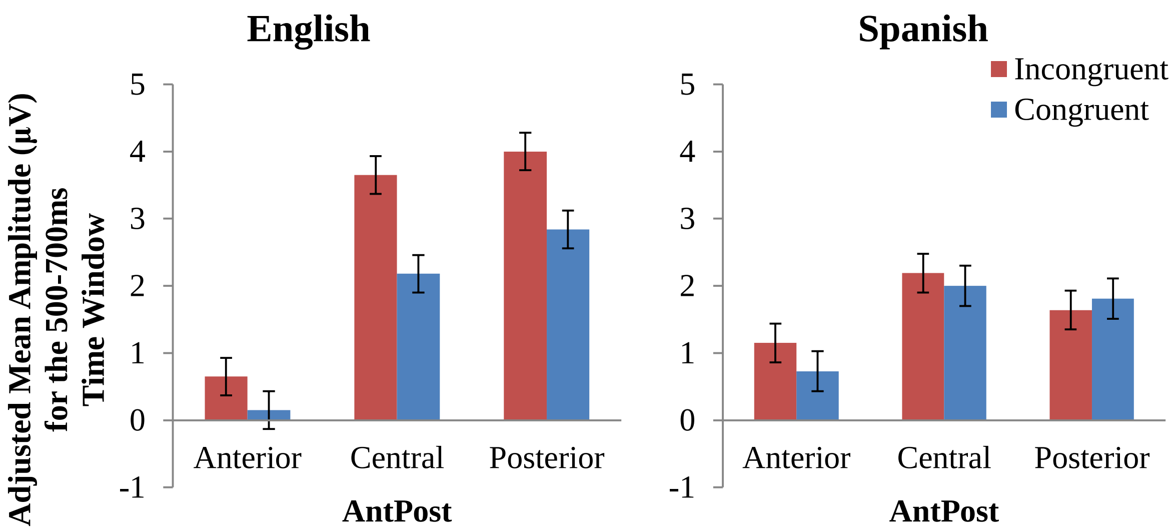

Figure 4.9 *Adjusted mean amplitudes and standard errors of the link for the Language x Congruency x AntPost interaction of Model 13.*

MotionType was not found to significantly contribute to the model fit for Model 12 (early latency) or Model 13 (late latency). As such both analyses were run again without controlling for WordFreq; however, removal of this random effect did not affect the ability of MotionType to improve model fit in either time window and did not change the overall pattern of results in either model. Therefore, these models are not reported here.

Altogether, the analyses on sensitivity to motion information expressed in the verb revealed a P600 effect for incongruent compared to congruent verbs. This effect was initially

stronger for Spanish than for English speakers in the earlier latency band, but became more prominent across all three AntPost RoIs for English speakers and more anterior for Spanish speakers in the later latency band. This effect was not affected by the type of motion that the verb expressed even when not controlling for verb frequencies.

4.2.2 Manner Outside the Verb

The grand average waveforms for the analysis motion sensitivity to manner outside the verb can be seen in Figure 4.10. The optimal model for sensitivity to manner information outside the verb in the 200 to 500ms time window is detailed in Model 14 and Table 4.15.

```
(14)   Amplitude ~ Congruency * Language * Block * AntPost
       * Laterality + (1 + Block|Subject) + (1|WordFreq)
```

Table 4.15 *Summary of effects for Model 14 of the mean amplitudes in the 200 to 500ms time window in response to sensitivity to manner information outside the verb.*

Factor	**SumSq**	**MeanSq**	**Num*DF***	**Den*DF***	**F-Value**	***p***	
Block	410.86	410.86	1	27.2	14.65	.001	***
Language	19.51	19.51	1	27.0	0.70	.41	
Congruency	27.49	27.49	1	5501.7	0.98	.32	
Laterality	176.16	88.08	2	11092.3	3.14	.04	*
AntPost	112.41	56.20	2	11092.3	2.00	.13	
Block x Language	53.49	53.49	1	27.2	1.91	.18	
Block x Congruency	**364.31**	**364.31**	**1**	**4578.0**	**12.99**	**> .001**	*******
Language x Congruency	3.14	3.14	1	5501.7	0.11	.74	
Block x Laterality	321.09	160.54	2	11092.3	5.72	.003	**
Language x Laterality	507.76	253.88	2	11092.3	9.05	> .001	***
Congruency x Laterality	30.27	15.14	2	11092.3	0.54	.58	
Block x AntPost	297.47	148.73	2	11092.3	5.30	.005	**
Language x AntPost	59.31	29.65	2	11092.3	1.06	.35	
Congruency x AntPost	**277.35**	**138.68**	**2**	**11092.3**	**4.94**	**.01**	******

Laterality x AntPost	219.66	54.92	4	11092.3	1.96	.10	.
Block x Language x Congruency	28.00	28.00	1	4578.0	1.00	.32	
Block x Language x Laterality	445.19	222.59	2	11092.3	7.94	> .001	***
Block x Congruency x Laterality	8.95	4.47	2	11092.3	0.16	.85	
Language x Congruency x Laterality	2.41	1.20	2	11092.3	0.04	.96	
Block x Language x AntPost	405.95	202.97	2	11092.3	7.24	.001	***
Block x Congruency x AntPost	84.91	42.46	2	11092.3	1.51	.22	
Language x Congruency x AntPost	2.59	1.30	2	11092.3	0.05	.95	
Block x Laterality x AntPost	294.96	73.74	4	11092.3	2.63	.03	*
Language x Laterality x AntPost	29.38	7.35	4	11092.3	0.26	.90	
Congruency x Laterality x AntPost	2.17	0.54	4	11092.3	0.02	1.00	
Block x Language x Congruency x Laterality	25.18	12.59	2	11092.3	0.45	.64	
Block x Language x Congruency x AntPost	2.11	1.06	2	11092.3	0.04	.96	
Block x Language x Laterality x AntPost	77.88	19.47	4	11092.3	0.69	.60	
Block x Congruency x Laterality x AntPost	18.67	4.67	4	11092.3	0.17	.96	
Language x Congruency x Laterality x AntPost	27.71	6.93	4	11092.3	0.25	.91	
Block x Language x Congruency x Laterality x AntPost	24.08	6.02	4	11092.3	0.21	.93	

‘***’ $p < .001$, ‘**’ $p < .01$, ‘*’ $p < .05$, ‘.’ < .10

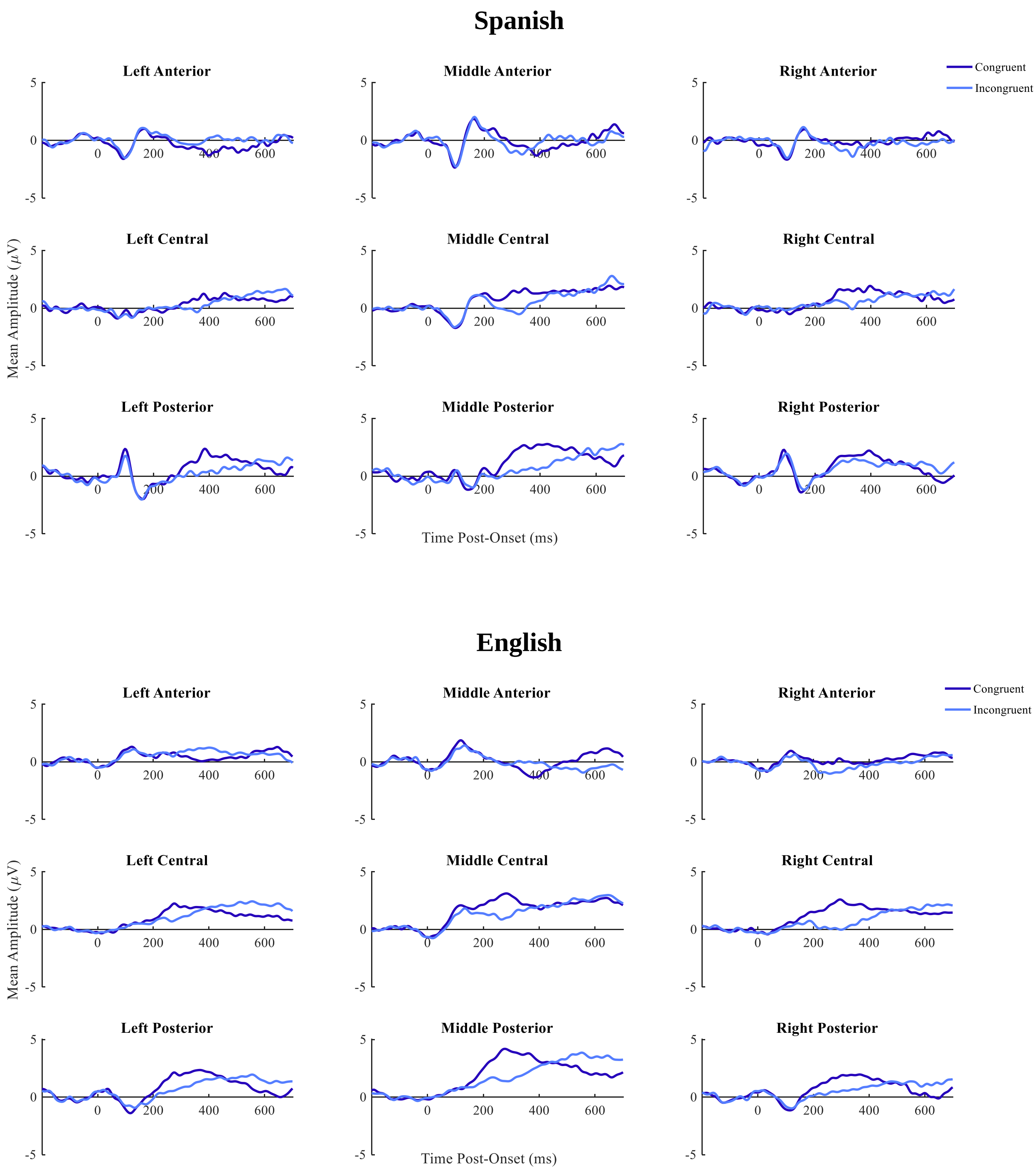

Figure 4.10 *Grand average waveforms for congruent (dark blue) and incongruent (light blue) manner expression outside of the verb for Spanish (top rows) and English (bottom rows) speakers.*

The Congruency x AntPost and Block x Congruency interactions were statistically significant. Simple main effects contrasts for the Congruency x AntPost interaction (Table 4.16; Figure 4.11) revealed greater negativities for incongruent compared to congruent trials in all three AntPost RoIs. Contrasts for the Block x Congruency interaction (Table 4.17; Figure 4.12) revealed that greater negativities for incongruent compared to congruent trials occurred in each of the four blocks.

Table 4.16 *Simple main effects analysis for the Congruency x AntPost interaction of Model 14.*

AntPost	**Incongruent** ***M* (*SE*)**	**Congruent** ***M* (*SE*)**	**Diff**	***DF***	**ChiSq**	***p***	
Anterior	0.38 (0.24)	0.82 (0.23)	-0.45	1	6.54	0.01	*
Central	1.11 (0.24)	2.58 (0.23)	-1.47	1	71.51	< .001	***
Posterior	0.89 (0.24)	2.53 (0.23)	-1.64	1	88.64	< .001	***

‘***’ *p* < .001, ‘**’ *p* < .01, ‘*’ *p* < .05, ‘.’ < .10; *M*: adjusted mean, *SE*: standard error of the link

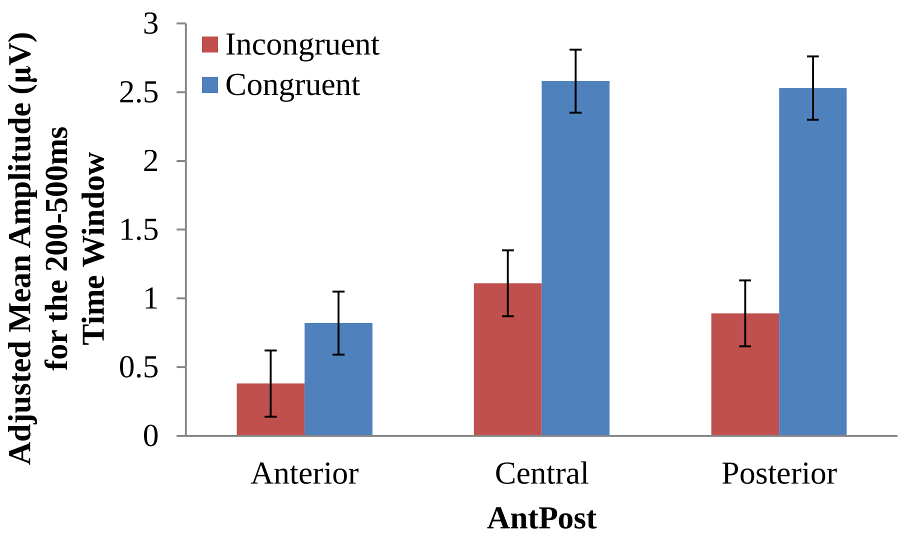

Figure 4.11 *Adjusted mean amplitudes and standard errors of the link for the Congruency x AntPost interaction of Model 14.*

Table 4.17 *Simple main effects analysis for the Block x Congruency interaction of Model 14.*

Block	**Incongruent** ***M (SE)***	**Congruent** ***M (SE)***	**Diff**	***DF***	**ChiSq**	***p***	
Block 1	0.24 (0.30)	0.93 (0.23)	-0.62	1	11.16	.001	***
Block 2	0.86 (0.30)	2.26 (0.23)	-0.98	1	68.83	< .001	***
Block 3	0.58 (0.22)	1.28 (0.31)	-1.33	1	147.20	< .001	***
Block 4	1.56 (0.22)	2.96 (0.31)	-1.68	1	96.52	< .001	***

'***' *p* < .001, '**' *p* < .01, '*' *p* < .05, '.' < .10; *M*: adjusted mean, *SE*: standard error of the link

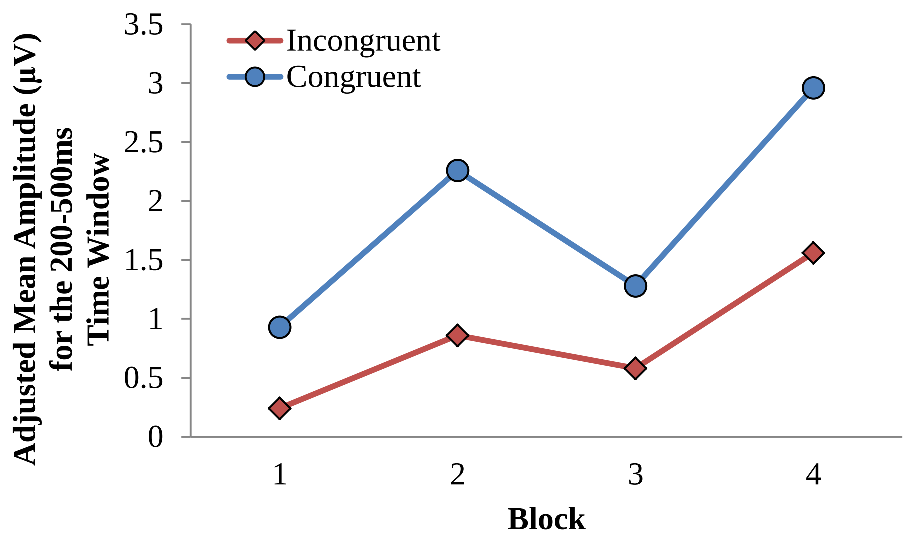

Figure 4.12*. Adjusted mean amplitudes for the Block x Congruency interaction of Model 14.*

For the 500 to 700ms time window, the optimal model for sensitivity to manner information outside of the verb is detailed in Model 15 and Table 4.18.

```
(15)    Amplitude ~ Congruency * Language * Block * AntPost
        * Laterality + (1 + Block|Subject) + (1|WordFreq)
```

Table 4.18 *Summary of effects for Model 15 of the mean amplitudes in the 500 to 700ms time window in response to sensitivity to manner information outside of the verb.*

Factor	**SumSq**	**MeanSq**	**Num*DF***	**Den*DF***	**F-Value**	***p***	
Block	971.82	971.82	1	28.7	20.58	< .001	***
Language	54.31	54.31	1	29.7	1.15	0.29	
Congruency	143.85	143.85	1	5089.3	3.05	0.08	.

Laterality	84.79	42.39	2	11100.1	0.90	0.41	
AntPost	1584.68	792.34	2	11100.1	16.78	< .001	***
Block x Language	131.30	131.30	1	28.7	2.78	0.11	
Block x Congruency	490.53	490.53	1	4172.8	10.39	0.001	**
Language x Congruency	55.99	55.99	1	5089.3	1.19	0.28	
Block x Laterality	533.12	266.56	2	11100.1	5.64	0.004	**
Language x Laterality	368.34	184.17	2	11100.1	3.90	0.02	*
Congruency x Laterality	49.25	24.62	2	11100.1	0.52	0.59	
Block x AntPost	680.31	340.16	2	11100.1	7.20	0.001	***
Language x AntPost	29.78	14.89	2	11100.1	0.32	0.73	
Congruency x AntPost	508.08	254.04	2	11100.1	5.38	0.005	**
Laterality x AntPost	151.55	37.89	4	11100.1	0.80	0.52	
Block x Language x Congruency	31.96	31.96	1	4172.8	0.68	0.41	
Block x Language x Laterality	548.38	274.19	2	11100.1	5.81	0.003	**
Block x Congruency x Laterality	85.44	42.72	2	11100.1	0.90	0.40	
Language x Congruency x Laterality	45.31	22.65	2	11100.1	0.48	0.62	
Block x Language x AntPost	186.71	93.35	2	11100.1	1.98	0.14	
Block x Congruency x AntPost	**612.24**	**306.12**	**2**	**11100.1**	**6.48**	**0.002**	**
Language x Congruency x AntPost	114.88	57.44	2	11100.1	1.22	0.30	
Block x Laterality x AntPost	410.97	102.74	4	11100.1	2.18	0.07	.
Language x Laterality x AntPost	85.78	21.45	4	11100.1	0.45	0.77	
Congruency x Laterality x AntPost	61.65	15.41	4	11100.1	0.33	0.86	
Block x Language x Congruency x Laterality	4.77	2.39	2	11100.1	0.05	0.95	
Block x Language x	170.12	85.06	2	11100.1	1.80	0.17	

Congruency x AntPost						
Block x Language x Laterality x AntPost	88.81	22.20	4	11100.1	0.47	0.76
Block x Congruency x Laterality x AntPost	37.80	9.45	4	11100.1	0.20	0.94
Language x Congruency x Laterality x AntPost	29.43	7.36	4	11100.1	0.16	0.96
Block x Language x Congruency x Laterality x AntPost	32.57	8.14	4	11100.1	0.17	0.95

‘***’ $p < .001$, ‘**’ $p < .01$, ‘*’ $p < .05$, ‘.’ < .10

The Block x Congruency x AntPost interaction was statistically significant, and simple main effects contrasts (Table 4.19; Figure 4.13) revealed a greater negativity for incongruent compared to congruent trials in the anterior and central AntPost RoIs for the second and third block.

Table 4.19 *Simple main effects analysis for the Block x Congruency x AntPost interaction of Model 15.*

Block x AntPost	**Incongruent *M* (*SE*)**	**Congruent *M* (*SE*)**	**Diff**	***DF***	**ChiSq**	***p***	
Block 1							
Anterior	0.43 (0.45)	-0.43 (0.46)	0.86	1	4.51	.10	
Central	1.77 (0.45)	1.29 (0.46)	0.48	1	1.42	.23	
Posterior	1.72 (0.45)	2.43 (0.46)	-0.71	1	3.07	.16	
Block 2							
Anterior	0.79 (0.33)	0.75 (0.33)	0.04	1	0.02	1.00	
Central	2.51 (0.33)	2.61 (0.33)	-0.10	1	0.15	1.00	
Posterior	2.30 (0.33)	2.83 (0.33)	-0.53	1	4.21	.12	
Block 3							
Anterior	1.16 (0.32)	1.93 (0.32)	-0.78	1	10.41	.004	**
Central	3.26 (0.32)	3.94 (0.32)	-0.68	1	8.03	.01	**
Posterior	2.88 (0.32)	3.23 (0.32)	-0.35	1	2.15	.14	
Block 4							

Anterior	1.52 (0.44)	3.11 (0.44)	-1.60	1	18.58	< .001	***
Central	4.01 (0.44)	5.27 (0.44)	-1.27	1	11.69	.001	**
Posterior	3.46 (0.44)	3.64 (0.44)	-0.18	1	0.23	.63	

'***' $p < .001$, '**' $p < .01$, '*' $p < .05$, '.' < .10; *M*: adjusted mean, *SE*: standard error of the link

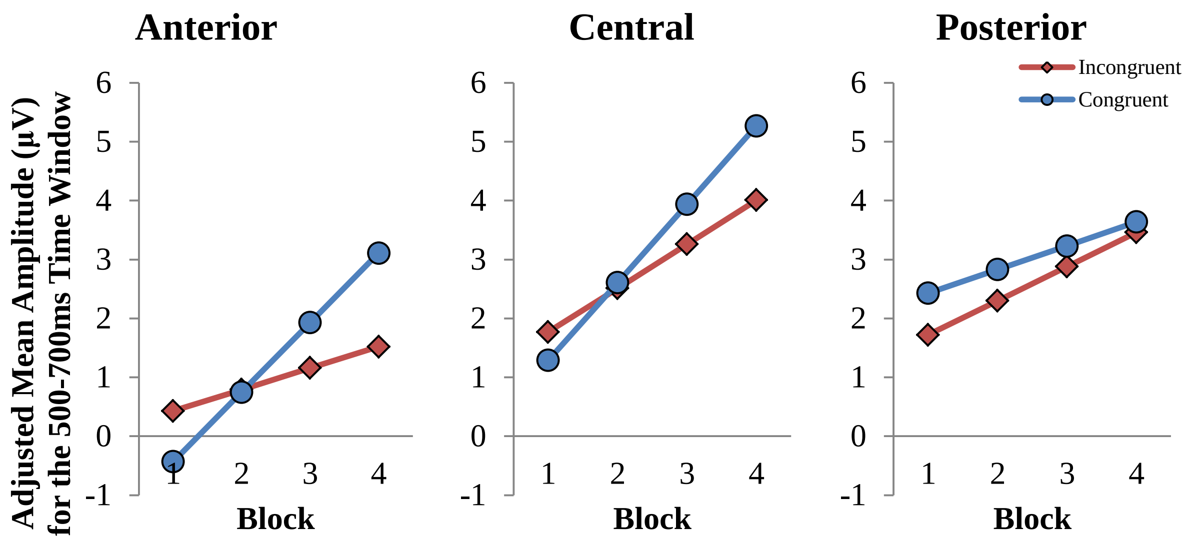

Figure 4.13 *Adjusted mean amplitudes for the Block x Congruency x AntPost interaction of Model 15.*

Altogether analysis of sensitivity to violations of manner information outside the verb (i.e., manner gerunds) revealed a greater negativity likely indicative of an N400 effect for incongruent compared to congruent trials for both English and Spanish speakers. This effect was apparent in all four blocks in the 200 to 500ms time window and extended into the later time window for the anterior and central RoIs for the second half of trials in the experiment.

4.2.3 Path Outside of the Verb

The grand average waveforms for the analysis motion sensitivity to path outside the verb can be seen in Figure 4.14. The optimal model for the analysis of sensitivity to path information

outside the verb for the 200 to 500ms time window is detailed in Model 16 and summarized in Table 4.20.

```
(16)   Amplitude ~ Congruency * Language * Block * AntPost
       + (1 + Block|Subject) + (1|Location)
```

Table 4.20 *Summary of effects for Model 16 of the mean amplitudes in the 200 to 500ms time window in response to sensitivity to path information outside the verb.*

Factor	**SumSq**	**MeanSq**	**Num*DF***	**Den*DF***	**F-Value**	***p***	
Block	434.04	434.04	1	35.2	14.87	< .001	***
Language	217.18	217.18	1	35.3	7.44	.01	**
Congruency	210.38	210.38	1	14719.1	7.21	.01	**
AntPost	194.56	97.28	2	16045.3	3.33	.04	*
Block x Language	201.42	201.42	1	35.2	6.90	.01	*
Block x Congruency	1.08	1.08	1	15260.8	0.04	.85	
Language x Congruency	484.58	484.58	1	14719.1	16.60	< .001	***
Block x AntPost	58.20	29.10	2	16045.3	1.00	.37	
Language x AntPost	46.19	23.09	2	16045.3	0.79	.45	
Congruency x AntPost	7.84	3.92	2	16045.3	0.13	.87	
Block x Language x Congruency	**239.58**	**239.58**	**1**	**15260.8**	**8.21**	**.004**	******
Block x Language x AntPost	281.26	140.63	2	16045.3	4.82	.01	**
Block x Congruency x AntPost	36.12	18.06	2	16045.3	0.62	.54	
Language x Congruency x AntPost	39.52	19.76	2	16045.3	0.68	.51	
Block x Language x Congruency x AntPost	124.08	62.04	2	16045.3	2.13	.12	

‘***’ $p < .001$, ‘**’ $p < .01$, ‘*’ $p < .05$, ‘.’ < .10

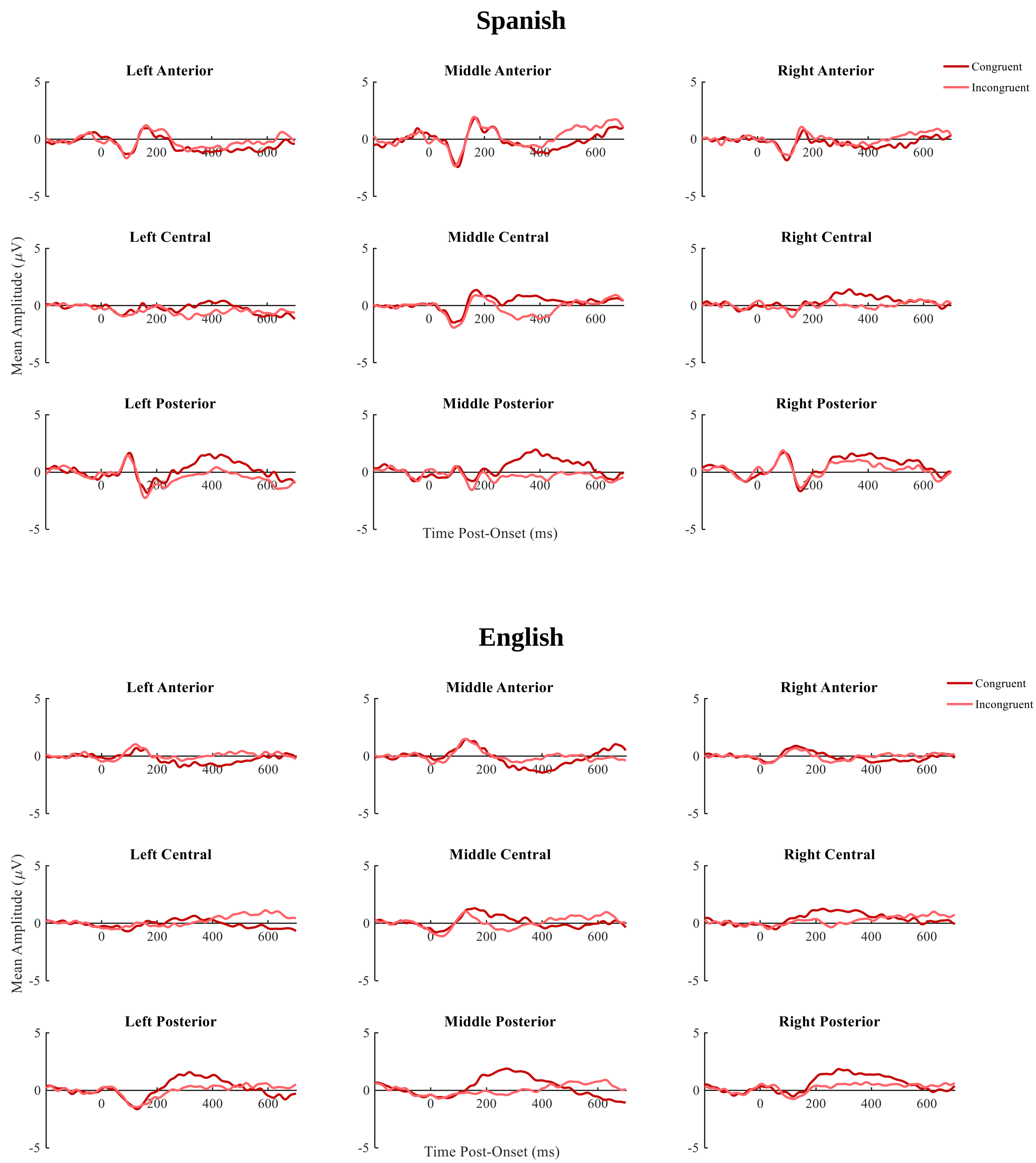

Figure 4.14 *Grand average waveforms for congruent (dark red) and incongruent (light red) path expression outside of the verb for Spanish (top rows) and English (bottom rows) speakers.*

The Block x Language x Congruency interaction was statistically significant, and simple main effects contrasts (Table 4.21; Figure 4.15) revealed greater negativities in response to incongruent compared to congruent trials for Spanish speakers in all four blocks and for English speakers in only the third and fourth blocks.

Table 4.21 *Simple main effects analysis for the Block x Language x Congruency interaction of Model 16.*

Block x Language	**Incongruent *M* (*SE*)**	**Congruent *M* (*SE*)**	**Diff**	***DF***	**ChiSq**	***P***	
Block 1							
English	0.41 (0.48)	0.34 (0.48)	0.07	1	0.14	.71	
Spanish	0.33 (0.49)	1.64 (0.48)	-1.31	1	28.06	< .001	***
Block 2							
English	0.89 (0.46)	1.06 (0.46)	-0.17	1	1.91	.17	
Spanish	0.55 (0.47)	1.65 (0.47)	-1.10	1	46.39	< .001	***
Block 3							
English	1.37 (0.49)	1.78 (0.49)	-0.41	1	12.28	< .001	***
Spanish	0.77 (0.49)	1.65 (0.49)	-0.89	1	36.23	< .001	***
Block 4							
English	1.85 (0.55)	2.50 (0.55)	-0.65	1	13.55	< .001	***
Spanish	0.99 (0.56)	1.66 (0.56)	-0.68	1	9.47	.002	**

‘***’ $p < .001$, ‘**’ $p < .01$, ‘*’ $p < .05$, ‘.’ < .10; *M*: adjusted mean, *SE*: standard error of the link

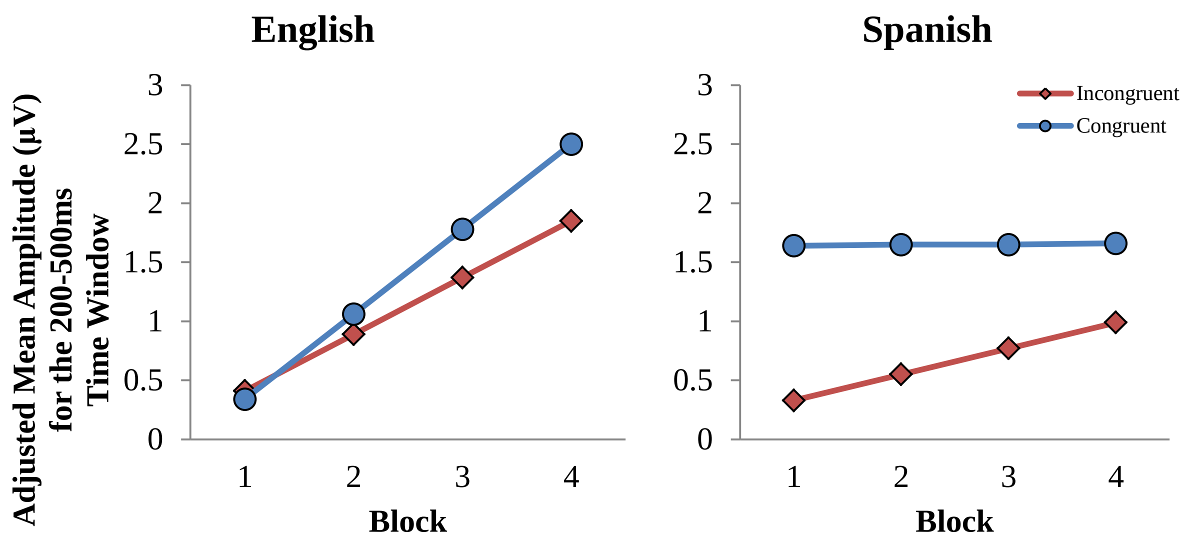

Figure 4.15 *Adjusted mean amplitudes for the Block x Language x Congruency interaction of Model 16.*

The optimal model for sensitivity to path information outside the verb in the 500 to 700ms time window is detailed in Model 17 and summarized in Table 4.22.

```
(17)    Amplitude ~ Congruency * Language * Laterality *
        AntPost + (1 + Block|Subject) + (1|Location)
```

Table 4.22 *Summary of effects for Model 17 of the mean amplitudes in the 500 to 700ms time window in response to sensitivity to path information outside the verb.*

Factor	**SumSq**	**MeanSq**	**Num*DF***	**Den*DF***	**F-Value**	***p***	
Language	244.31	244.31	1	43.7	5.25	.03	*
Congruency	24.50	24.50	1	16034.7	0.53	.47	
Laterality	1336.53	668.26	2	16039.8	14.37	< .001	***
AntPost	2160.19	1080.10	2	16039.8	23.22	< .001	***
Language x Congruency	2012.67	2012.67	1	16034.7	43.26	< .001	***
Language x Laterality	1919.65	959.82	2	16039.8	20.63	< .001	***
Congruency x Laterality	3.80	1.90	2	16039.8	0.04	.96	
Language x AntPost	509.12	254.56	2	16039.8	5.47	.004	**
Congruency x AntPost	112.69	56.34	2	16039.8	1.21	.30	

Laterality x AntPost	547.23	136.81	4	16039.8	2.94	.02	*
Language x Congruency x Laterality	170.57	85.29	2	16039.8	1.83	.16	
Language x Congruency x AntPost	**508.35**	**254.17**	**2**	**16039.8**	**5.46**	**.004**	**
Language x Laterality x AntPost	167.11	41.78	4	16039.8	0.90	.46	
Congruency x Laterality x AntPost	45.04	11.26	4	16039.8	0.24	.91	
Language x Congruency x Laterality x AntPost	131.23	32.81	4	16039.8	0.71	.59	

‘***’ $p < .001$, ‘**’ $p < .01$, ‘*’ $p < .05$, ‘.’ < .10

The Language x Congruency x AntPost interaction was statistically significant, and simple main effect contrasts (Table 4.23; Figure 4.16) revealed that for English speakers, incongruent trials produced a significantly greater positivity in all three AntPost RoIs compared to congruent trials. In contrast, for Spanish speakers, incongruent trials produced a significantly larger negativity in the central and posterior AntPost RoIs.

Table 4.23 *Simple main effects analysis for the Language x Congruency x AntPost interaction of Model 17.*

Language x AntPost	**Incongruent *M* (*SE*)**	**Congruent *M* (*SE*)**	**Diff**	***DF***	**ChiSq**	***p***	
English							
Anterior	0.65 (0.51)	0.12 (0.51)	0.54	1	5.05	.05	*
Central	1.98 (0.51)	0.91 (0.51)	1.07	1	20.11	< .001	***
Posterior	1.98 (0.51)	1.12 (0.51)	0.86	1	12.94	.002	**
Spanish							
Anterior	1.58 (0.53)	1.50 (0.53)	0.08	1	0.07	.79	
Central	1.69 (0.53)	2.69 (0.53)	-0.99	1	10.85	.003	**
Posterior	1.28 (0.53)	2.35 (0.53)	-1.07	1	12.57	.002	**

‘***’ $p < .001$, ‘**’ $p < .01$, ‘*’ $p < .05$, ‘.’ < .10; *M*: adjusted mean, *SE*: standard error of the link

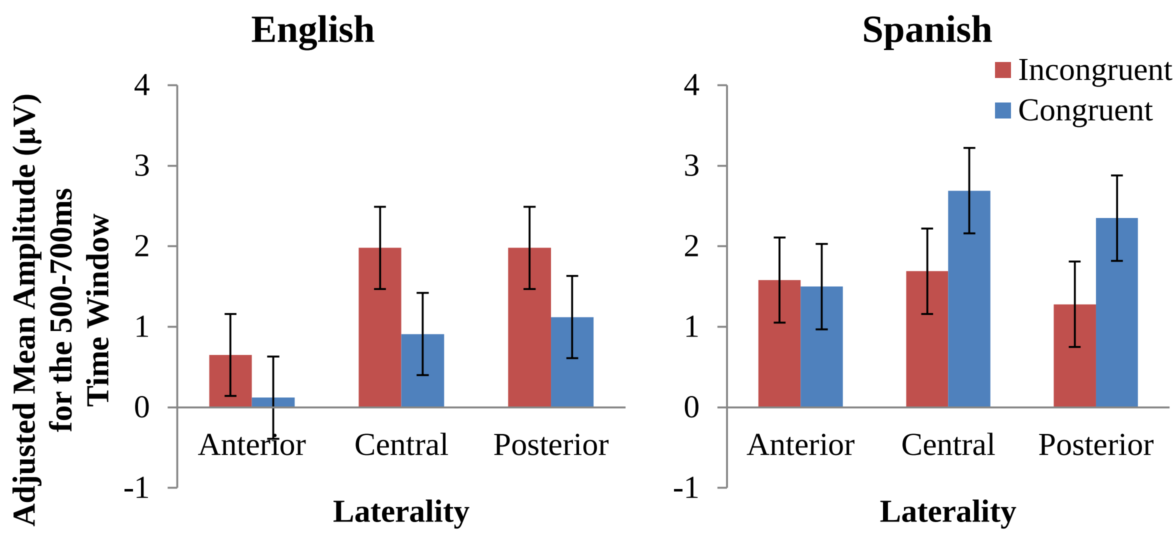

Figure 4.16 *Adjusted mean amplitudes and standard errors of the link for the Language x Congruency x AntPost interaction of Model 17.*

Altogether the analyses of sensitivity to the expression of path outside of the verb suggest that Spanish speakers exhibit an N400 in response to incongruent path expressions outside the verb (i.e., path prepositions and adverbs) that begins in the 200 to 500ms time window but also extends into the 500 to 700ms time window. In English, by contrast, this N400 effect for path expressions outside the verb (i.e. path prepositions) only appears in the early window for trials in the second half of the experiment and is followed in the later window by a P600 effect. It is likely that these two components overlap in English speakers leading to the reduction of the N400 effect seen in the earlier half of the experiment.

Importantly, English speakers' preference for manner-verb sentences makes path expression more likely to occur outside the verb compared to Spanish where it is more likely to occur in the verb. In contrast, manner expression outside the verb is unlikely to occur in either language: It is infrequent in English because manner is typically expressed in the verb. In Spanish it is infrequent because speakers have the option to either express manner as a verb in an additional sentence. Thus, the only typical expression for motion outside of the verb was path

for English speakers; path outside of the verb for Spanish speakers—relative to path outside the verb for English speakers—and manner gerunds for both groups of speakers is fairly uncommon. As such, violation of this greater expectancy may trigger the P600 effect, whereas situations with relatively lower expectancy might only trigger an N400 effect.

5 DISCUSSION

5.1 Lexical Expectations

This study examined both the lexical expectancies for motion expression and the processing of violations to manner and path expression within and outside of the verb in speakers of two typologically distinct languages. Analysis of lexical expectancy (question 1) revealed that syntactically correct but atypical lexicalizations of motion information elicited P600 effects rather than the traditionally predicted N400 effect. For verbs, manner elicited a larger P600 amplitude than path for Spanish speakers and vice versa for English. This effect had an early latency (200 to 500ms latency band) for verbs; however, it was entirely mediated by word frequency. This suggests that, similar to expression, speakers have a higher expectancy for the verb to encode the same type of information that is habitually expressed and that this effect is directly an outcome of the frequency with which those words are expressed.

The same P600 effect was also observable for motion expression outside of the verb but only for English speakers: A larger P600 was seen for manner expressions outside of the verb (gerunds) compared to path expressions outside of the verb (prepositions). Importantly, while this effect also had an early latency, it was not affected by word frequency. In contrast, no differences were found between manner and path expressions outside of the verb in Spanish. While the verb is an obligatory component of any sentence, these other motion expressions are

not particularly required in the path-verb construction preferred by Spanish speakers. Given this "loose" construction, Spanish speakers are relatively accustomed to separate expressions of both path and manner. As such it is likely that no differences were found between manner and path expressions outside of the verb for these speakers because they are more accustomed to both types of expressions. In contrast, English speakers strongly prefer the manner-verb construction in which the optional expression of path outside of the verb (i.e., in a preposition) occurs more often than not. As such, English speakers may have a strong bias to expect these path prepositions but not the less frequently occurring manner gerunds. Thus, these differences might reflect a stronger expectancy for path over manner outside of the verb in English but no such expectancies in Spanish. Importantly, these results persisted even after controlling for the effect of word frequency, suggesting that the expectancy biases present in English speakers go beyond the effects of rate of expression.

Interestingly, the P600 found in response path verbs and manner expressions outside the verb in English had an early latency (i.e., were present in the 200 to 500ms time window). A recent study by Qi and et al. (2017) linked early latencies of a P600 effect in an individual's native language to their initial ability to learn the syntax of a miniature artificial language. This link between early P600 and syntactic abilities might suggest that English speakers were more sensitive to the atypical lexicalizations involved in the path-verb constructions than Spanish speakers were to the manner-verb constructions.

Altogether, examination of the lexical expectancies suggest that speakers do expect motion to be lexicalized in ways similar to how it is habitually expressed in that language. Contrary to traditional predictions, this was exhibited in the form of greater P600 amplitudes rather than greater N400 amplitudes.

5.2 Motion Sensitivity

Overall, the results of the analyses of sensitivity to motion violation (question 2) encoded in the verb or a manner gerund do not provide full support for the crosslinguistic differences in motion sensitivity suggested by the salient verb, encodability, or path universal hypotheses. While speakers of both languages were sensitive to the incongruities with the preceding video, there were no differences in ERPs elicited by manner or path verbs, nor were there any differences between English and Spanish speakers for ERPs elicited by manner gerunds. Despite similar roots, however, verbs and manner gerunds did elicit different ERP components: Incongruent verbs elicited a P600 effect while incongruent manner gerunds elicited an N400 effect. This provides partial evidence for the salient verb hypothesis in that the verbs of the sentence were indeed processed in a qualitatively different way than other parts of speech in the sentence.

Crosslinguistic differences, by contrast, were seen for path expressions outside the verb, which included path prepositions in both languages (i.e., '*across*', '*toward*', '*up*', '*down*', '*través*', '*hacia*') and path adverbs for Spanish (i.e., '*arriba*', '*abajo*'). Similar to the manner expressions outside the verb, incongruent path expressions outside the verb elicited an N400 effect in both languages—albeit only in the third and fourth blocks for English speakers. But in addition to this component, English speakers also exhibited a P600 effect for these stimuli. The differences in English compared to Spanish speakers' responses to the incongruent path stimuli outside of the verb may have one of several implications.

The first possibility is that Spanish speakers are more sensitive to path violations than English when that information is lexicalized outside of the verb. This is evidenced by the appearance of the N400 effect in response to incongruent path expressions outside of the verb

during the first block of trials in Spanish speakers compared to English speakers who required repeated exposure to these errors prior to the appearance of the component. This effect does not support any of the three hypotheses directly; however, the salient verb hypothesis could be extended to support the idea that the habitual expression of path in the verb has a beneficial effect on the processing of path information elsewhere in the sentence; though this would not explain the absence of that benefit for processing path violations compared to manner violations that were lexicalized within the verb.

A second implication is that there is a qualitative difference in the way English and Spanish speakers process path information when it is encoded outside the verb. Unfortunately, at present, it is unclear which factors might contribute to the elicitation of an N400 effect in contrast to a semantic P600 effect. As such it is difficult to say if the presence of this additional component indicates a difference in sensitivity to the path information itself or rather the lexicalization of that information. Thus, it is difficult to interpret these qualitative crosslinguistic differences in the processing of path outside of the verb with respect to the three motion sensitivity hypotheses.

A final possible implication of these crosslinguistic differences is that a temporal overlap in the N400 and P600 components in English speakers led to the delayed appearance of the N400 in the third and fourth blocks of the study. While Block did not significantly contribute to model fit for the analysis of path expressions outside of the verb in the 500 to 700ms time window, it is still possible that the P600 effect in English may have had an earlier latency during the first and second blocks of the experiment. If this were the case, the increased positive amplitudes of the P600 could have cancelled out any greater negativities seen on the scalp from the N400 effect during those two blocks. If this were the case, rather than suggesting greater sensitivity to path

information outside of the verb in Spanish speakers, the crosslinguistic differences in the presence or absence of the N400 effect across the four blocks would simply reflect interference by the P600 component instead.

Altogether, these results are difficult to interpret with respect to their implications for crosslinguistic differences in sensitivity to motion information. While qualitative differences were seen in the processing of verbs compared to other parts of speech—as exhibited by a P600 component compared to the predicted N400 component—this effect did not interact with motion information. And while both qualitative (different components) and quantitative (delayed appearance across blocks) crosslinguistic differences did appear for path expressions outside of the verb, possible temporal overlap between components and the dearth of information on the causes of the semantic P600 make interpretation of these effects difficult with respect to the three theories of motion sensitivity.

5.3 ERPs

In contrast to traditional predictions, atypical lexicalizations of motion information and incongruent motion information encoded in the verb (and in path prepositions for English speakers) elicited an unexpected P600 effect rather than the traditionally predicted N400 effect. While traditionally thought of as reflecting syntactic congruity (Osterhout & Holcomb, 1992), more recent studies have shown that certain types of semantic violations may also elicit P600 effects in addition to or instead of N400 effects (see Kuperberg, 2007 for review). There are currently three main theories that attempt to explain the circumstances that elicit a so called ‘semantic P600’.

5.3.1 Theories for the 'Semantic P600' Effect

The first theory was posited by Kuperberg (2007). Kuperberg suggested that the P600 may reflect a stream of processing for linguistic input that involves the continual combinatory analysis of both morphosyntactic constraints as well as certain semantic-thematic constraints. With respect to semantic-thematic constraints, she suggested that there are four main factors that, when combined, may produce a semantic P600 effect rather than an N400 effect. First, semantic P600 effects have been seen in response to violations of thematic roles with a particular emphasis on animacy constraints. For example, the verb '*eat*' in the sentence "*Every morning at breakfast the eggs would eat*..." violates the thematic roles assigned to the verb for an inanimate subject such as *eggs* (Kuperberg et al., 2003). Second, a semantic P600 may be triggered when the violating verb is semantically associated with the rest of the sentence. For example, when the sentence stem "*John saw that the elephants the trees...*" was completed with the semantically associated *pruned*, the violating verb produced a P600 while the less associated *caressed* produced an N400 (van Herten et al., 2006). Third, semantic P600 effects are more likely when participants are making an explicit acceptability judgment for the sentences. For example, the verb *played* in "*The trees that in the park <u>played</u>...*" elicited a P600 effect when participants were asked to judge the acceptability of the sentence but produced an N400 when they were asked to read sentences for comprehension (Kolk et al., 2003). Finally, semantic P600s are more likely when they are presented within a coherent context. For example, the noun *suitcase* in the sentence "*the woman told the suitcase that she thought [a man] looked really trendy*" produced a P600 when it was preceded by a story that led to a situation in which a person might speak to an inanimate suitcase but produced an N400 when it did not follow the story (Nieuwland & Van

Berkum, 2005). While Kuperberg's (2007) theory focuses primarily on verbs, this study suggests that the semantic P600 may be elicited by other parts of speech, such as nouns, as well.

A second theory was labeled the Monitoring Theory by Vissers et al. (2008). Vissers and et al. suggest that rather than reflecting morphosyntactic violations alone, the P600 more broadly reflects any reanalysis of an initial interpretation of a linguistic structure. In other words, a P600 effect occurs whenever a highly unexpected linguistic stimulus triggers the participant to reanalyze their interpretation of the sentence in order to ensure that they have "read the sentence correctly". In order to test this theory, Vissers and et al. created an experiment where participants first saw two shapes on a screen (e.g., a square above a triangle). Next, participants read sentences that either matched the preceding screen ("*The triangle stands below the square*"), contained an intra-dimensional mismatch ("*The triangle stands above the square*") or an extra-dimensional mismatch ("*The triangle stands behind the square*"). Both the intra-dimensional and extra-dimensional mismatched prepositions produced a larger P600 compared to the matched prepositions despite being grammatical and syntactically unambiguous.

In support of this theory, a recent source analysis for the semantic P600 effect found that the anterior cingulate cortex (associated with conflict monitoring) and to a lesser extent the right anterior prefrontal cortex (associated with semantic retrieval) might be the origins of the potential at the scalp rather than the left superior temporal gyrus (associated with syntactic processing; Shen, Fiori-Duharcourt & Isel, 2016). This suggests that the semantic P600 is more likely to reflect executive processing such as the reanalysis of a sentence's meaning rather than of its syntactic structure.

In line with Kuperberg's (2007) theory, the mismatched prepositions in Vissers et al. (2008) were semantically associated with the rest of the sentence and participants were asked to

complete an explicit acceptability task (i.e., identify whether the sentences matched or mismatched the preceding image). Similar to the violations of animacy described by Kuperberg, the study by Vissers et al. also involved a thematic violation. However, in Kuperberg's study, the violations involved an implausible combination between the inanimate noun phrase and verb. In contrast, the violations in Vissers et al. were logically permissible (i.e., the relationship described between the two shapes was physically possible) but were unexpected given the context of the preceding picture. Furthermore, in stark contrast to Kuperberg's prediction that a *congruent* context elicits P600 effects, the study by Vissers et al. found a P600 effect in response to prepositions that were *incongruent* with the visual context of the trial. Because Kuperberg states that a stimulus must contain only some of the four critical factors for a semantic P600 to be elicited, the results of Vissers et al. (2008) are not entirely incompatible with Kuperberg's theory. While more parsimonious than the syntactic theory proposed by Kuperberg (2007), the Monitoring Theory does not provide a mechanism to predict *a priori* which semantic violations will trigger a semantic P600 compared to a more traditional N400 effect. Furthermore, both Visser et al. and Kuperberg assume that the semantic P600 effect reflects a mechanism that is language-specific. More recent theories, however, suggest that the P600 effect in general—not just the one elicited by unexpected semantic stimuli—may reflect a domain-general mechanism indexing the effort required to integrate an unexpected stimulus into any structured system (Christiansen et al., 2012).

In line with this idea of that the P600 may reflect domain-general processes, the third theory for the semantic P600 effect suggests that the component reflects processes related to episodic memory retrieval (Van Petten & Luka, 2012). Van Petten and Luka cite studies of old/new judgments of stimuli from lists of pictures or words that found larger P600 effects when

participants correctly judged a stimulus as old than when they correctly or incorrectly judged it as new or incorrectly judged it as old (Rubin, Van Petten, Glisky, & Newberg, 1999; Senkfor & Van Petten, 1998; Van Petten & Senkfor, 1996). Unlike the other conditions, an individual must actively search and retrieve the item in question from episodic memory to make a correct judgment that the item is old.

A similar process might underlie the semantic P600 effect: When an individual hears an unexpected word, they must actively recall the sentence in order to reanalyze it in an attempt to reconcile the incongruous word with the rest of the sentence. As such, the P600 may reflect processes related to retrieval of information from episodic memory in order to integrate a stimulus—linguistic or otherwise—into the broader sequence. Importantly, the theory that the P600 indexes an *active* search of episodic memory suggests that this that this is a *controlled* process in which the participant engages. Thus, the elicitation of a P600 effect requires three criteria to be met: (1) The unexpected stimulus must trigger an reanalysis of the stimulus, (2) the individual must make an active search of episodic memory for the surrounding information, and (3) the individual must then attempt—successfully or unsuccessfully—to use that information to reconcile the unexpected stimulus with the surrounding context. While it is uncontroversial that the P600 reflects the reanalysis and an attempt at integration, Van Petten and Luka's theory adds the critical role of episodic memory to the mechanisms underlying the P600.

This crucial distinction may also account for some of the findings described by Kuperberg (2007) and Vissers et al. (2008). In each case, it is possible that the context surrounding the unexpected stimulus was strong enough to trigger the reanalysis of the critical word—a necessary criterion also accepted all three theories. Van Petten and Luka's theory suggests that this reanalysis would rely heavily on an active search of episodic memory. In other

words, the participant would have to recall the rest of the sentence or preceding context (i.e., story or picture) and hold that information in working memory to re-examine the unexpected word in relation to the surrounding information. Finally, with that information in mind, the participant could then attempt to reintegrate the unexpected word back into the sentence.

Importantly, this theory can reconcile why an unexpected word that is *congruent* with a preceding context could produce a P600 in some circumstances (e.g., Nieuwland & Van Berkum, 2005) while a word that is *incongruent* with the preceding context could produces a P600 in other circumstances (Vissers et al., 2008). In particular, Nieuwland and Van Berkum (2005) found an unexpected noun presented in a sentence without a preceding context produced an N400 effect. However, when that same sentence was presented after a story that gave a reasonable context for that noun, the word elicited a P600 effect instead. In contrast, Vissers et al. (2008) found a P600 effect when a preposition inaccurately described the location of an object in a preceding image. Van Petten and Luka's theory would suggest that in each case, after the reanalysis process was triggered, participants had to search their episodic memory of the preceding context (i.e., the story or a picture) in order to reassess the unexpected word's role in the sentence. With respect to Vissers et al., the participant would have been able to recall the picture and then use that information to determine that the information expressed by the preposition could not be reconciled. With respect to Nieuwland and Van Berkum, when the sentence was preceded by a story, the participant could search episodic memory for that story to pull out the information that they needed to conclude that the unexpected noun was justifiable within that context. However, when sentence was not preceded by a story, there was no episodic memory to search; thus, the unexpected noun elicited an N400 effect instead of a P600 effect.

Unlike the theories posited by Kuperberg (2007) and Vissers et al. (2008), the inclusion of a search of episodic memory in Van Petten and Luka's (2012) theory provides a mechanism for making *a priori* predictions about whether a particular violation will elicit a P600 effect. However, the theory still lacks specifications on what circumstances are needed to trigger the initial controlled reanalysis process, and it is possible that this process may be determined to a greater or lesser degree by individual differences.

5.3.2 Semantic P600 Effects to Lexical Expectations and Motion Congruity

In the current study, I found semantic P600 effects in response to (1) atypical lexicalization patterns for motion information including path verbs in English speakers, manner verbs in Spanish speakers, and manner gerunds for English speakers and (2) incongruent motion verbs in English and Spanish speakers and incongruent path prepositions in English speakers but not in incongruent path expressions outside of the verb in Spanish or in manner gerunds in either language. I will discuss how these results relate to each of the three theoretical explanations of the semantic P600 effect in turn.

First, Kuperberg (2007) suggested that a semantic P600 is more likely to occur in the presence of (1) semantic-thematic violations to animacy, (2) the incongruent stimulus is semantically associated to the expected stimulus, (3) participants are asked to make acceptability judgments, or (4) the unexpected stimulus is congruent with some preceding context. Kuperberg suggests that these—and possibly other—criteria work together to increase the probability of obtaining a P600 effect. As such, satisfying only some of these criteria may have been sufficient to elicit the P600 effects seen in the current experiment.

With respect to Kuperberg's first criterion, violating the semantic-thematic constraints between an inanimate object and the plausible verbs that could be associated with that object may play a role in eliciting the semantic P600. In the present study, the subject of each sentence was an animate character and the verbs and other critical expressions all described motions that were possible for the character to perform. Thus, no semantic-thematic violations occurred. However, the lexicalization analyzes do reveal semantic P600 effects in response to *lexico-semantic* violations. In other words, there was a mismatch between the syntactic category and the type of semantic information that was lexicalized within that element. For example, for Spanish speakers, verbs typically connote path of motion; thus encountering a verb that connotes manner information provokes a semantic mismatch with their expectations for that syntactic category, and vice versa for English.

In addition to verbs, I also found a semantic P600 effect in response to manner gerunds compared to path prepositions in English speakers but no such effect for Spanish speakers. Importantly, English speakers have a strong preference to express manner in the verb and rarely express manner outside of the verb in contrast to Spanish speakers who are relatively more accustomed to expressing motion in a variety of ways. Thus, for English speakers the lexico-semantic expectancy for path to be expressed in a preposition is relatively high while the expectancy for manner to be expressed in a gerund is relatively low. This discrepancy between lexico-semantic expectancies might have led to the P600 effect seen in English speakers for gerunds.

As such, it is possible that like the semantic-thematic constraints of animacy, habitual patterns of motion expression may establish certain lexico-semantic expectancies that may also lead to similar semantic P600 effects. Alternatively, it could be the case that the P600 is

sensitive to relative lexical expectancy instead. Notably, the interaction between language and motion verb in this study was entirely mediated by the lemma frequency for the motion words suggesting that rarer verbs were more likely to elicit a P600 effect compared to more frequent verbs. And while the effect for motion expression outside of the verb in English was robust to the effect of word frequency, the use of gerunds is relatively rare in English speakers, especially when compared to the use of prepositions, suggesting that the rarity of the inclusion of an optional manner gerund at the end of a sentence was the trigger of the P600 effect. Furthermore, the critical verbs used by Kuperberg et al. (2003) and in other studies of animacy may not have be particularly rare, but in combination with the preceding inanimate object they may have formed n-grams with particularly low levels of frequency. For example, a collocate search in the Corpus of Contemporary English (COCA; Davies, 2008) of the lemmas in the bigram '*boy eat*' resulted in 66 hits (out of 560 million words) whereas the bigram '*egg eat*' resulted in only 6 hits (in the grammatical forms of '*eggs eaten*' and '*egg eating*'). Thus it is possible that, rather than the thematic-semantic or lexico-semantic relationships being one cause of the semantic P600, it is the relatively low expectancy for that particular word within that given context that elicits the effect.

With respect to Kuperberg's second criterion (i.e., semantic association), the violating stimulus was always semantically associated with the sentential context in both the lexical analysis and the motion sensitivity analysis. For the lexical analyses, the unexpected stimulus was always a grammatical motion word that was congruent with the preceding video and plausible within the context of the sentence; and for the motion sensitivity analyses, the incongruent stimuli were always the same motion type as the congruent stimuli and plausible within the context of the sentence.

With respect to the third criterion, explicit acceptability judgments, in the current study, participants were asked to make judgments about whether or not the sentences had matched the preceding video. This therefore placed participants' attention directly on the congruity of the stimuli with the preceding context, which may have contributed to the P600 effects seen in the analyses of motion sensitivity. However, the P600 for motion sensitivity was only seen in response to incongruent verbs in both languages and incongruent path prepositions in English, but N400 effects were seen instead for the manner gerunds in both languages and for the path expressions outside of the verb (adverbs and prepositions) for Spanish speakers (as well as an N400 in the latter half of trials for path prepositions in English in addition to the P600). Furthermore, participants were not asked to make explicit judgments about the acceptability of the sentence structure, but P600 effects were still seen in response to atypical motion expression structures—albeit mediated by word frequency in the case of the verbs. It is possible that any type of acceptability judgment that draws attention to the critical words will trigger a reanalysis of that word thus leading to the P600 in the lexical analyses, but this still does not explain why certain congruity violations but not others would elicit a P600 effect in the motion sensitivity analyses.

The final criterion suggested by Kuperberg (2007) is the presence of a congruent context. In stark contrast to this prediction, the motion sensitivity analysis revealed P600 effects in response to words that were *incongruent* with a preceding context. These results are more in line with the results of Vissers et al. (2008) who found a P600 effect when a preposition connoting location mismatched a preceding image.

As discussed previously, the Monitoring Theory (Vissor et al., 2008) suggests that all P600 effects—not just the semantic P600—reflect a reanalysis of the initial interpretation of the

sentence. Thus, the P600 findings of the motion sensitivity analysis are more in line with the Monitoring Theory than Kuperberg's (2007) theory. In particular, the Monitoring Theory would suggest that a P600 should be elicited whenever participants encountered a word that mismatched their expectancies based on the preceding video context. Likewise, a similar reanalysis may have been triggered whenever participants read a syntactic structure that expressed an unexpected motion type in the lexical analyses. Importantly, in the former case, P600 effects were only seen for incongruent verbs in both languages and path prepositions in English. In contrast, manner gerunds in both languages and path expression outside of the verb (prepositions and adverbs) in Spanish did not elicit P600 effects but rather exhibited the traditionally predicted N400 effect instead. And the English path prepositions actually produced both an N400 and a P600. The Monitoring Theory does not provide a mechanism to explain why certain incongruities would produce a P600 effect while others would produce an N400 effect, and others still would produce both.

The final theory is that of Van Petten and Luka (2012) that states a P600 effect occurs whenever a stimulus triggers an active search of *episodic memory* in order to reanalyze and reintegrate the stimulus with its surrounding context. In the present study, the motion sensitivity analyses revealed a P600 effect in response to verbs and English prepositions when they were incongruent with a preceding video. According to Van Petten and Luka's theory, the incongruity of these words may have triggered a reanalysis in which the participant had to recall the preceding video in order determine whether they could reintegrate the critical word into the context of the sentence. However, manner gerunds for speakers of both languages and path outside the verb for Spanish speakers in all four blocks and during the second half of trials for

English speakers elicited N400 instead of P600 effects despite being privy to the same preceding video contexts.

One possible explanation is that the failure to elicit a P600 in these conditions is related to a failure to *trigger a reanalysis* rather than a lack of an episodic memory to contextualize the critical words. As suggested by Papafraou et al.'s (2002) salient verb hypothesis, the verb plays a critical role in the formation of a sentence in any language. Similarly, for English speakers who prefer to express motion with manner-verb constructions (and in line with some behavioral work showing heightened sensitivities to path information in English speakers in line with the encodability hypothesis; e.g., Emerson et al., 2016; Gennari et al., 2002; Kersten et al., 2010; Lai & Narasimhan, 2015), path prepositions are a common and vital component of motion expression in English. As such, the lexicalization of incongruent motion information—whether it be path or manner—in a 'privileged' element, such as the verb for speakers of either language or in the preposition for speakers of English, may serve as a catalyst for the reanalysis of that information. However, more secondary expressions, such as the inessential manner gerunds in either language or the path prepositions or path adverbs in Spanish, may not have been salient or vital enough for the speakers to trigger this reanalysis process despite having the information for that analysis readily available for them in episodic memory.

In addition to the P600 in response to motion incongruities, Van Petten and Luka's theory could also pose a possible explanation for the P600 effect found in response to atypical but congruent descriptions of motion. For this analysis, all of the critical stimuli were congruent with the preceding video. Instead, the trigger for a reanalysis in these stimuli would have been the atypical lexicalization of motion information. Upon reaching a word expressing motion information that the participant was not expecting, the theory suggests they would then have to

recall the video from episodic memory in order to verify whether or not that information accurately matched. Once verified, the participant would be able to successfully reintegrate the critical word with the rest of the sentence. In this sense, these results are similar to the P600 effect seen in response to the unexpected but congruent stimuli that followed stories in the Nieuwland and Van Berkum (2005) study.

An alternative but related explanation for the P600 effects in the lexical analyses is that after a reanalysis was triggered, participants relied on information about the typical and allowed forms of that type of motion information stored in *semantic memory*[5] rather than relying on the episodic memory of the preceding videos. After comparing the usage of the critical word to other potential options in semantic memory, the participant could then decide whether the word constituted an error or could be successfully reintegrated with the rest of the sentence. If this were the case, it would suggest that the P600 effect reflects an active search of any form of *declarative memory* rather than episodic memory alone.

While all three theories provide potential explanations for the P600 results seen in the lexical and motion sensitivity analyses, more empirical research is needed to validate which of the three is more likely. Furthermore, more research is needed to identify *a priori* which circumstances will reliable elicit an N400 effect, a semantic P600 effect, or both.

5.4 Limitations & Future Directions

The present study is the first to examine the neural correlates of motion expression and is one of the few studies which have found P600 effects in response to linguistic violations that

[5]The term semantic memory is used here to refer to a form of declarative memory responsible for the retention of facts and knowledge rather than of or related to the meaning of words.

were not syntactic in nature. As the first study of its kind within the domain of motion, it also has several limitations that could be explored in future research.

First, participants in the study were not monolinguals of the languages they represented, and as such, exposure to other languages may have influenced participants' neural processing of the stimuli. In particular, while none of the English-speaking participants were native speakers of Spanish, it is possible that many have been exposed to some degree of Spanish (e.g., secondary school courses, popular media). Furthermore, participants were not excluded from participation if they were also fluent in another language, which may have included V-languages other than Spanish. Importantly, participants in the Spanish-speaking sample were all fluent and relatively proficient in English because they were recruited from an English-speaking university. Furthermore, many were simultaneous bilinguals who had both Spanish and English as their native languages. As such, it is possible that these samples—particularly the Spanish-speaking sample—may have exhibited different language-specific biases than Spanish monolinguals.

A second limitation to the present study is the sentence placement of the motion information outside the verb. Previous studies have found differences in ERP amplitudes based on the location at which the words are placed in the sentence (Payne et al., 2015; Van Petten & Kutas, 1990, 1991). Due to language- and motion-type-specific constraints on lexicalization, the placement of manner and path information varied such that they occurred either in the penultimate or final screen presentation for each sentence. Specifically, manner outside of the verb was encoded as a gerund for both languages and always occurred in the final position in the sentence. In contrast, path outside the verb was expressed as a preposition and occurred in the last screen for all English manner-verb sentences and in half of the manner-verb sentences for Spanish. However, for the other half of these stimuli in Spanish, path was expressed as an

adverb in the final position. As such, word order might have created a potential confound for the analyses of motion information outside the verb. In order to ameliorate any effects of word order in the present analyses, "Location" (i.e., position in the penultimate or final screen of the sentence presentation) was included as a random effect in all optimal models of all relevant analyses in order to account for different baseline levels based on sentence location. However, to improve upon these methods, future research should (1) include languages in which motion expressions outside of the verb are more comparable between typologically distinct languages, (2) examine within-language variability for the neural correlates of motion expression based on location within the sentence, and (3) examine these neural correlates after training on miniature artificial languages, which can more easily be constructed to control for word order.

A final limitation is that these data cannot be used to differentiate between the three theories for the presence of 'semantic P600' effects. The stimuli conformed to many of the criteria described by Kuperberg (2007) as potential contributors towards eliciting semantic P600 effects. They were also presented within a context (i.e., preceding animations) that might elicit reanalysis of participants' initial interpretation of the stimuli as suggested by Visser et al.'s (2008) Monitoring Theory. Alternatively, this same context may have served to create an episodic memory, and retrieval of that memory may have been the true source of the P600, as suggested by Van Petten and Luka (2012). The current design does not allow for distinguishing between these possibilities; therefore, future research is required to elucidate the causes of the P600, particularly when it occurs in response to semantic violations.

5.5 Conclusions

Overall, the results suggest that speakers of typologically distinct languages do develop expectancies for how motion information should be lexicalized based on patterns of habitual expression; however, the present data do not provide strong support for the idea that habitual expression increases speakers' sensitivity to either manner or path information in cognitive processing. Of particular interest, the study found P600 effects in response to atypical patterns of lexicalization of motion information and for expressions that were incongruent with a preceding video but only when lexicalized in certain parts of speech (i.e., the verb for speakers of both languages and path prepositions for English speakers). These unexpected ERP results suggest a new domain of stimuli which elicit the so called 'semantic P600' effect and open new questions about the types of stimuli that elicit N400 compared to P600 effects as well as the nature of the P600 effect in general.

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APPENDICES

Appendix A

Sentence stimuli for the manner-verb construction (preferred construction of native English speakers). Words that appear simultaneously on the same screen are underlined together. A gloss is presented below each Spanish stimulus in italics.

Video	English	Spanish			
1	Felix walks up the bridge.	Félix *Felix*	camina *walks*	puente *bridge*	arriba. *up*
2	Felix walks down the bridge.	Félix *Felix*	camina *walks*	puente *bridge*	abajo. *down*
3	Felix walks towards the bridge.	Félix *Felix*	camina *walks*	hacia *towards*	el puente. *the bridge*
4	Felix walks across the bridge.	Félix *Felix*	camina *walks*	a través del *across*	puente. *bridge*
5	Felix runs up the bridge.	Félix *Felix*	corre *runs*	puente *bridge*	arriba. *up*
6	Felix runs down the bridge.	Félix *Felix*	corre *runs*	puente *bridge*	abajo. *down*
7	Felix runs towards the bridge.	Félix *Felix*	corre *runs*	hacia *towards*	el puente. *the bridge*
8	Felix runs across the bridge.	Félix *Felix*	corre *runs*	a través del *across*	puente. *bridge*
9	Felix jumps up the bridge.	Félix *Felix*	salta *jumps*	puente *bridge*	arriba. *up*
10	Felix jumps down the bridge.	Félix *Felix*	salta *jumps*	puente *bridge*	abajo. *down*
11	Felix jumps towards the bridge.	Félix *Felix*	salta *jumps*	hacia *towards*	el puente. *the bridge*
12	Felix jumps across the bridge.	Félix *Felix*	salta *jumps*	a través del *across*	puente. *bridge*
13	Felix flies up the bridge.	Félix *Felix*	vuela *flies*	puente *bridge*	arriba. *up*
14	Felix flies down the bridge.	Félix *Felix*	vuela *flies*	puente *bridge*	abajo. *down*
15	Felix flies towards the bridge.	Félix *Felix*	vuela *flies*	hacia *towards*	el puente. *the bridge*
16	Felix flies across the bridge.	Félix *Felix*	vuela *flies*	a través del *across*	puente. *bridge*

Video	English	Spanish			
17	Felix crawls up the bridge.	Félix	se gatea	puente	arriba.
		Felix	*crawls*	*bridge*	*up*
18	Felix crawls down the bridge.	Félix	se gatea	puente	abajo.
		Felix	*crawls*	*bridge*	*down*
19	Felix crawls towards the bridge.	Félix	se gatea	hacia	el puente
		Felix	*crawls*	*towards*	*the bridge*
20	Felix crawls across the bridge.	Félix	se gatea	a través del	puente
		Felix	*crawls*	*across the*	*bridge*
21	Felix rolls up the bridge.	Félix	roda	puente	arriba.
		Felix	*rolls*	*bridge*	*up*
22	Felix rolls down the bridge.	Félix	roda	puente	abajo.
		Felix	*rolls*	*bridge*	*down*
23	Felix rolls towards the bridge.	Félix	roda	hacia	el puente
		Felix	*rolls*	*towards*	*the bridge*
24	Felix rolls across the bridge.	Félix	roda	a través del	puente
		Felix	*rolls*	*across the*	*bridge*
25	Felix marches up the bridge.	Félix	marcha	puente	arriba.
		Felix	*marches*	*bridge*	*up*
26	Felix marches down the bridge.	Félix	marcha	puente	abajo.
		Felix	*marches*	*bridge*	*down*
27	Felix marches towards the bridge.	Félix	marcha	hacia	el puente
		Felix	*marches*	*towards*	*the bridge*
28	Felix marches across the bridge.	Félix	marcha	a través del	puente
		Felix	*marches*	*across the*	*bridge*
29	Felix slides up the bridge.	Félix	se desliza	puente	arriba.
		Felix	*slides-himself*	*bridge*	*up*
30	Felix slides down the bridge.	Félix	se desliza	puente	abajo.
		Felix	*slides-himself*	*bridge*	*down*
31	Felix slides towards the bridge.	Félix	se desliza	hacia	el puente
		Felix	*slides-himself*	*towards*	*the bridge*
32	Felix slides across the bridge.	Félix	se desliza	a través del	puente
		Felix	*slides-himself*	*across the*	*bridge*

Appendix B

Sentence stimuli for the path-verb construction (preferred construction of native Spanish speakers). Words that appear simultaneously on the same screen are underlined together. A gloss is presented below each Spanish stimulus in italics.

Video	English	Spanish			
1	Felix ascends the bridge walking.	Félix *Felix*	sube *ascends*	el puente *the bridge*	caminando. walking
2	Felix descends the bridge walking.	Félix *Felix*	baja *descends*	el puente *the bridge*	caminando. walking
3	Felix approaches the bridge walking.	Félix *Felix*	se acerca al *approaches-to*	puente *the bridge*	caminando. walking
4	Felix crosses the bridge walking.	Félix *Felix*	cruza *crosses*	el puente *the bridge*	caminando. walking
5	Felix ascends the bridge running.	Félix *Felix*	sube *ascends*	el puente *the bridge*	corriendo. running
6	Felix descends the bridge running.	Félix *Felix*	baja *descends*	el puente *the bridge*	corriendo. running
7	Felix approaches the bridge running.	Félix *Felix*	se acerca al *approaches-to*	puente *the bridge*	corriendo. running
8	Felix crosses the bridge running.	Félix *Felix*	cruza *crosses*	el puente *the bridge*	corriendo. running
9	Felix ascends the bridge jumping.	Félix *Felix*	sube *ascends*	el puente *the bridge*	saltando. jumping
10	Felix descends the bridge jumping.	Félix *Felix*	baja *descends*	el puente *the bridge*	saltando. jumping
11	Felix approaches the bridge jumping.	Félix *Felix*	se acerca al *approaches-to*	puente *the bridge*	saltando. jumping
12	Felix crosses the bridge jumping.	Félix *Felix*	cruza *crosses*	el puente *the bridge*	saltando. jumping
13	Felix ascends the bridge flying.	Félix *Felix*	sube *ascends*	el puente *the bridge*	volando. flying
14	Felix descends the bridge flying.	Félix *Felix*	baja *descends*	el puente *the bridge*	volando. flying
15	Felix approaches the bridge flying.	Félix *Felix*	se acerca al *approaches-to*	puente *the bridge*	volando. flying
16	Felix crosses the bridge flying.	Félix *Felix*	cruza *crosses*	el puente *the bridge*	volando. flying
17	Felix ascends the bridge crawling.	Félix *Felix*	sube *ascends*	el puente *the bridge*	gateando. *crawling*

Video	English	Spanish			
18	Felix descends the bridge crawling.	Félix *Felix*	baja *descends*	el puente *the bridge*	gateando. *crawling*
19	Felix approaches the bridge crawling.	Félix *Felix*	se acerca al *approaches-to*	puente *the bridge*	gateando. *crawling*
20	Felix crosses the bridge crawling.	Félix *Felix*	cruza *crosses*	el puente *the bridge*	gateando. *crawling*
21	Felix ascends the bridge rolling.	Félix *Felix*	sube *ascends*	el puente *the bridge*	rodando. *rolling*
22	Felix descends the bridge rolling.	Félix *Felix*	baja *descends*	el puente *the bridge*	rodando. *rolling*
23	Felix approaches the bridge rolling.	Félix *Felix*	se acerca al *approaches-to*	puente *the bridge*	rodando. *rolling*
24	Felix crosses the bridge rolling.	Félix *Felix*	cruza *crosses*	el puente *the bridge*	rodando. *rolling*
25	Felix ascends the bridge marching.	Félix *Felix*	sube *ascends*	el puente *the bridge*	marchando. *marching*
26	Felix descends the bridge marching.	Félix *Felix*	baja *descends*	el puente *the bridge*	marchando. *marching*
27	Felix approaches the bridge marching.	Félix *Felix*	se acerca al *approaches-to*	puente *the bridge*	marchando. *marching*
28	Felix crosses the bridge marching.	Félix *Felix*	cruza *crosses*	el puente *the bridge*	marchando. *marching*
29	Felix ascends the bridge sliding.	Félix *Felix*	sube *ascends*	el puente *the bridge*	deslizandose. *sliding-himself*
30	Felix descends the bridge sliding.	Félix *Felix*	baja *descends*	el puente *the bridge*	deslizandose. *sliding-himself*
31	Felix approaches the bridge sliding.	Félix *Felix*	se acerca al *approaches-to*	puente *the bridge*	deslizandose. *sliding-himself*
32	Felix crosses the bridge sliding.	Félix *Felix*	cruza *crosses*	el puente *the bridge*	deslizandose. *sliding-himself*

Appendix C

Lemma frequencies for the critical motion words in English and Spanish. Lemma frequencies were calculated from the Corpus of Contemporary American English (COCA; Davies, 2008) for English and the Corpus del Español (Davies, 2016) for Spanish and were converted to frequency per million. Mean centered frequency was calculated across all lemma frequency. Lemma's were limited to only verbs, prepositions, or adverbs to match the part of speech used in the stimuli. Manner outside the verb was always expressed as a gerund and as such was always one lemma form of the manner verbs. Thus the manner verbs and manner expressions outside of the verb were equal.

English	Frequency per Million	Mean Centered Frequency	Spanish	Frequency per Million	Mean Centered Frequency
Manner					
crawl	18.14	-91.42	*gatear*	1.07	-108.49
walk	280.25	170.69	*caminar*	80.76	-28.81
run	462.72	353.15	*correr*	137.43	27.87
slide	41.06	-68.51	*deslizar*	8.72	-100.84
march	20.04	-89.53	*marchar*	32.85	-76.72
roll	79.90	-29.66	*rodar*	17.07	-92.50
jump	69.53	-40.03	*saltar*	43.75	-65.81
fly	99.05	-10.51	*volar*	41.88	-67.68
	***M* = 133.84**			***M* = 45.44**	
	***SD* = 157.12**			***SD* = 44.73**	
Path Verbs					
approach	67.49	-42.07	*acercar*	111.92	2.36
descend	17.06	-92.51	*bajar*	132.50	22.93
cross	68.62	-40.94	*cruzar*	52.47	-57.10
ascend	3.97	-105.59	*subir*	142.38	32.81
	***M* = 39.28**			***M* = 109.82**	
	***SD* = 33.65**			***SD* = 40.28**	
Path Outside of the Verb					
across	277.35	167.79	*través*	379.34	269.78
down	96.57	-12.99	*abajo*	65.17	-44.40
up	209.17	99.60	*arriba*	87.75	-21.81
toward	300.65	191.08	*hacia*	65.17	-44.40
	***M* = 220.94**			***M* = 149.36**	
	***SD* = 91.54**			***SD* = 153.69**	

Appendix D

BACKGROUND INFORMATION

This information will be used to prepare a summary report about the people taking part in our study. You do not have to answer any questions that you do not want to answer.

Your date of birth: __ __ __ __ __ __
M M D D Y Y

Your sex: M F

I am (choose one): Right Handed Left Handed

I am (choose one or more):
____ American Indian/Alaska Native
____ Asian
____ Black/African-American
____ Hispanic/Latino
____ Native Hawaiian/ Other Pacific Islander
____ White
____ Other (please specify: ________________________)

Your highest degree of education:
____ 8th grade or less
____ High school degree
____ Some college (at least 1 year)
____ College or university degree
____ Graduate professional degree (MA, MD, PhD)

— PLEASE CONTINUE TO PAGE 2 —

Your native language(s): ______________________________

____

____

Languages—other than your native language(s)—that you have learned.

Language	**Age in yrs. (when started)**	**Learning Situation (e.g., school, home…)**	**Fluency (fluent, somewhat fluent, not fluent)**

How many years have you been living in the United States?

____

What language do you speak at home?

____

What language do you primarily use in your everyday life?

____