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The research and writing of this thesis is

dedicated to everyone who helped along the way.

Many thanks,

Timothy McCormick

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**CHAPTER 1: Introduction**

**Statement of the Problem**

Processing language in our surroundings involves constant uptake and interpretation. As the language parser receives input, it incorporates new pieces of information into the structure sequentially, building an interpretation in real time with each new linguistic item. However, the hierarchical structure of language and the linear nature of this uptake means the parser will face complex linguistic structures that lead to incorrect interpretations, which must be resolved in order to reach the correct interpretation (Frazier & Fodor, 1978; Frazier & Clifton, 1998; MacDonald Pearlmutter, Seidenburg, 1994; Tanenhaus, Spivey-Knowlton, Eberhard & Sedivy, 1995).

Cognitive control (CC), also referred to as inhibitory control or attentional control, is a cognitive variable involved in the resolution of conflict in our input (WHAT IS COGNITIVE CONTROL). Among the conflicts that CC is involved in resolving are these incorrect initial interpretations that occur during language processing. The use of online measures like functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) has allowed researchers to confirm that a shared brain structure is involved in the resolution of both linguistic and nonlinguistic conflict: data from psycholinguistic, neuropsychological and imaging studies converge to show that linguistic ambiguity resolution and non-linguistic cognitive control processes co-localize within the left ventrolateral prefrontal cortex (specifically the left anterior frontal gyrus, LIFG, and anterior cingular cortex, ACC) (Thompson-Schill, Bedny, & Goldberg, 2005; Novick, Kan, Trueswell & Thompson-Schill, 2009; January, Trueswell, Thompson-Schill, 2009, Teubner-Rhodes et al., 2016; see Luk, Green, Abutalebi & Grady, 2012 for a meta-analysis). The relationship between the left ventrolateral prefrontal cortex, CC and linguistic ambiguity resolution has also been established in behavioral studies. For example, failure to abandon incorrect interpretations (or delayed abandonment) have been obtained of populations with cognitive control deficiencies associated with underdevelopment of or injury to the prefrontal cortex, in other words, children (Trueswell, Sekerina, Hill & Logrip, 1999) and patients (Novick et al., 2009), respectively.

This region, then, can be considered a major player in the correct selection of information during goal-specific tasks; in the case of sentence processing, it allows the abandonment of an incorrect initial analysis to facilitate correct comprehension (Novick, Trueswell & Thompson-Schill, 2005). Recent research has also shown that when CC is engaged by conflict, there is a carryover effect that sustains CC and speeds up subsequent conflict resolution, such as abandoning the incorrect interpretation of a following sentence, even when the triggering conflict is non-linguistic (Hsu & Novick, 2016).

While CC is widely studied in research on ambiguity resolution by monolinguals from these different populations, it also receives considerable attention in research on bilingualism (e.g. Hilchey & Klein, 2011; Struys, Mohades, Bosch & van den Noort, 2015; Teubner-Rhodes et al., 2016; Torres & Sanz, 2016). The conflict resolution associated with CC is also reflected by the bilingual’s suppression of one language impulse to promote the other, both of which are active to a greater or lesser extent at any given moment (see Kroll, Dussias, Bogulski, & Valdes Kroff, 2012, for a review). Researchers have taken great interest in how this abundance of practice translates to other roles of CC, generally using non-linguistic tasks like the attentional network task (ANT) to compare cognitive abilities in bilinguals and monolinguals (e.g. Abutalebi et al., 2012; Bialystok and Majumder, 1998; Bialystok, 1999; Bialystok and Martin, 2004; Zelazo, Frye & Rapus, 1996)

The role of inhibition and conflict resolution in bilingual language processing is an area of research with many questions yet to answer. Several studies have documented that cognitive control plays a role in lexical processing, evidenced by delays in the processing of cross-linguistic homographs (Martín, Macizo & Bajo, 2010), shorter CC recovery periods following lexical processing compared to monolinguals (Blumenfeld & Marian, 2011), and sustained inhibition of the L1 following production of the L2 (Misra, Guo, Bobb & Kroll, 2012).

Of course, language extends beyond words, and bilingualism beyond knowledge of two lexicons. Bilinguals also maintain two morphosyntactic systems. However, our understanding of bilingual sentence processing also leaves many questions to be asked and answered. As Kroll & Bialystok (2013) highlight, our questions concerning bilingual sentence processing have generally focused on the interaction between or coexistence of two grammars in a bilingual system or on L2 learners’ eventual attainment of a “native-like” L2 grammar (p. 509). In the former line, for example, Dussias and colleagues have shown that the native grammar is affected by extended exposure to the L2 grammar (Dussias, 2003; Dussias & Cramer-ScDussias & Sagarra, 2007;

The present dissertation, in a sense, reunites these two separate lines of questioning through proficiency and cognitive control, by asking how THIS IS WHERE YOU STOPPED “What we don’t know, of course, is whether the consequences of repeatedly resolving conflict or ambiguity across two grammars draw on the same cognitive and neural mechanisms that are affected by lexical competition.” (p. 510, Kroll & Bialystok, 2013)

Jegerski (2013

Parsing preferences: (e.g., Dussias, 2003; Dussias & Sagarra, 2007)

Hakuta, K., Bialystok, E., & Wiley, E. (2003). Critical evidence: A test of the critical period hypothesis for

second language acquisition. Psychological Science,

14, 31􏰀38.

(e.g., Bernolet, Hartsuiker, & Pickering, 2007;

## Dussias & Cramer Scaltz, 2008; 4. Discussion

Current findings within the bilingual domain suggest that proficient L2 speakers are not very different from L1 speakers of the target language in their use of lexical–semantic information to compute structural relations among different words in a sentence. These studies indicate that lexical–semantic processing in L2 speakers parallels that of monolingual speakers, and that any differences observed between the two groups arise because processing is slowed down during L2 reading. In contrast, L1 and L2 speakers appear to show qualitative differences in their ability to employ structural information and phrase-structure based on locality principles. Recently, [Clahsen and Felser (2006)](https://www-sciencedirect-com.proxy.library.georgetown.edu/science/article/pii/S0001691807001011" \l "bib3)captured this difference in their “shallow structure hypothesis”, which states that the parsing operations in a second language do not reflect the interaction between syntactic and lexical processing that is characteristic of adult monolingual speakers.

……However, the reading patterns exhibited at the disambiguating region when verb bias was not congruent with sentence continuation, although not statistically significant at first, suggested that the comprehension system of bilingual speakers did not analyze every noun following a verb as its syntactic direct object, even when plausibility information provided supports this analysis. If this had been the case, then direct-object continuations should have been read as quickly following a direct-object bias verb as with a sentential-complement one. The fact that this was not the case indicates that the L2 speakers were not favoring the simplest structural analysis, as would be expected if they applied universal parsing strategies, nor were they prioritizing on plausibility information, as suggested in [Clahsen and Felser (2006)](https://www-sciencedirect-com.proxy.library.georgetown.edu/science/article/pii/S0001691807001011#bib3).

Rather, these L2 speakers were more likely using a combination of verbal information from the L1 and the L2 to resolve the ambiguity. In fact, once the English verbs for which the L2 speakers had not learned the L2 biases were removed from the analysis, the behavior of L2 speakers closely resembled that of native speakers of the target language.

and see Kroll & Dussias, 2013, for a recent review)

Jegerski, 2013

“What we don’t know, of course, is whether the consequences of repeatedly resolving conflict or ambiguity across two grammars draw on the same cognitive and neural mechanisms that are affected by lexical competition.” (p. 510, Kroll & Bialystok, 2013)

From Kroll & Bialystok, 2013: Fromthe perspective of lan- guage processing, there is evidence suggesting that language comprehension and production depend on the absolute and relative levels of proficiency of both languages, that those levels are moderated by context and experience, and that these processing effects are found bidirec- tionally with each language affecting the other (e.g., Kroll & Dussias, 2013; Kroll, Dussias, et al., 2012). From the perspective of cognitive systems, there is evidence suggesting that bilinguals at all stages of the lifespan perform better than mono- linguals on nonverbal executive control tasks, that bilingual performance compared to that of mono- linguals depends on task materials and demands, and that symptoms of dementia in bilinguals are generally delayed relative to comparable mono- linguals (review in Bialystok, Craik, Green, & Gollan, 2009). What is not yet well understood is how the network of cognitive resources that regulates language processing also modifies do- main-general cognitive and brain mechanisms; that is, how does a specific experience in language processing lead to a change in nonverbal cogni- tive processing.

(Kroll & Bialystok, 2013; Kroll & Sunderman, 2005)

Kroll, J. F., & de Groot, A. M. B. (1997). Lexical and conceptual memory in the bilingual: Mapping form to meaning in two languages. In J. F. Kroll (Ed.), *Handbook of Bilingualism: Psycholinguistic approaches* (pp. 169–199). Mahway, NJ: Erlbaum.

Kroll, J. F., & Sunderman, G. (2005). Cognitive Processes in Second Language Learners and Bilinguals: The Development of Lexical and Conceptual Representations. In C. J. Doughty & M. H. Long (Eds.), *The Handbook of Second Language Acquisition*. Oxford, United Kingdom: Blackwell Publishers.

Despite this gap in the literature, we can assert that CC has two roles in language processing in this population of early bilinguals: first, CC works to suppress one language during the processing of the other, and second, CC intercedes to resolve conflict when the parser cannot incorporate new linguistic material into the running structure. This raises the first problem that the current dissertation aims to address. Hsu & Novick (2016) studied monolingual reanalysis following CC engagement. However, given that CC is otherwise employed in early bilinguals, suppressing the language that is not in active use, the question that emerges is how does CC engagement affect the abandonment of incorrect parses in early bilinguals?

Different types of bilinguals must employ their CC to different extents to suppress the language that is not in active use. Adult language learners learning a second language (L2), for example, have a clearly established dominant language, but as they improve their proficiency, the structures and abilities associated with CC work less hard to suppress this dominant language during the use of the L2. This is indicated in both neuroimaging studies that show higher activation of the LIFG during non-proficient language use (Abutalebi, 2008) and in behavioral studies that show a higher correlation between outcomes and executive functions at lower proficiencies (Serafini & Sanz, 2016). This shift in the extent of reliance on CC by non-native language users introduces the second set of problems that this dissertation attempts to address. First, while we have data on language outcomes and brain activity, If low proficiency L2 learners are relying more heavily on CC to suppress their first language (L1) than higher proficiency learners, a question that emerges is how this affects their direction of CC resources to resolve linguistic ambiguity in the L2.

From Lü, Liang & Chen (2019):

n Experiment 1, results showed that compared to monolinguals, the bilingual advantage in interference suppression occurred in the task with high storage demand (i.e., modified flanker task) and not in the low demand task (i.e., flanker task); however, this advantage effect was not observed in response inhibition. In Experiment 2, with the increasing working memory processing demand of tasks, the bilingual advantage in response inhibition was observed.

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**Introduction**

In addition to cognitive control’s role in ambiguity resolution, it is also of considerable interest during the acquisition of a second language (L2). In brain imaging studies, increased activity is observed in the prefrontal brain region associated with cognitive control during the processing of a non-native, non-highly proficient language (Abutalebi, 2008). However, this increased activity is not observed during proficient or native processing. Behavioral data suggest a similar tendency. In a longitudinal study investigating the relationship between cognitive variables and the automaticity of morphosyntactic structures in Spanish for L2 learners, Serafini and Sanz (2016) found robust correlations for learners at beginning proficiency levels. Advanced learners do not obtain this same relationship between linguistic and non-linguistic behavior. This suggests a decreased reliance on cognitive control at increasing proficiency levels (probably meaning less effort needed to suppress L1 at higher L2 proficiencies). These findings fit within a long line of previous research revealing a differential influence of cognitive function at early but not later stages of language learning (compare Linck & Weiss, 2011; Sagarra & Herschensohn, 2010, vs. Grey, Cox, Serafini & Sanz, 2015; however, see Linck et al., 2013 for a review).

What do we know? What do people investigate instead of this question? WHAT ARE THE PROBLEMS? WHERE ARE THE QUESTIONS?

Section on language processing – L1 adult, child, patient

In a recent study, Pozzan and Trueswell (2015) investigate the differences between adult and child L1 processing by elaborating on the idea of the child as a language learner. The authors investigated adult L1 and L2 processing to determine what aspects of child processing are common among learners with full cognitive development, and what aspects should be attributed to immature cognitive control.

In order to investigate this, they study L2 learners’ reanalysis of the same garden-paths used to study child disambiguation. They reason that children will differ from adults (both native and L2 speakers) if these differences relate to immature cognitive control, but that L1 and adult L2 learners will obtain similar results if these difficulties are a learner phenomenon. Importantly, however, a third possibility exists: that L2 processing impinges on cognitive control, which makes learners perform like children during disambiguation. That is, similar results may be obtained, not because the structure is difficult for both sets of learners but because low-proficiency L2 processing occupies cognitive control abilities in adults (Abutalebi, 2008), making comprehension run aground in cases when revision is needed, as is the case in children for whom these same abilities have not yet fully developed.

In their study, native speakers of English and intermediate L2 learners of English (L1 = Italian) participated in a two-by-two study design, allowing researchers to consider the role of syntactic ambiguity (temporarily ambiguous vs. unambiguous) and referential context (though this condition is not pertinent to the current proposal, as L2 adults performed like L1 adults in this aspect). Participants listened to temporarily ambiguous sentences, as in (5a), or unambiguous sentences, as in (5b), while also presented with a coordinating visual world (such as 5c) with a target (frog on the napkin), a goal (box), a competitor-target (frog on the phonebook or eagle on the phonebook, depending on referential condition), and a distractor-goal (napkin):

The language ambiguities included above are cases of information conflict. Reconsider the classic example from (1): The horse raced past the barn fell. The conflict in this case lies between the lexical items in the input and the syntactic structure constructed during the parse. Much of the early processing literature considers ambiguous sentences, especially RC-attachment in double genitive constructions, such as (3a-b) (e.g. Cuetos & Mitchell, 1988; Cuetos et al., 1996; Dussias, 2003; Fernández, 1995, 1999). More recent research tends to focus on temporarily ambiguous constructions such as (2a-b). Temporary ambiguities are resolved as more information is obtained from the input; in the case of (2a-b), later material forces the parser to reinterpret a noun as the subject of a CP instead of a direct object. Temporary ambiguities can also use gender agreement (e.g., Dussias & Sagarra, 2007), or strong structural preferences in one direction (e.g., subject-first RC word order, Teubner-Rhodes et al., 2016). Consider the following example from Teubner-Rhodes and colleagues, where the subject-first interpretation is much preferred:

(4a) Este es el general que vigilaba al espía desde la ventana.

“This is the general that watched the spy from the window.”

(4b) Este es el general que vigilaba el espía desde la ventana.

“This is the general that the spy watched from the window.” (Teubner-Rhodes et al., 2016, 1-2)

These temporarily ambiguous structures are used to allow for online data collection, such as eye-tracking, self-paced reading, ERPs or fMRI scans. With these methodologies, researchers can collect data that reveals resolution of the ambiguity and not just preferences for a certain structure (for example, compare Dussias & Sagarra, 2007, and Dussias, 2003).

Cognitive control, the ability to resolve information conflict, is required to correctly interpret all of these garden-paths, temporary or not. I assume the term ‘cognitive control’, as opposed to other terms such as ‘inhibitory control’, following other researchers who reason that conflict can be resolved through inhibition of irrelevant information or promotion of relevant information, or a combination of both (Botvinick, Braver, Barch, Carter & Cohen, 2001; Teubner-Rhodes et al., 2016). The use of online measures has allowed researchers to isolate the region of the brain involved in cognitive control: data from psycholinguistic, neuropsychological and imaging studies converge to show that linguistic ambiguity resolution and non-linguistic cognitive control processes co-localize within the left ventrolateral prefrontal cortex (specifically the left anterior frontal gyrus, LIFG, and anterior cingular cortex, ACC) (Thompson-Schill, Bedny, & Goldberg, 2005; Novick, Kan, Trueswell & Thompson-Schill, 2009; January, Trueswell, Thompson-Schill, 2009, Teubner-Rhodes et al., 2016). This region, then, can be considered the center for the correct selection of information during goal-specific tasks, and in the case of sentence processing, it allows the abandonment of an incorrect initial analysis to facilitate correct comprehension (Novick, Trueswell & Thompson-Schill, 2005).

Cognitive individual differences in language acquisition have been an area of much research within psycholinguistics (Pozzan & Trueswell, 2015; Kroll & Sunderman, 2005, among many others), neuroimaging and cognitive psychology (Abutalebi, 2008; Abutalebi & Green, 2007; Indefry, 2006, among others), and Second Language Acquisition (Serafini & Sanz, 2016; Linck et al., 2013, among many others). Many of these studies observe a decreased role of cognitive control as language proficiency develops. Consider the behavioral data collected in previous studies, for example. Serafini & Sanz (2016) conducted a longitudinal study with proficiency as an independent variable. They measured the role of cognitive functions in the acquisition process by comparing automaticity of ten different morphological structures in Spanish, two cognitive variables (cognitive control and phonological short term memory), within different proficiency groups (beginning, intermediate and advanced learners). The authors only observed robust correlations between linguistic performance and cognitive variables for beginners, while more advanced learners revealed far fewer significant correlations between linguistic and non-linguistic performance, suggesting a decreased reliance on the ability to encode, store and retrieve information as exposure and proficiency increase in classroom learning. While Serafini and Sanz (2016) are among the very first researchers to specifically compare the role of cognitive functions at various points of L2 proficiency using the same assessment measures, their findings do fit within a long line of previous research supporting the finding of a differential influence of cognitive function at early but not later stages of language learning (compare Linck & Weiss, 2011; Sagarra & Herschensohn, 2010, vs. Grey, Cox, Serafini & Sanz, 2015; however, see Linck et al., 2013 for a review).

These behavioral findings are also supported by neuroimaging data. Collecting neuroimaging data from several fMRI and PET studies of neural structures during bilingual processing, Abutalebi (2008) observed increased activity of the LIFG and other prefrontal structures critical for cognitive control among participants processing a non-native, non-proficient language. The suggestion of this finding is that, as the speaker attains a sufficient level of L2 proficiency, the extra activity fades (Abutalebi & Green, 2007). Bear in mind that the role of cognitive control is to promote relevant information (or suppress irrelevant information), which in the case of bilingual processing can be considered competing forms and linguistic structures, i.e. conflict between languages, and as repeated activation strengthens these networks, the need for cognitive control to intervene decreases (Fedorenko & Thompson-Schill, 2014). Researchers disagree whether this decreased activity is a convergence to the activity involved in L1 activity or if the decreased activity is better understood within the notion of neural organizational efficiency (Indefrey, 2006). However, for our purposes, the observation that there is decreased hemodynamic activity is sufficient to suggest that cognitive control’s influence lessens with increased L2 proficiency.

As Serafini and Sanz (2016) observe, their study is among the first to use the same targets across proficiencies to compare cognitive engagement at different stages of learning, but it considers a range of ten linguistic structures. They motivate the need to isolate fewer specific targets to increase subsequent studies’ power. One target that can serve to fill this gap is syntactic temporary ambiguities, which have been shown to directly engage cognitive control. The authors encourage maintaining a cross-sectional study, which would permit a more detailed understanding of the working memory constructs involved at increasing levels of L2 development. Recent research in child language processing conducted by Pozzan and Trueswell (2015) has also motivated this same cross-sectional study of cognitive control and ambiguity resolution, creating an opportunity for cross-field communication, as will be discussed below.

L2 Sentence Processing and Ambiguity Resolution

Children present a particular difficulty abandoning an initial interpretation when parsing a temporarily ambiguous sentence (Trueswell, Sekerina, Hill & Logrip, 1999). This so-called ‘kindergarten-path effect’ has been associated with immature cognitive control as a result of protracted maturation of prefrontal cortical structures (Choi & Trueswell, 2010; Novick et al., 2005; Woodard, Pozzan, & Trueswell, 2016). Difficulty of the same nature has been observed in patients with impaired cognitive control due to brain damage in these same areas (Novick et al., 2009).

In a recent study, however, Pozzan and Trueswell (2015) question whether the difficulties observed in child processing of syntactic garden-paths are better explained as a L1 learner phenomenon, rather than due to immature cognitive control. In order to investigate this, they study L2 learners’ reanalysis of the same garden-paths used to study child disambiguation. They reason that children will differ from adults (both native and L2 speakers) if these differences relate to immature cognitive control, but that L1 and adult L2 learners will obtain similar results if these difficulties are a learner phenomenon. Importantly, however, a third possibility exists: that L2 processing impinges on cognitive control, which makes learners perform like children during disambiguation. That is, similar results may be obtained, not because the structure is difficult for both sets of learners but because low-proficiency L2 processing occupies cognitive control abilities in adults (Abutalebi, 2008), making comprehension run aground in cases when revision is needed, as is the case in children for whom these same abilities have not yet fully developed.

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5a. Put the frog on the napkin onto the box. (Pozzan & Trueswell, 2015)

5b. Put the frog that’s on the napkin onto the box.

5c.

During processing of the temporarily ambiguous sentence, the first prepositional phrase encountered tends to be interpreted as the goal rather than the modifier, but upon reaching the disambiguating information, the parser must reinterpret the sentence’s syntactic structure to reach the appropriate interpretation.

L2 adults’ behavioral and eye-movement data reflected increased consideration of the incorrect goal. This is the same patterns observed in children during the abandonment of incorrect parses (Trueswell et al., 1999), while native adults are far superior in reanalyzing the structure at this point. However, as noted, the L2 adults did use referential context while processing, while children do not to the same extent, providing evidence that the mature parser does indeed incorporate more information into the one-pass analysis, which is foundational for visual-world studies (e.g. Trueswell et al., 1999; Tanenhaus et al., 1995). The researchers suggest that the similarity of the parsing difficulties may be attributable to fully engaged cognitive control in the low-proficiency L2 participants. However, due to the limited scope of the study, they cannot make this conclusion beyond speculation. The study aimed to fill a gap in the research on child language processing. In turn, it opened a gap in L2 sentence processing. Because the researchers only included L2 learners of one proficiency level (intermediate, as assessed by the oral comprehension subtest of the Michigan Test of English Language Proficiency), the decreased ability for revision of the garden-paths may be the result of task difficulty for the intermediate learner. Pozzan and Trueswell open the opportunity to study how successful disambiguation of syntactic garden-paths at different stages of L2 proficiency correlates to performance on the ANT, in order to understand the correlation between cognitive control and L2 sentence processing of ambiguities across the learning process. However, as will be motivated below, through a slight modification of the paradigm to modulate conflict engagement, a second study can also make causational claims about cognitive control’s involvement in this process.

What do we know to date? What are the problems with this research or the gaps left by it?

Given the dearth, there are questions…

What are the questions about X

And about Y

**Goals and Potential Contributions of the Proposed Study**

To that end, the current dissertation includes three studies aiming to investigate the role of cognitive control in syntactic disambiguation by emergent (L2) bilinguals and early bilinguals who engage in frequent language-switching.

Study 1

The participants of this study are L2 learners of Spanish enrolled in 3rd-, 5th- and 7th- semester Spanish courses. Participants complete a self-paced reading task with two types of structural ambiguity. Reading times of the critical region will be compared to outcomes of the Attentional Network Task to consider how cognitive control correlates to reading times.

Study 2

The participants of this study are also L2 learners from 3rd-, 5th-, and 7th-semester Spanish courses, who completed a self-paced reading task with the same stimuli. However, following recent research in psycholinguistics, the task in this study uses the conflict adaptation paradigm to interleave the linguistic stimuli with non-linguistic flanker stimuli (e.g., Hsu & Novick, 2016; Huang, Gerard, Hsu, Kowalski & Novick, 2016), leveraging the Stroop effect (a phenomenon of prolonged cognitive engagement following conflict) to compare participants’ processing of these ambiguities at engaged vs. nonengaged states of cognitive control.

Study 3

The final study of this dissertation aims to contribute to the research on early bilinguals by investigating how frequent language-switchers respond to the same paradigm as that of Study 2. Given the relationship between cognitive control and language switching (e.g. Abutalebi et al., 2012), the study questions how cognitive control engagement affects subsequent ambiguity resolution, which in practice can inform us how language-switching affects sentence processing and garden-path resolution.

Implications

To date, this paradigm has only been used with monolingual native speakers and with intermediate learners of Italian, but the current three studies will elucidate how cognitive control plays a role in language processing at different stages of language learning and for different profiles of bilinguals. By comparing the results of Study 1 and Study 2, the dissertation will also have implications for designs in L2 research beyond correlational designs.

Chapter 2

Syntactic ambiguity

Cognitive control

Cognitive control in L2

Cognitive control in early bilinguals

PHD EXAM

With recent advancements in the online measures used to study sentence processing and the psychological components involved in these processes, many questions have emerged, especially questions regarding sentence processing in bilinguals, a group historically understudied in the various interdisciplinary fields involved in sentence processing. Even more grave, a great number of studies conflate different language profiles into the broader ‘bilingual’, even though these distinctions may result in entirely distinct linguistic and cognitive development patterns, suggesting that research explicitly exploring these narrower profiles is in order.

One recent trend in research builds on the association between cognitive control and conflict resolution to determine how the linguistic system engages with conflict. However, how different language profiles engage with conflict, particularly in a second or non-dominant language, remains entirely unclear. In what follows, I will motivate research that considers the role of cognitive control during sentence processing at different proficiencies for the adult second language learner and at different levels of language dominance in the heritage language bilingual. This research will bridge findings from several different fields of cognitive science, particularly second language acquisition, psycholinguistics and neuroscience and neuroimaging.

**Sentence processing**

When participating in a conversation, it’s commonly assumed that it is the content of the conversation that creates difficulty for an interlocutor: the more unfamiliar the content, the more difficult. In some cases, we hear reference to ‘ten-dollar words’, suggesting that a participant in a conversation may also experience difficulty from the unfamiliar lexicon of their partner. The grammatical or syntactic structure of the speech often seems entirely unremarkable. However, sentence processing is a highly complex system, incorporating various levels of coordination. Although this coordination is very rapid and generally very smooth, there are cases in which a syntactic peculiarity is encountered that causes a processing interruption, or ‘boggle’. One particularly frequent example is the famous garden-path below:

1. *The horse raced past the barn fell.*

While this garden-path is unlikely to be encountered in daily communication, linguists often use it to discuss the need for reanalysis that would present itself, were it to be encountered ‘in the wild’. Given the linear nature of spoken (and written) language, the parser must create the syntactic structure online as they are encountered, processing new items and incorporating them into the existing structure according to syntactic rules and restrictions. In (1), the parser would first interpret *raced* as the main verb of the sentence. However, when the listener encounters *fell*, she must abandon her incorrect analysis and re-interpret the sentence in order to acquire the correct interpretation within a grammatically licit structure, such that *raced past the barn* is a reduced relative clause (RC) (i.e. *~~that was~~ raced past the barn*) while *fell* fills the role of main verb.

**Models of Sentence Processing**

The example in (1) presents a case of reanalysis, which has received significant attention in the sentence processing literature and has been used to build several models of parsing, generally divided into universal (two-phase) parsers and Constraint-based (one-phase) parsers. Frazier and colleagues’ Garden Path model (and its later update, Construal Theory) is the predominant two-phase model (Frazier & Fodor, 1978; Frazier & Clifton, 1998). Constraint-based or experience-based models (e.g. Cuetos & Mitchell, 1988; Tanenhaus, Spivey-Knowlton, Eberhard & Sedivy, 1995; MacDonald Pearlmutter, Seidenburg, 1994) have received more recent focus.

**Two-phase parsers**

In the two-phase models, put forward by Frazier, Fodor and colleagues, the parser’s first pass incorporates new material into the active syntactic structure using a highly restricted system of incorporation limited to the syntax. This is driven by syntactic economy, specifically Frazier’s Minimal Attachment principle, which requires the first pass to create the structure that requires the fewest syntactic nodes while remaining grammatically-permissible, as well as Frazier’s (1978) Late Closure principle, which requires new material be incorporated into the current constituent whenever grammatically possible. Thus, only the lexical items’ subcategorization information (e.g., part of speech) is consulted when constructing the syntactic structure. The parser’s second-phase considers semantic and pragmatic information beyond the syntax, and if a boggle is encountered, the parser rejects the structure and initiates a reanalysis.

Following evidence that identical syntactic structures with differing lexical items may cause differences in ease of recovery or reanalysis based on biases of the lexical items, these researchers updated their two-phase model with the Construal Theory (Frazier & Clifton, 1998). Construal Theory allows lexical information, such as bias or frequency data, to be consulted during the second phase. Compare the following structures, each with temporarily ambiguous structures that require reanalysis:

(2a) *The woman knew the nervous man would leave*. (Ferreira & Henderson, 1998, 6a-b)

(2b) *The woman saw the nervous man would leave.*

Both main verbs can assume either a noun phrase (NP) or a propositional complement (CP). According to Construal Theory, then, *the nervous man* would be incorporated into the structure as a NP in order to minimize the number of nodes used during the first phase. However, upon encountering *would leave*, the parser must reanalyze *the nervous man* as the subject of a CP and reconstruct the structure accordingly. Here, the CP-bias of *know* makes reanalysis simpler than reanalysis of (2b), where *saw* has a NP-bias (Ferreira & Henderson, 1998).

**Constraint-based models**

Despite its update to incorporate lexical biases, the Garden Path/Construal model cannot account for preferences that go beyond lexical biases to cross-linguistic phenomena. Differences in Spanish- and English-speaker preferences related to RC attachment were among the first of these cross-linguistic preferences observed. Specifically, RC attachment preferences in multiple genitive constructions that do not inherently cause boggles (i.e. not ungrammatical but rather fully ambiguous without the appropriate context) cast the two-phase, syntactically-restricted parser into doubt. Consider the following:

(3a) *El periodista entrevistó a la hija del coronel que tuvo el accidente.*

(3b) *The journalist interviewed the daughter of the colonel who had had the accident*[[1]](#footnote-1).

The preference in Spanish is for the high-attachment reading that the daughter had the accident, which contrasts with the English preference that the colonel had the accident (Cuetos & Mitchell, 1998). More importantly for theoretical purposes, it also contrasts with the universal preference that the Late Closure principle would force. In addition, a corpus study showed that exposure to the high-attachment is, in fact, much more frequent in Spanish (Cuetos, Mitchell & Corley, 1996), which suggests that exposure-frequency accounts for cross-linguistic preferences, a finding that has been supported by more recent research.

Most current research in sentence processing recognizes this need for the parser to consider several sources of information simultaneously: frequency, syntax, semantics, and discourse, for example, may all contribute to the resolution of ambiguity during one-pass processing. Evidence shows that parsers do use information beyond the syntax to correctly process during the parse, providing evidence for these Constraint-based models (Tanenhaus et al., 1995; Trueswell, Tanenhaus, & Garnsey, 1994; Novick, Thompson-Schill & Trueswell, 2008; Pozzan & Trueswell, 2015). One example within the research of Trueswell and colleagues is the use of referential context in the visual-world paradigm through controlled definite article use. When there are two competitors in the visual world, the use of a definite article triggers participants to expect the following information to specify which of the two competitors is being referred to, as the use of a definite article is otherwise anomalous.

While the specific models are still underspecified, certain assumptions are characteristic of them all: an ambiguous strain results in multiple alternatives through bottom-up processing, and constraining evidence from several domains is integrated on the first pass to resolve the ambiguity, or rather, to select the most felicitous option. However, the extent to which each domain plays a role varies from model to model (for example, Tanenhaus et al., 1995; MacDonald et al., 1994). These models have been shown to account for phenomena associated with bilingual sentence processing, as well, an area of psycholinguistic research that remains highly understudied.

**Parsing in bilinguals**

Different aspects of the nature of bilingual processing research likely contribute to the many gaps in this research, including the many variables that must be controlled when studying bilingual participants as well as the dearth of a clear understanding of the monolingual parser (Dussias, 2001). However, the bilingual parser is a key component to understanding the human language parser, and as methodological practices and tools improve, bilingual sentence processing research should be a more motivated area of research. This is particularly true provided that the bilingual is the norm in the global context (Linguistic Society of America, 2012).

The first study to investigate processing of the ambiguities such as those discussed above by bilingual speakers worked within a framework of Universal Grammar, supposing that language acquisition is driven by an internal, innate mechanism, and that adult language learners fail to learn a second language (L2) to a native-like level because they use processes, including processing strategies, of their first language (L1) (Fernández, 1995, 1999). Fernández’s study, which included monolingual English speakers and early and late L1-Spanish L2-English bilinguals, found the strongest preference for Late Closure (or low attachment) among the monolinguals (73% preference), followed by the early bilingual group (49%) and late bilingual group (37%), figures which were not significantly different, though finer-grained analyses did show differences between these groups. This suggests that the exposure to English shifts preferences of the native Spanish speakers towards a more English-like bias, though at a greater extent of a shift of preference for earlier bilinguals.

Dussias (2003) tested Spanish-English bilinguals in both languages, investigating preference for RC-attachment. While monolingual control groups showed the previously observed preferences for high- and low-attached RCs (Spanish and English, respectively), both English- and Spanish-dominant bilinguals preferred low attachment. She suggests that amount of exposure may play a role in these preferences. This question was subsequently investigated by Dussias and Sagarra (2007), who forced high attachment or low attachment using noun-adjective agreement and utilized a self-paced reading methodology. They elaborated the question to include exposure, with groups sorted into monolinguals, bilinguals with limited exposure, and bilinguals with extensive exposure. The authors found that extensive exposure to the low-attachment-heavy L2 greatly facilitated total reading times in the L1, diverging from the native monolingual and limited-exposure bilingual data. These findings all suggest that experience plays a major role in bilingual processing, providing further evidence for an exposure-based model of processing.

**Cognitive Control in Disambiguation**

The language ambiguities included above are cases of information conflict. Reconsider the classic example from (1): *The horse raced past the barn fell.* The conflict in this case lies between the lexical items in the input and the syntactic structure constructed during the parse. Much of the early processing literature considers ambiguous sentences, especially RC-attachment in double genitive constructions, such as (3a-b) (e.g. Cuetos & Mitchell, 1988; Cuetos et al., 1996; Dussias, 2003; Fernández, 1995, 1999). More recent research tends to focus on temporarily ambiguous constructions such as (2a-b). Temporary ambiguities are resolved as more information is obtained from the input; in the case of (2a-b), later material forces the parser to reinterpret a noun as the subject of a CP instead of a direct object. Temporary ambiguities can also use gender agreement (e.g., Dussias & Sagarra, 2007), or strong structural preferences in one direction (e.g., subject-first RC word order, Teubner-Rhodes et al., 2016). Consider the following example from Teubner-Rhodes and colleagues, where the subject-first interpretation is much preferred:

(4a) *Este es el general que vigilaba al espía desde la ventana.*

“This is the general that watched the spy from the window.”

(4b) *Este es el general que vigilaba el espía desde la ventana.*

“This is the general that the spy watched from the window.” (Teubner-Rhodes et al., 2016, 1-2)

These temporarily ambiguous structures are used to allow for online data collection, such as eye-tracking, self-paced reading, ERPs or fMRI scans. With these methodologies, researchers can collect data that reveals resolution of the ambiguity and not just preferences for a certain structure (for example, compare Dussias & Sagarra, 2007, and Dussias, 2003).

Cognitive control, the ability to resolve information conflict, is required to correctly interpret all of these garden-paths, temporary or not. I assume the term ‘cognitive control’, as opposed to other terms such as ‘inhibitory control’, following other researchers who reason that conflict can be resolved through *inhibition* of irrelevant information or *promotion* of relevant information, or a combination of both (Botvinick, Braver, Barch, Carter & Cohen, 2001; Teubner-Rhodes et al., 2016). The use of online measures has allowed researchers to isolate the region of the brain involved in cognitive control: data from psycholinguistic, neuropsychological and imaging studies converge to show that linguistic ambiguity resolution and non-linguistic cognitive control processes co-localize within the left ventrolateral prefrontal cortex (specifically the left anterior frontal gyrus, LIFG, and anterior cingular cortex, ACC) (Thompson-Schill, Bedny, & Goldberg, 2005; Novick, Kan, Trueswell & Thompson-Schill, 2009; January, Trueswell, Thompson-Schill, 2009, Teubner-Rhodes et al., 2016). This region, then, can be considered the center for the correct selection of information during goal-specific tasks, and in the case of sentence processing, it allows the abandonment of an incorrect initial analysis to facilitate correct comprehension (Novick, Trueswell & Thompson-Schill, 2005).

**Cognitive Control: a ‘bilingual advantage’?**

While extensive evidence exists to support a ‘bilingual advantage’ in cognitive control, certain researchers have called into question this advantage. Therefore, the population still affords several questions to psycholinguists regarding exactly *how* a bilingual advantage might transcend into sentence processing, especially provided that much of the work on ‘bilingual advantages’ considers non-linguistic constructs.

**Bilingualism and Cognitive Individual Differences**

Psychological research has revealed that for many populations, the increased use of a certain behavior results in observably improved skills on similar tasks or in observable differences in associated brain structures. For example, architects outperform non-architects on tasks evaluating visuo-spatial ability (Salthouse & Mitchell, 1990), and video game playing has been correlated to heightened modification of perceptual-motor ability (Abutalebi et al., 2012). Just as video-gamers and architects serve as easily identifiable population distinctions, so too is the bilingual. Although ‘architect’ proves to be a much simpler population to isolate, psychologists and psycholinguists have shown that bilinguals differ from their monolingual counterparts in many different facets, both physiologically and behaviorally (Bialystok, 2008).

One reality of the bilingual that distinguishes him from his monolingual peer is the consistent need to suppress one language according to the context. The bilingual does not separate the mental lexicons and grammars, but rather both are active during any language use (Kroll & de Groot, 1997). This perpetual activation was the subject of Green’s (1998) Inhibitory Control (IC) model of bilingual language processing, and has been attested in behavioral studies (e.g. Kroll & Bialystok, 2013; Kroll & Sunderman, 2005); imaging studies (e.g. Abutalebi et al, 2012); and patient data (e.g. Abutalebi, Miozzo & Cappa, 2000).

Within Green’s (1998) IC model, the competitor is suppressed by inhibitory control (or cognitive control). Given two competing forms, the salient but contextually-infelicitous form is suppressed by cognitive control while the desired form is promoted. This model and much of the early research that followed investigated whether this constant activation of cognitive control led to improved performance of bilinguals on nonlinguistic tasks, based on the idea that consistent use of cognitive control would lead to more apt cognitive control (see Bialystok, 2008, for a review). This would become known as the ‘bilingual advantage’. Bilingual advantages have subsequently been attested through neuroimaging and behavioral studies. In neuroimaging, larger gray matter volume has been observed in brain areas that serve executive functioning (Olulade et al., 2015). Likewise, the ACC and the LIFG, both neural structures involved in conflict detection and resolution, the activation of which correlates to poorer performance on conflict tasks, have been observed to be activated more by monolinguals than by bilinguals when performing high-conflict tasks (Abutalebi et al., 2012, Abutalebi, 2008). Likewise, a large effect-size was observed in a meta-analysis conducted by Adesope, Lavin, Thompson and Ungerleider (2010), comparing attentional control of monolingual and bilingual populations, which suggests another bilingual advantage in attentional control. In a high-conflict N-back task, Teubner-Rhodes and colleagues (2016) observe more accurate performance by bilinguals regardless of trial type (lures, targets and fillers), suggesting an advantage that extends beyond conflict resolution to conflict monitoring, a cognitive capacity that becomes especially important in high-conflict contexts when the need for conflict resolution is decided on a moment-to-moment basis. This finding is supported by previous findings (Botvinick et al., 2001; Kerns et al., 2004). However, it should be noted that this advantage has not been found to extend to late bilinguals, i.e. classroom learners, whose performance on a flanker task was compared to that of early bilinguals and monolinguals and found not to differ from the monolingual performance (Luk, De Sa & Bialystok, 2011; but compare Torres & Sanz, 2016, who study heritage language bilinguals and find no difference between late bilinguals and heritage learners, addressed further below).

As far as linguistic development, bilingualism has also been connected to certain ‘disadvantages’, including decreased vocabulary size in one language (e.g. comparing English vocabulary size of monolingual English speakers and bilingual speakers who speak English and another language) (Bialystok, Luk, Peets & Yang, 2009; Bialystok & Luk, 2011); slower lexical access in picture-naming tasks (Gollan, Fennema-Notestine, Montoya, & Jernigan, 2007) and lexical decision tasks (van Hell & Dijkstra, 2002); and decreased verbal fluency in semantic (or categorical) and phonemic (or letter) fluency tasks (e.g. Gollan, Montoya & Werner, 2002; Rosselli et al., 2000). However, when bilinguals are compared to monolinguals of equivalent vocabulary size, bilinguals were shown to perform better in this same task (Bialystok, Craik, & Luk, 2008). These differences, among many observed in the research of Bialystok and colleagues, are attributed to the perpetual activation of both languages during an extended period of time (compare late bilinguals in Luk et al., 2011), thus causing consistent competition and conflict during language use between first- and second language forms.

However, the research has not always so neatly fit within Green’s IC model. Principle among the critiques are Hilchey and Klein (2011), whose extensive review compiled bilingual research and suggested that these ‘advantages’ are not as all-encompassing as the research may suggest. Often, there is a major effect of time, where bilinguals have an initial advantage on non-linguistic cognitive control tasks that dissipates after extensive practice (e.g. Costa, Hernández & Sebastián-Gallés, 2008). Similarly, Paap and Greenberg (2013) found no bilingual advantage in three executive function tasks. In a later review, upon tabulating 76 additional studies that were not considered in Hilchey and Klein’s review, Paap, Johnson and Sawi (2014) found that there was a clear tendency to find bilingual advantages in studies with fewer participants, while null findings were often found regardless of *n*-size. However, the task effect observed by Paap and Greenberg (2013) and the tendency not to find effects in immense studies (Paap et al., 2014) does not necessarily imply that bilingual advantages do not exist. Rather, it leads to a methodological issue: are we asking the right question? While we know that the flanker task requires cognitive control, for example, is the complexity of the task sufficient to observe an extended bilingual advantage in this capacity, if this does exist? A correlational study can only reveal as much as the tools allow, and it may be the case that a flanker task does not simulate sufficiently the complex conflict encountered during language processing.

Another major issue recently observed in bilingual research relates to distinct populations’ representation in the literature (e.g., Torres & Sanz, 2016; Paap & Greenberg, 2013). Given the blurry nature of bilingualism, an umbrella term with many interacting variables, such as biliteracy (see Sanz, 2000; Costa et al., 2008), and which can be used to include diverse populations, ranging from those who use two languages on a daily basis to those who interact with their non-dominant language only very infrequently (Linguistic Society of America, 2012), future research in bilingual sentence processing should include distinct populations to grasp how variables such as literacy, dominance and age of acquisition play a role in processing and how the bilingual advantage may differ between populations. I address the latter question regarding population controls first, followed by the former, methodological question.

**Heritage Speakers and Cognitive Individual Differences**

As Torres and Sanz (2016) address, many studies that consider bilingual speakers may not sufficiently separate distinct language profiles such as heritage language (HL) bilinguals, despite researchers in both camps having asserted that a host of social, economic and other circumstances contribute to linguistic and cognitive development (Hilchey & Klein, 2011; Bialystok, 2001). The bilinguals in some research, such as the Catalonians studied by Costa and colleagues (2008), for example, received bilingual education, thereby possessing an inherently different language profile from HL bilinguals in the US, many of whom have a certain degree of proficiency at an early age and use their HL in their homes but not in school, work or other environments (Polinsky & Kagan, 2007). Even this definition of HL bilinguals is simplistic, though a more detailed definition is beyond the scope of the present project. Torres and Sanz (2016) are the first to bridge and important gap: although much bilingual research likely considers heritage speakers, very few isolate HL bilinguals to investigate the effect of this distinct language profile on cognition; likewise, most research exclusively considering heritage language speakers approaches the population from a perspective that is sociolinguistic (e.g. Goble, 2016), pedagogical (e.g. Polinsky & Kagan, 2007), or developmental (e.g. Benmamoun, Montrul & Polinsky, 2013). Torres and Sanz are the first researchers to isolate this language profile to search for a HL bilingual advantage. The authors find no differences between HL bilinguals and late classroom-emerging bilinguals of Spanish in performance on the Attentional Network Task (ANT), developed to measure cognitive control by (Fan, McCandliss, Sommer, Raz, & Posner, 2002). However, the researchers did note that data trended to show that HL bilinguals resolved conflict easier and at fewer inter-task costs.

While Torres & Sanz (2016) take the important first step to investigate how or whether cognitive differences exist between HL bilinguals and late-L2 bilinguals, differences in the *employment* of executive control during linguistic tasks, such as ambiguity resolution, remain to be investigated. Indeed, the participants of both groups sampled are at the prime age of cognitive control, and so although we don’t see differences in performance on the ANT, a task for which task effects have been observed (see Hilchey & Klein, 2011), temporary ambiguity resolution involves much more coordination. Therefore, a linguistic task modified by a non-linguistic cognitive control task (i.e. a conflict adaptation paradigm) may raise task difficulty to the point of revealing the subtle differences in young adult bilinguals that we cannot observe in strictly nonlinguistic tasks, as discussed above.

In addition, recent neuroimaging studies suggest that it is *language switching* in particular that may be the key factor for the bilingual advantage (Abutalebi et al., 2012). In this neuroimaging study, bilinguals were required to switch languages during a picture-naming task, a process which showed a hemodynamic response in the same region as conflicting flanker trials. Likewise, in a study in progress, heritage speakers were presented with a subcomponent of the ANT following four separate blocks of linguistic ambiguities (English, Spanish, inter-orational code-switches, and intra-orational code-switches), and reaction time and accuracy following the intra-orational code-switches improved beyond the other three blocks (Adler, in progress). This again suggests that frequent alternation between languages may require more cognitive control resources, regardless of whether bilinguals have more cognitive control resources at their disposal, in the vein of Bialystok and colleagues. As Teubner-Rhodes and colleagues suggest, “bilingualism apparently acts as a form of cognitive control training, bestowing measurable advantages in conflict monitoring – the ability to detect unpredictable conflict and flexibly adjust recruitment of cognitive control resources” (Teubner-Rhodes et al., 2016, p. 227). Therefore, to understand the role of HL bilingualism on cognitive control activation during linguistic tasks, researchers should also consider how frequency of use and dominance contribute to cognitive control demands and use of resources.

**Second Language Acquisition and Cognitive Individual Differences**

Cognitive individual differences in language acquisition have been an area of much research within psycholinguistics (Pozzan & Trueswell, 2015; Kroll & Sunderman, 2005, among many others), neuroimaging and cognitive psychology (Abutalebi, 2008; Abutalebi & Green, 2007; Indefry, 2006, among others), and Second Language Acquisition (Serafini & Sanz, 2016; Linck et al., 2013, among many others). Many of these studies observe a decreased role of cognitive control as language proficiency develops. Consider the behavioral data collected in previous studies, for example. Serafini & Sanz (2016) conducted a longitudinal study with proficiency as an independent variable. They measured the role of cognitive functions in the acquisition process by comparing automaticity of ten different morphological structures in Spanish, two cognitive variables (cognitive control[[2]](#footnote-2) and phonological short term memory), within different proficiency groups (beginning, intermediate and advanced learners). The authors only observed robust correlations between linguistic performance and cognitive variables for beginners, while more advanced learners revealed far fewer significant correlations between linguistic and non-linguistic performance, suggesting a decreased reliance on the ability to encode, store and retrieve information as exposure and proficiency increase in classroom learning. While Serafini and Sanz (2016) are among the very first researchers to specifically compare the role of cognitive functions at various points of L2 proficiency using the same assessment measures, their findings do fit within a long line of previous research supporting the finding of a differential influence of cognitive function at early but not later stages of language learning (compare Linck & Weiss, 2011; Sagarra & Herschensohn, 2010, vs. Grey, Cox, Serafini & Sanz, 2015; however, see Linck et al., 2013 for a review).

These behavioral findings are also supported by neuroimaging data. Collecting neuroimaging data from several fMRI and PET studies of neural structures during bilingual processing, Abutalebi (2008) observed increased activity of the LIFG and other prefrontal structures critical for cognitive control among participants processing a non-native, non-proficient language. The suggestion of this finding is that, as the speaker attains a sufficient level of L2 proficiency, the extra activity fades (Abutalebi & Green, 2007). Bear in mind that the role of cognitive control is to promote relevant information (or suppress irrelevant information), which in the case of bilingual processing can be considered competing forms and linguistic structures, i.e. conflict between languages, and as repeated activation strengthens these networks, the need for cognitive control to intervene decreases (Fedorenko & Thompson-Schill, 2014). Researchers disagree whether this decreased activity is a convergence to the activity involved in L1 activity or if the decreased activity is better understood within the notion of neural organizational efficiency (Indefrey, 2006). However, for our purposes, the observation that there is decreased hemodynamic activity is sufficient to suggest that cognitive control’s influence lessens with increased L2 proficiency.

As Serafini and Sanz (2016) observe, their study is among the first to use the same targets across proficiencies to compare cognitive engagement at different stages of learning, but it considers a range of ten linguistic structures. They motivate the need to isolate fewer specific targets to increase subsequent studies’ power. One target that can serve to fill this gap is syntactic temporary ambiguities, which have been shown to directly engage cognitive control. The authors encourage maintaining a cross-sectional study, which would permit a more detailed understanding of the working memory constructs involved at increasing levels of L2 development. Recent research in child language processing conducted by Pozzan and Trueswell (2015) has also motivated this same cross-sectional study of cognitive control and ambiguity resolution, creating an opportunity for cross-field communication, as will be discussed below.

**L2 Sentence Processing and Ambiguity Resolution**

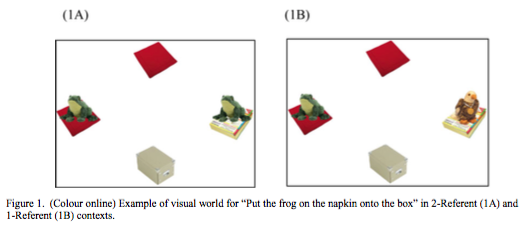
Children present a particular difficulty abandoning an initial interpretation when parsing a temporarily ambiguous sentence (Trueswell, Sekerina, Hill & Logrip, 1999). This so-called ‘kindergarten-path effect’ has been associated with immature cognitive control as a result of protracted maturation of prefrontal cortical structures (Choi & Trueswell, 2010; Novick et al., 2005; Woodard, Pozzan, & Trueswell, 2016). Difficulty of the same nature has been observed in patients with impaired cognitive control due to brain damage in these same areas (Novick et al., 2009).

In a recent study, however, Pozzan and Trueswell (2015) question whether the difficulties observed in child processing of syntactic garden-paths are better explained as a L1 learner phenomenon, rather than due to immature cognitive control. In order to investigate this, they study L2 learners’ reanalysis of the same garden-paths used to study child disambiguation. They reason that children will differ from adults (both native and L2 speakers) if these differences relate to immature cognitive control, but that L1 and adult L2 learners will obtain similar results if these difficulties are a learner phenomenon. Importantly, however, a third possibility exists: that L2 processing impinges on cognitive control, which makes learners perform like children during disambiguation. That is, similar results may be obtained, not because the structure is difficult for both sets of learners but because low-proficiency L2 processing occupies cognitive control abilities in adults (Abutalebi, 2008), making comprehension run aground in cases when revision is needed, as is the case in children for whom these same abilities have not yet fully developed.

In their study, native speakers of English and intermediate L2 learners of English (L1 = Italian) participated in a two-by-two study design, allowing researchers to consider the role of syntactic ambiguity (temporarily ambiguous vs. unambiguous) and referential context (though this condition is not pertinent to the current proposal, as L2 adults performed like L1 adults in this aspect). Participants listened to temporarily ambiguous sentences, as in (5a), or unambiguous sentences, as in (5b), while also presented with a coordinating visual world (such as 5c) with a target (*frog on the napkin*), a goal (*box*), a competitor-target (*frog on the phonebook* or *eagle on the phonebook*, depending on referential condition), and a distractor-goal (*napkin*):

5a. *Put the frog on the napkin onto the box*. (Pozzan & Trueswell, 2015)

5b. *Put the frog that’s on the napkin onto the box*.

5c.

During processing of the temporarily ambiguous sentence, the first prepositional phrase encountered tends to be interpreted as the goal rather than the modifier, but upon reaching the disambiguating information, the parser must reinterpret the sentence’s syntactic structure to reach the appropriate interpretation.

L2 adults’ behavioral and eye-movement data reflected increased consideration of the incorrect goal. This is the same patterns observed in children during the abandonment of incorrect parses (Trueswell et al., 1999), while native adults are far superior in reanalyzing the structure at this point. However, as noted, the L2 adults did use referential context while processing, while children do not to the same extent, providing evidence that the mature parser does indeed incorporate more information into the one-pass analysis, which is foundational for visual-world studies (e.g. Trueswell et al., 1999; Tanenhaus et al., 1995). The researchers suggest that the similarity of the parsing difficulties may be attributable to fully engaged cognitive control in the low-proficiency L2 participants. However, due to the limited scope of the study, they cannot make this conclusion beyond speculation. The study aimed to fill a gap in the research on child language processing. In turn, it opened a gap in L2 sentence processing. Because the researchers only included L2 learners of one proficiency level (intermediate, as assessed by the oral comprehension subtest of the Michigan Test of English Language Proficiency), the decreased ability for revision of the garden-paths may be the result of task difficulty for the intermediate learner. Pozzan and Trueswell open the opportunity to study how successful disambiguation of syntactic garden-paths at different stages of L2 proficiency correlates to performance on the ANT, in order to understand the correlation between cognitive control and L2 sentence processing of ambiguities across the learning process. However, as will be motivated below, through a slight modification of the paradigm to modulate conflict engagement, a second study can also make causational claims about cognitive control’s involvement in this process.

**Conflict Detection and Conflict Adaptation**

The detection of conflict, linguistic or otherwise, has been shown to trigger sustained cognitive control; for example, the Stroop effect can be lessened for an incongruent trial if it is immediately preceded by another incongruent trial (Freitas, Bahar, Yang, & Banai, 2007; Kerns et al, 2004). This pattern has also been observed in adults’ performance on cross-task conflict adaptation, where recovery from an incorrect interpretation due to syntactic ambiguity is facilitated when the language-comprehension trial is immediately preceded by a conflict Stroop trial (Hsu & Novick, 2016). The opposite has also been found, where linguistic conflict in a preceding trial can improve performance on non-linguistic conflict resolution tasks, such as the ANT (Adler, in progress).

However, a different pattern has been observed in children: while conflict engagement results have been found within singular task designs for children (e.g. incongruent Stroop trial preceding incongruent Stroop trial), in a cross-task design, recovery from syntactic misanalysis is more difficult following an incongruent Stroop trial (Huang, Gerard, Hsu, Kowalski & Novick, 2016), and again, patients with damage to the prefrontal cortex have shown similar cross-task difficulties (Novick, personal communication, Nov. 3, 2016). The authors suggest this may be due either to the depletion of immature cognitive control resources or to task difficulty fatigue.

Provided the decreased recruitment of cognitive control-related neural structures (e.g. Abutalebi, 2008) and the decreased role of other executive functions (e.g. Serafini & Sanz, 2016) that is associated with higher proficiencies, the conflict adaptation paradigm can serve as a tool to force specific conflict-engagement states, providing causational data reflecting cognitive control’s role in second language syntactic ambiguity recovery. If cognitive control plays a differential role online at different proficiencies, a conflict adaptation paradigm will reveal different responses from different groups: if cognitive control is not engaged to capacity at higher proficiencies, a garden-path preceded by an incongruent trial will reveal faster disambiguation. However, if cognitive control is fully engaged, an incongruent preceding trial will not be able to trigger cognitive control activation beyond capacity, resulting in similar reanalysis abilities in both preceding-trial conditions. Alternatively, L2 learners with all cognitive control resources engaged will obtain slower reanalysis following incongruencies if they too experience the ‘depletion’ hypothesized to cause these findings in children and patients (Huang et al., 2016).

The same task can inform us of engagement of cognitive control by heritage speakers of different levels of language dominance and frequency of use. Although Torres and Sanz (2016) found no difference between heritage speakers and L2 learners on the ANT, more complex linguistic tasks may reveal differences that the ANT cannot reveal. For example, as mentioned above, Adler (in progress) found improved performance on the ANT following intra-orational code-switches, a finding not obtained following the monolingual or inter-orational blocks, which suggests that frequent language switching requires significant cognitive control resources. A conflict adaptation paradigm may be able to contribute more to our understanding of heritage language learners’ cognitive control recruitment during disambiguation. While Adler (in progress) uses a block-by-block adaptation paradigm to study how linguistic conflict triggers a non-linguistic advantage, a trial-by-trial adaptation may reveal how preceding non-linguistic conflict may improve linguistic-conflict resolution and reanalysis. This question is particularly interesting when paired with language use and dominance data, which may correlate to cognitive control engagement, following previous findings (Adler, in progress; Abutalebi et al., 2012)

**Conclusion: Bridging gaps through interdisciplinary research**

This project has outlined several gaps in the psycholinguistic and second language acquisition research. First, there is a dearth of studies that consider the role of cognitive control at different stages of L2 proficiency by using the same linguistic structures or processes. Cognitive control has been shown to be a vital component of sentence processing, especially the resolution of conflict. Therefore, the current project, following Serafini and Sanz (2016) and Pozzan and Trueswell (2015), motivates research on the relationship between these three variables. By conducting two studies of this nature, one correlational and one causational, we may also contribute to the understanding of the conflict adaptation paradigm in psycholinguistic research, a burgeoning methodology.

Meanwhile, while research has shown that language profile differences make an important difference in linguistic and cognitive development (Hilchey & Klein, 2011; Bialystok, 2001), distinct language populations have tended to be conflated in the literature. Torres and Sanz (2016) take the first step to isolate heritage language learners in the ‘bilingual advantage’ literature, but more research is needed, particularly regarding the role of HL bilingualism in linguistic tasks, such as sentence processing and resolution of garden-paths. Beyond the disambiguation of these linguistic conflicts, cognitive control has also been shown to be particularly relevant in language switching for bilinguals, including HL bilinguals. Therefore, the current study motivates the investigation of a cross-task conflict adaptation task to investigate the role of cognitive control and language use in linguistic conflict resolution.

**1. Introduction**

As presented in my previous doctoral exam, cognitive control is directly involved in both non-linguistic and linguistic ambiguity resolution. Recent research shows that language proficiency and language dominance and switching are also closely related to cognitive control. Recent work in psycholinguistics has developed a method to engage cognitive control in order to directly improve syntactic ambiguity resolution, provided that cognitive control resources are not already maximally engaged, at which point, the engagement has no effect or even worsens ambiguity resolution. The current work proposes three studies that utilize variations of this methodology to further investigate the relationships between second language proficiency and cognitive control and between bilingual language use/dominance and cognitive control.

**2. Cognitive Control and Proficiency in Emergent Bilinguals**

The role of cognitive control during the acquisition of a second language (L2) is an area of SLA that merits more research. This brain region associated with cognitive control has been shown through neuroimaging studies to play a major role during the processing of a non-native, non-highly proficient language, a role which becomes less significant during proficient or native processing (Abutalebi, 2008), but how cognitive control differences affect linguistic performance at these different stages of learning is still very unclear. While many studies consider working memory capacity’s (WMC) role in different aspects of L2 development (e.g. Baralt, 2010), WMC is a more monolithic cognitive variable, while cognitive control is a specific capacity within working memory with a specific linguistic correlate: conflict resolution. The very few studies that have compared the role of cognitive control at different proficiency levels are presented below.

One study that has considered L2 development’s correlation with cognitive control differences considered Chinese learners of English who differed in L2 proficiency and/or in language interpreting experience (Dong & Xie, 2014). However, despite significant differences between groups in most measures of development (verbal fluency, general proficiency, language exposure), there was an overall homogeneity between these groups and their experiences. For example, all groups were English language or English interpretation majors at Guangdong University; self-reported exposure to English ranged from 41.5-48.4% (where the sum of Chinese and English exposure is 100%); and self-reported proficiency averages, from 0-40, were also quite similar for three of the four groups, though all but two differed statistically (21.5 > 23.2, 22.9 > 29.8). Results indicate that flanker task performance did not differ according to English proficiency, although the data does trend towards favoring higher proficiency, regardless of flanker condition. The raw scores are presented in Table 1. However, the ANOVA revealed no main effect for participant group, nor an interaction between participant group and condition.

Table 1. Raw data from flanker task of Dong & Xie (2014) for each of four groups.

|  | **Noninterp-1 *n* = 45** | **Noninterp-2 *n* = 43** | **Interp-1 *n* = 46** | **Interp-2 *n* = 20** |
| --- | --- | --- | --- | --- |
| Neutral | 543 (103) | 536 (91) | 533 (76) | 518 (90) |
| Incongruent | 583 (111) | 578 (87) | 569 (83) | 548 (67) |
| Congruent | 528 (119) | 516 (81) | 518 (73) | 497 (86) |
| Difference | 55 ms (36) | 62 ms (50) | 51 ms (33) | 51 ms (35) |

Linck and Weiss (2011) investigated the role of WMC and cognitive control on the acquisition of a L2 over the course of a semester, and found that WMC became a stronger predictor of success in language performance at the end of the semester, while cognitive control was not a predictor. While this finding is often used to discuss proficiency and cognitive capacity, there are issues with this interpretation, since beginning German and intermediate Spanish participants were combined when no group differences were found in the model’s predictor or criterion measures in the preliminary analyses, even though these participants completed different language measures (German: fifteen fill-in-the blank items from University of Wisconsin placement exam; Spanish: grammar and vocabulary section of the *Diplomas de Español como Lengua Extranjera, DELE*). Therefore, the role of cognitive variables during a semester of classroom-learning may be hidden by other confounds, especially considering the findings of Serafini and Sanz that succeeded this study.

As outlined in my previous doctoral exam, Serafini and Sanz (2016) conducted a longitudinal study considering proficiency, cognitive capacities, and gains during one semester on ten different morphological structures in Spanish. The robust correlations between linguistic gains and cognitive variables were only observed for beginners, while cognitive capacity differences revealed no significant correlations with gains in the advanced learners. This study’s findings therefore help interpret the neuroimaging findings of Abutalebi (2008): cognitive capacity may play a major role in language learning at low proficiencies, but as the L2 becomes more proficient, cognitive capacity advantages begin to wane. Serafini and Sanz (2016) are the first researchers, to my knowledge, to compare the role of cognitive functions at several highly distinct points of L2 proficiency (beginner, intermediate and advanced). However, the researchers motivate the use of fewer targets to investigate more deeply how cognitive variables play a role in the second language learning process.

Syntactic ambiguity resolution, directly associated with cognitive control, is one target that can answer that call of Serafini and Sanz (2016). As mentioned in the previous exam, Pozzan and Trueswell (2015) observed childlike resolution of syntactic ambiguity by adult intermediate learners of English (L1: Italian), despite high familiarity with the structure in the first language. Relating their findings to those of Abutalebi (2008), who observed higher cognitive control demand during non-highly proficient L2 processing, they suggest this finding may relate to a lack of available cognitive control resources to intercede during reanalysis, which would explain the childlike performance. However, because they only consider intermediate learners and do not collect any cognitive control measures, they cannot conclude with certainty any such relationship. Given the differential role of cognitive control during linguistic performance that has been observed in the literature outlined above, the assumption of Pozzan and Trueswell likely reflects some relationship between these variables. However, more research is in order to justify this claim empirically. A study to respond to this need is outlined in Section 6.1, and the corresponding testable hypothesis in Section 5.1.

**3. Conflict Adaptation: Stroop effects and Cognitive Control**

The Stroop effect is one of the most important findings in modern experimental psychology. Since it was first published in English over 80 years ago, the Stroop task has been the subject of hundreds of studies and has been used in many distinct branches of cognitive science (MacLeod, 1991). In the original of its many incarnations, the Stroop task requires participants to respond to the color of the ink in which a color-word is written, rather than reading the color-word itself (Stroop, 1935). Manipulations of the Stroop task all hinge on presenting conflicting information to examine the role of interference in different cognitive processes. The consensus of these Stroop-like interference tasks is that an incongruent trial is more difficult than a congruent trial, revealed by slower reaction times (RTs) and higher error rates (see MacLeod, 1991 for review).

Variations of the color-word Stroop task often present a center target flanked by either congruent or incongruent distractors, and the Stroop effect of such flanker tasks is relative to the congruency of the flanking elements. For example, the Attentional Network Task (ANT), discussed in my first doctoral exam, is a flanker task utilizing a rightward or leftward central arrow with either congruent or incongruent flanking arrows, where participants must resist responding to the four flanking arrows and respond strictly based on the center arrow’s direction. The ANT was developed to mitigate linguistic interference (by eliminating words from the paradigm) and isolate cognitive control procedures (Fan, McCandliss, Sommer, Raz & Posner, 2002). Due to the simple design utilizing non-linguistic conflict, the task can be used with populations with known executive function problems, such as children, patients and monkeys, and can be used to make conclusions about domain-general cognitive functions.

Much of the literature that utilizes Stroop-like tasks has considered the role of the anterior cingular cortex (ACC) and cognitive control in the Stroop effect. The shared resources involved in ACC activation, cognitive control, and conflict resolution have been sufficiently well documented in the literature (see MacLeod, 1991 for review). And while it has been understood for many years that the conflict involved in Stroop trials engages cognitive control, researchers have also understood that the Stroop effect extends beyond a trial-by-trial basis. The detection of conflict during a given Stroop trial has been shown to initiate *sustained* cognitive control procedures, specifically conflict resolution, that continue into the subsequent trial. For example, Logan and Zbrodoff (1979) observed that manipulations to the probability of conflict stimuli modulate the Stroop effect, where higher probabilities of conflictive trials result in proportionally faster responses on incongruent trials. Likewise, Gratton, Coles and Donchin (1992) showed that the preceding trial’s congruency contributes to the speed of a response, specifically that an incongruent trial immediately preceding an incongruent critical trial (i-I) leads to faster responses than congruent trials immediately preceding incongruent critical trials (c-I). Theoretically, these results have been attributed to economy: sustaining cognitive control attenuates the cost of subsequent conflict resolution.

It should be noted that this finding was questioned by Mayr, Awh and Laurey (2003), who observe the same phenomenon as a case of stimulus-specific priming (the “repetition-priming” account). In a conceptual replication of Gratton and colleagues’ study, they found that faster reactions were associated with pairs of trials in which the latter’s target was a repetition of the former’s target. However, subsequent research confirmed the earlier “conflict monitoring” account, specifically because sequential dependency effects do present themselves regardless of repetition of stimuli (Ullsperger, Bylsma & Botvinick, 2005). For example, in the second experiment of Ullsperger and colleagues (2005), the conflict adaptation effect was still observed when participants were presented with a numerical, underlined single-digit target between 1-9 with 4 competing flankers, also a single digit. This paradigm eliminated the risk of priming because the researchers were able to exclude trial-to-trial repetition. While the researchers found slower reaction times than in the standard two-option directional flanker task, they attribute this to a speed-accuracy tradeoff associated with nine options that did not diminish the effect of conflict engagement. In other words, preceding trial incongruency in this experiment still resulted in a conflict adaptation effect, where i-I RTs were 26% faster than c-I RTs.

**3.1 Conflict Adaptation and Dynamic (Cross-Task) Engagement of Cognitive Control**

Non-linguistic conflict resolution has been shown to co-localize within the ACC and to share cognitive control resources with linguistic conflict (Thompson-Schill, Bedny, & Goldberg, 2005; Novick, Kan, Trueswell & Thompson-Schill, 2009; January, Trueswell, Thompson-Schill, 2009, Teubner-Rhodes et al., 2016). These shared resources have also been observed in correlational behavioral studies in children with protracted cognitive control development (Trueswell, Sekerina, Hill & Logrip, 1999); and in patients with prefrontal damage affecting cognitive control (Novick et al., 2009). Domain-general cognitive control is suggested to be responsible for both behavioral adjustments to resolve conflict during information processing (Botvinick, Braver, Barch, Carter & Cohen, 2001) and reanalysis following incorrect linguistic interpretation (Novick, Trueswell & Thompson-Schill, 2005).

Despite this, it is only very recently that researchers used the principles of sustained cognitive control engagement to develop a cross-task conflict adaptation paradigm. Hsu and Novick (2016) developed such a paradigm that allows the observance of causal relationships between non-linguistic conflict detection and linguistic conflict resolution. Specifically, the researchers conducted a 2x2 experiment on healthy adult sentence processing by pseudo-randomly presenting congruent and incongruent Stroop trials and temporarily ambiguous and unambiguous sentences. Here, a temporary ambiguity is a sentence that forces a particular incorrect initial analysis that must later be reanalyzed as more of the sentence is processed, such as their example (1), which can be compared to the unambiguous example in (2):

1. Put the dumpling on the plate into the wok.
2. Put the dumpling that’s on the plate into the wok.

In their study, Hsu and Novick asked participants to carry out the instructions they heard, always similar to those in (1) or (2), within a visual world represented on a computer screen. During processing, participants interpret the first prepositional phrase (the reduced relative clause that modifies the noun) as the goal due to the verb *put*’s subcategorization (Spivey, Tanenhaus, Eberhard & Sedivy, 2002). However, when they reach the second prepositional phrase, a reanalysis must take place. As participants engaged with the visual world, researchers collected both act-out moves and eye movement data. Hsu and Novick interleaved Stroop and linguistic trials and observed that Stroop incongruity in the preceding trial reduced the participants’ commitment to the initial incorrect parse of ambiguities when compared to Stroop congruity, in terms of both behavioral and eye-tracking data. It is important to bear in mind that critical analyses in this study were pairings of conditions: incongruent-ambiguous (i-A) and congruent-ambiguous (c-A).

In both the action responses and the fixations to the correct goal, a significant sentence-type-by-Stroop-trial-type interaction was encountered, whereby participants made fewer performance errors or fewer fixations to the incorrect goal on i-A trials than on c-A trials. As expected, Stroop incongruity did not modulate consideration of the correct goal in the unambiguous linguistic condition (i-U did not statistically differ from c-U), likely because there was no conflict to be resolved and online interpretation and action responses approached ceiling. These results show that cognitive-control engagement helps listeners abandon incorrect parses earlier and correctly carry out instructions without the same degree of error.

Thus, returning to the questions outlined in Section 2, this cross-task conflict adaptation paradigm can be used to test how cognitive control plays a differential role during ambiguity processing at different L2 proficiencies. When cognitive control resources are maximally engaged, as is the case in child- and patient-processing, i-A trials will not differ from c-U trials. However, where cognitive control resources are available, i-A trials will show earlier disambiguation. This hypothesis is further outlined in Section 5.2, and a description of a study to test it is outlined further in Section 6.2.

**4. Language dominance and Cognitive Control in Heritage Language Bilinguals**

In recent years, fields such as education, linguistics, sociology and psychology have rekindled interest in heritage language (HL) speakers. Montrul (2010) defines heritage speaker, broadly, as “child or adult members of a linguistic minority who grew up exposed to their home language and the majority language” (p. 4). Theoretical and sociolinguistic research has granted researchers better understanding of the grammars of HL speakers, including vocabulary, morphology, syntax and semantics, (for reviews, see: Montrul, 2010; Brinton, Kagan, & Bauckus, 2008), while other areas such as instructional strategies have also received considerable attention (Montrul & Bowles, 2008, for example). The role of metalinguistic knowledge has been a major focus of this pedagogical HL research, often comparing HL learners and L2 learners. For example, Bowles (2011) evaluated both groups in an array of tasks that ranged from more to less explicit. She found that HL learners performed better than L2 learners on tasks requiring less metalinguistic or explicit knowledge, while L2 learners outperformed HLLs on those with more metalinguistic knowledge requirements.

However, despite the increased interest in these many different aspects of HL language use and control, online sentence processing has been much less studied, which is particularly interesting given that language processing paradigms, such as the visual world paradigm used in Hsu and Novick (2016) or Pozzan and Trueswell (2015), often require effectively no metalinguistic knowledge and can serve to ask relevant questions regarding language interpretation and processing.

In a certain regard, this dearth of literature is more appropriately a failure to distinguish between distinct populations of bilinguals in language processing literature; as Torres and Sanz (2016) note, heritage speakers are often grouped under the umbrella term ‘bilingual’ in psycholinguistic studies. In other words, while researchers do in fact study heritage language speakers, they do not clearly distinguish them from other bilingual populations. However, this is a flawed practice because different environments contribute to the development of distinct language profiles (Hilchey & Klein, 2011; Bialystok, 2009). For example, research suggests that bilingualism at the individual level can manifest differently according to external conditions such as societal bilingualism (Sanz, 2000). Thus, biliterate Catalan-Spanish speakers in Barcelona, for example, are inherently different from many heritage speakers of Spanish in the United States, where Spanish is a minority language and where many heritage speakers never attain literacy in their HL.

In fact, the term ‘heritage bilingual’ is itself an umbrella term. Most adult heritage speakers are dominant in the majority language, while minority or heritage language skills vary considerably from speaker to speaker (Montrul, 2010), to the extent that some heritage speakers are limited to receptive skills while others show advanced oral and written skills. The development of these skills often depends on the community and the language, in addition to the *sequence* of bilingualism: simultaneous bilinguals who learn both the majority and minority languages at the same time tend to show less dominance of the minority language when compared to sequential bilinguals who exclusively use the minority language for a longer period and therefore generate greater exposure (Montrul, 2008, 2010).

Torres and Sanz (2016) are the first researchers to isolate this language profile to investigate the ‘bilingual advantage’ in cognitive control as it pertains to HL speakers. The authors find no differences between HL bilinguals and late emergent bilinguals of Spanish in performance on the ANT, although they do note that data trended to show that HL bilinguals resolved conflict easier and at fewer cross-task costs. Despite this trend, these results are surprising when situated within the ‘bilingual advantage’ research of Bialystok and colleagues, outlined in my first doctoral exam, which tends to situate this advantage as dependent on pre-critical period bilingualism (see Bialystok, 2007, 2009, for reviews)[[3]](#footnote-3). According to the findings of Torres and Sanz, however, HL and emergent-L2 bilinguals performed comparably on the ANT, which raises several questions for further research.

For example, the study by Torres and Sanz (2016) and a previous study by Costa, Hernández and Sebastián-Gallés (2008) both compare early bilinguals to a group that is not fluent in a L2. In Costa and colleague’s (2008) study, bilingual, biliterate Catalan-Spanish speakers were compared to Tenerife Spanish speakers, who are considered ‘monolingual’ in the study despite certain knowledge of a L2 because of foreign language courses they took in school[[4]](#footnote-4). Meanwhile, Torres and Sanz (2016) compared heritage Spanish speakers in the U.S. to classroom learners of Spanish. Both teams of researchers gathered information through questionnaires regarding their participants’ language skills. Costa and colleagues (2008) gathered information on a five-point Likert scale, from 0 (*‘very bad’*) to 4 (*‘native speaker’*), while Torres and Sanz (2016) gathered similar information on a six-point Likert scale, from 1 (‘*beginning’*) to 6 (*‘native*’). Although these scores aren’t comparable because they are different scales, some observations can be made from the relative scores, so for ease of comparability, this data was converted to a ratio and is presented in Table 2. Torres and Sanz also utilize a modified version of the DELE to evaluate proficiency of both their groups, following previous HL research such as Montrul (2005), the sections of which were chosen to specifically tap skills that are shared by both sets of learners without presenting tasks that are highly explicit, to favor the L2 learners, or highly implicit, to favor the HL speakers. The results of the modified DELE are also presented in Table 2.

While only Torres and Sanz used such a standardized test, some observances can be drawn from the self-reported data. The heritage speakers rate themselves as far less confident in all four language skills than their bilingual Catalan peers. In addition, despite Costa and colleagues’ classification of the comparison group as ‘monolingual’, they rate themselves as moderately capable in a second language. In fact, they rate themselves higher than the emergent L2 bilinguals in Torres and Sanz’s study do on their respective scales.

Another important consideration is the power of the respective studies. While Catalan-Spanish bilinguals are quite accessible in Barcelona, heritage Spanish speakers of the narrow definition that Torres and Sanz assume are much more difficult to gather, which may contribute to the different sizes of the participant pools. Therefore, the findings of the U.S.-heritage population may not have enough power to reveal a significant difference, especially if advantages are on a gradient scale reflecting bilingual proficiency.

Table 2. Language skills of participants in two ‘bilingual advantage’ studies

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Costa et al. (2008) | | | | Torres & Sanz (2016) | | | |
| Language Skill | ‘Monolingual’  (n = 100) | | Bilingual  (n = 100) | | Emergent (L2)  (n = 23) | | Heritage  (n = 25) | |
|  | Spanish | L2 | Spanish | Catalan | English | Spanish | English | Spanish |
| Comprehension | 1.0 | .575 | 1.0 | 1.0 | .98 | .40 | .97 | .86 |
| Reading | 1.0 | .60 | 1.0 | 1.0 | .98 | .42 | .97 | .76 |
| Speaking | 1.0 | .50 | .95 | 1.0 | .98 | .30 | .92 | .74 |
| Pronunciation | 1.0 | .475 | .925 | 1.0 | -- | -- | -- | -- |
| Writing | 1.0 | .525 | .975 | .975 | .98 | .44 | .90 | .60 |
| DELE (placement) | -- | | -- | | .504  (low) | | .650  (intermediate) | |

To recap, in a study of cognitive control using the ANT, biliterate-bilingual Catalan-Spanish speakers who report themselves to be ‘native’ or native-like in *all four* linguistic skills outperformed Tenerife Spanish speakers whose dominance of a L2 was moderate, but not ‘very bad’[[5]](#footnote-5). A separate study using the same task considered U.S.-English Spanish-heritage speakers, whose skills as a group ranged from intermediate (DELE) to native-like (listening comprehension). The heritage speakers did not outperform late bilinguals, who were self-rated as intermediate in all linguistic skills but who received a ‘low’ according to the DELE.

These findings are far from cut-and-dry, and as mentioned earlier, should not be compared. We can, however, observe them simultaneously, and as they stand, a nuanced analysis would suggest that variables such as language use, proficiency, dominance and literacy may play a role in capturing the subtle cognitive performance advantages at hand in bilingual research. However, to my knowledge, only one other study has considered how low literacy may play a role in the development of the oft-cited ‘bilingual advantage’ in cognitive control. Finger, Billig and Scholl (2011) investigated performance on a non-linguistic and linguistic inhibitory control task in older-adult (60-71 years old) population of Hunsrückisch-Portuguese bilingual farmers with low levels of education and a monolingual comparison group with otherwise similar characteristics. The authors cite a bilingual advantage in the non-linguistic task but not in the Stroop task due to linguistic interference, which follows their hypothesis and previous research (e.g. Bialystok, Craik and Luk, 2008). However, the authors advise that the results should be taken with caution because of the population size (21 participants in each group). In addition, both groups had very little exposure to written sources on a daily basis, according to the authors. This study also considers older adults’ cognitive control, but no study to my knowledge has considered the role of literacy on cognitive control advantages within young adult bilinguals, who are at the height of their cognitive control (Bialystok, Craik & Luk, 2008). It is quite clear, then, that more studies are needed to explore the interaction between cognitive variables and language use and dominance within heritage bilinguals, especially since we know that increased language use is a clear predictor of maintenance and complete acquisition of the heritage language (Montrul, 2005).

One strategy to tease apart the findings presented above is to conduct a study that looks at these language skills as continuous variables in order to investigate whether there is a connection between cognitive control and language dominance or use. Many of these studies try to control these characteristics in their samples, a wise methodological practice but one that may not reveal all of the subtle distinctions within the bilingual population. Considering these phenomena as continuous variables is a particularly promising strategy given that recent studies suggest that frequent language switching is a leading cause of the bilingual advantage in conflict monitoring. For example, a recent neuroimaging study showed that it is precisely language switching trials that activate the same brain region as conflicting flanker trials (Abutalebi et al., 2012). Likewise, in a study on code-switching, using a modification of the cross-task conflict adaptation task first developed in this same lab, heritage speakers were presented with a block of flanker trials following each of four separate blocks of linguistic ambiguities, including English, Spanish, inter-orational and intra-orational code-switches (Adler, in progress). Reaction times and accuracy following the intra-orational code-switches improved beyond the other three blocks, suggesting that this frequent alternating may engage cognitive control resources beyond other language tasks. As Teubner-Rhodes and colleagues suggest, “bilingualism apparently acts as a form of cognitive control training, bestowing measurable advantages in conflict monitoring – the ability to detect unpredictable conflict and flexibly adjust recruitment of cognitive control resources” (Teubner-Rhodes et al., 2016, p. 227).

In addition, these studies reveal that cognitive control resources are particularly engaged during certain linguistic tasks, which also raises the question of how the groups in Costa et al. (2008) and Torres and Sanz (2016), who were alike in terms of education, age and other cognitive factors, might differ in their *employment* of cognitive control during *linguistic* conflict resolution. To consider this question, a conflict adaptation task, utilizing a linguistic conflict task modified by a non-linguistic cognitive control task, in the vein of Hsu and Novick (2016) may allow us to observe differences between the heritage and emergent bilinguals of Torres and Sanz (2016) that are hidden or too subtle to observe during a non-linguistic task. A hypothesis concerning these questions is presented in Section 5.3, and a study to test it is outlined in Section 6.3.

**5. Research Questions and Hypotheses**

**5.1. Research Questions and Hypothesis regarding Study 1**

1. RQ1.2: How does cognitive control correlate to L2 syntactic ambiguity resolution?
2. RQ1.1: How does L2 proficiency correlate to L2 syntactic ambiguity resolution?
3. RQ1.3: Does cognitive control relate to L2 syntactic ambiguity resolution for learners at different proficiency levels?

Given that previous research suggests that the role of cognitive capacities, such as executive function and short-term phonological memory, decreases at increasing levels of proficiency, the working hypothesis of Study 1 is that cognitive control (as measured by the ANT) will play a differential role in ambiguity resolution across proficiency levels. Specifically, use of a the L2 will impinge more on the cognitive control resources available for syntactic ambiguity resolution at low proficiencies than at high proficiencies, meaning that beginner learners’ ANT scores will correlate to faster abandonment of incorrect parses and more accurate behavioral responses, but this advantage for high cognitive control participants will diminish with increasing proficiency, as cognitive control resources become available for adult-like parsing.

**5.2. Research Questions and Hypothesis regarding Study 2**

1. RQ2.1: How does cognitive control engagement affect L2 syntactic ambiguity resolution by L2 learners?
2. RQ2.2: How do different reactions to cognitive control engagement during L2 syntactic ambiguity resolution relate to different proficiency levels of learners?

Given that previous research suggests a greater role of cognitive control at lower levels of proficiency, the working hypothesis of Study 2 is that cognitive control engagement will play a differential role in ambiguity resolution across proficiency levels. Specifically, for lower proficiencies, the presentation of an incongruency before critical trials will not facilitate disambiguation, because cognitive control resources will already be engaged, regardless of the congruency of the preceding trial, due to the use of a non-highly proficient second language. However, as cognitive control resources are freed up at higher proficiencies, cognitive control engagement will begin to play more of a role to facilitate disambiguation, approximating native speaker patterns.

* 1. **Research Questions and Hypothesis regarding Study 3**

1. RQ3.1: How does cognitive control engagement affect syntactic ambiguity resolution by heritage bilinguals?
2. RQ3.2: How do different reactions to cognitive control engagement during syntactic ambiguity resolution relate to distinct language profiles?

Study 3 is more exploratory than Studies 1 and 2. However, given the results of Costa and colleagues (2008), Torres and Sanz (2016), and Adler (in progress), the working hypothesis of Study 3 is that participants who interact the most with the heritage language will be the fastest to process and reanalyze the ambiguities. However, those who engage in the most language switching will respond most to cognitive control engagement (that is, will have the most drastic difference between i-A and c-A trials) because of high cognitive control development associated with frequent language switching (Abutalebi et al., 2012). Because this is the first study of this kind, an alternate possibility is that those who engage in the most language switching will have the most occupied cognitive control resources and therefore, like patients and children, will show less response to the engagement of these resources through an incongruent preceding trial.

**6. Methodology**

**6.1. Study 1**

*6.1.1. Participants*

Study 1 will recruit participants from 3 levels of Spanish, each 2 semesters apart (that is, Beginner I, Intermediate I, Advanced I *or* Beginner II, Intermediate II, Advanced II). Participants will be between 18 and 28 years old, an age range that entails most university students and avoids protracted prefrontal development or cognitive control degeneration. This age range follows Hsu and Novick (2016) and Pozzan and Trueswell (2015). Participants will be included if they are (i) native speakers of English, (ii) learning Spanish as a second language, with limited knowledge of any other language, and (iii) have normal or corrected-to-normal vision, to allow for proper interaction with the eye-tracker and visual world. Approximately 15-20 participants will be needed per group to conduct analyses at power similar to previous studies (Hsu & Novick, 2016, for example).

*6.1.2. Procedures and Materials*

Participants will complete the experiment in one session, first completing a language background questionnaire and a segment of the DELE, then the Visual World component, and finally the ANT.

Attentional Network Task

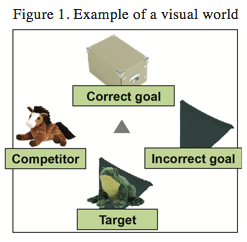
To measure cognitive control, participants will complete the ANT (Fan et al., 2002), following Torres and Sanz (2016), Costa and colleagues (2008), and recommendations from Novick (personal communication, April, 2016), to avoid the linguistic interference of the Stroop task that may manifest with second language speakers of varying proficiencies. In the ANT task, participants focus at a center fixation point and are presented with one of four cue conditions (no cue, center cue, double cue, and spatial cue) immediately followed by a flanker type (neutral, congruent, or incongruent). Inter-trial intervals are jittered between three conditions (400 ms, 1000 ms, 1600 ms). Participants must indicate the direction of the central arrow, suppressing the information of flanker arrows, during each trial presentation by pressing a key on the right or left side of the keyboard (‘z’ or ‘/’). The critical comparison for cognitive control psychometry is [no cue, incongruent] vs. [no cue, congruent].

Visual World Syntactic Disambiguation

All linguistic stimuli will be presented using Tobii Studio. Eye movements will be recorded using Tobii pro TX300. Previous research has recorded act-out movements using a digital camcorder centered on the computer screen. Alternative option is a four-button mouse situated to represent the four quadrants of the visual world. The linguistic stimuli will be Spanish translations of the stimuli used in previous renditions of this paradigm (Hsu and Novick, 2016; Pozzan and Trueswell, 2015; Trueswell et al., 1999). Specifically, like Hsu and Novick, the current study will not include referential context as a condition, given that Pozzan and Trueswell found that adults use referential context while children do not. Given that no child comparisons will be made, this condition is irrelevant.

Participants will listen to spoken instructions and interact with the visual world on a computer screen according to the instructions (that is, act out the instructions). These instructions will be pre-recorded by a female speaker of Mexican Spanish. This dialect was chosen, recognizing that L2 students come from classes with instructors of many dialects, and therefore, a neutral, highly-spoken dialect with a high written grapheme-spoken phone ratio was desired. Of the dialects that meet such a description, Mexican Spanish is likely to accommodate more heritage speakers (for Study 3), given that the great majority of Hispanics in the U.S. are of Mexican descent: 63% in 2010 according to the U.S. Census Bureau (Ennis, Rios-Vargas & Albert, 2011).

Instructions in this task consist of single sentences with a “*poner*” command. Sentences will be temporarily ambiguous (24), unambiguous (24), or filler sentences (48). Sentences will be counterbalanced resulting in two versions of the paradigm: if a sentence is in the unambiguous condition in version 1, it will be in the ambiguous condition in version 2. Item locations will also be counterbalanced, following previous studies using this task.

Examples of the sentences to be used follow (3-5), all of which instruct the participant to act out with respect to a visual world such as the world presented in Figure 1:

1. Temporarily ambiguous: *Pon la rana en la servilleta encima de la caja*.
2. Unambiguous: *Pon la rana que está en la servilleta encima de la caja*.
3. Filler: *Pon la rana en la caja*.

As the ambiguous sentences are heard, listeners fixate on the modifier (e.g. ‘*en la servilleta*’) as if it is the goal until the disambiguating information (e.g. ‘*encima de la caja*’) is reached, at which point the parser must reanalyze the structure. With such sentences, eye movements to the correct goal are delayed when compared to unambiguous sentences such as (4), which is the critical comparison as it concerns syntactic disambiguation.

Language Background Questionnaireand *Diplomas de Español como Lengua Extranjera*

The language background questionnaire (LBQ) will gather information relating to participants’ experience with English and Spanish, as well as any potential experience with an additional language. Questions will focus on variables such as age at which second language study began, years studying Spanish, and external exposure to Spanish. In addition to the LBQ, and to ensure that participants from each proficiency are appropriately sorted, a component of the DELE will be completed. The same portion used in Torres & Sanz (2016) will be used, consisting of a fill-in-the-blank vocabulary section and a cloze passage. This will be used for both the L2 and heritage participants (Studies 1-3) because it avoids highly-explicit and highly-implicit knowledge, to accommodate both groups, and to minimize variability of materials between studies.

**6.2. Study 2**

*6.2.1. Participants*

Study 2 will follow Study 1 chronologically by one semester and will recruit participants from the same level of Spanish as Study 1, with the same inclusion/exclusion criteria. Approximately 15-20 participants will be needed per group to conduct analyses at power similar to previous studies (Hsu & Novick, 2016, for example).

*6.2.2. Procedure and Materials*

Study 2 will be completed in one session. The same LBQ and segment of the DELE will be used as Study 1, both of which will be presented before the interleaved language comprehension-flanker component. The critical difference between Studies 1 and 2 is that Study 2 will interleave flanker tasks within the syntactic disambiguation trials to engage cognitive control before select trials, instead of presenting two distinct tasks.

Interleaved flanker-to-sentence sequences

Before data collection begins, participants will complete a practice phase of both the flanker task (during which they will learn the appropriate response buttons, the different conditions, etc.) and the sentence interpretation task (during which they will learn to act out the instructions, will become familiar with the speaker, etc.). Following the practice phases, the will begin the interleaved task.

The pseudorandom presentation of trials will allow incongruent or congruent flanker trials to precede ambiguous or unambiguous sentence-interpretation trials, resulting in four conditions: i-A, i-U, c-A, and c-U. Twelve pairs of each condition will be prepared, using the same stimuli as Study 1 and counterbalancing in the same vein, to ensure that if a sentence falls in the i-A condition in version 1, it will fall within the i-U condition in version 2. In addition, the 48 filler sentences of Study 1 and additional flanker trials will serve as distractors to prevent participants from predicting the upcoming trial type or condition. However, the critical comparisons are the four primary conditions listed above. At the end of the study, participants will have engaged with the same number of flanker trials and sentence comprehension trials as the participants in Study 1, though the order of the presentation varies between studies.

**6.3. Study 3**

*6.3.1. Participants*

Study 3 will recruit participants from Georgetown University who speak Spanish and who meet Montrul’s (2008) definition of ‘heritage speaker’ (members of a linguistic minority who grew up exposed to their home language and the majority language) within the age range used in Studies 1 and 2 (18-28 years old). While many studies aim to recruit participants from a very narrowed, controlled linguistic profile of heritage speakers, the current study aims to explore differences *between* heritage speakers based on differences in the linguistic profile, so language use and proficiency heterogeneity is preferred. However, educational level and other socioeconomic factors may contribute to differences in cognitive control, so Study 3 will aim to limit differences in these variables. Participants will be excluded if they (i) do not have normal or corrected-to-normal vision; (ii) moved to the U.S. after the age of 6;0; or (iii) received formal education in Spanish other than foreign language or heritage language high school or university courses. Exclusion criteria (ii-iii) follow the definitions of second- and third- generation Spanish-speaker in the U.S. proposed by Hualde, Olarrea, Escobar and Travis (2010), combining definitions from Silva-Corvalán (1994) and Otheguy, Sentella and Livert (2007), among other research. Participants who meet these criteria are difficult to find, but a target of 25 participants will be needed to conduct analyses at power similar to previous studies (Hsu & Novick, 2016, for example).

*6.3.2. Procedures and Materials*

Participants will complete the study in one session. The same segment of the DELE will be used as in Studies 1 and 2, presented following a language background questionnaire specific to the heritage language experience (HLBQ). Following these two components, participants will engage in the same interleaved language comprehension-flanker task outlined in Study 2.

Heritage Language Background Questionnaire

To gather information regarding language background, Study 3 looks to Torres and Sanz (2016) and Gollan, Starr & Ferreira (2015). The information presented in these studies is included in Table 3 to compare related information. The HLBQ will combine select questions from the questionnaires used in these two studies and as recommended in other research (e.g. Montrul, 2008, 2010).

Table 3. Language background questionnaire data points collected by Gollan et al. (2015) and Torres & Sanz (2016)

|  |  |  |
| --- | --- | --- |
|  | Gollan, Starr & Ferreira (2015) | Torres & Sanz (2016) |
| Age of Acquisition | * English | * English * Spanish |
| Self-rated proficiency | * English * Heritage language | * English (each of four linguistic skills) * Spanish (each of four linguistic skills) |
| Years of study | --- | * Spanish * Dual/immersion program? |
| Frequency of use | * Reading in heritage language * Daily language use in English * Daily language use in English as child | * Use of English * Use of Spanish |
| Frequency of language switching | * Frequency of language switching when conversing with bilinguals * Frequency of language switching as child | --- |
| Caregiver language abilities | * Primary caregiver’s ability to speak English * Primary caregiver’s ability to speak heritage language * Secondary caregiver’s ability to speak English * Secondary caregiver’s ability to speak heritage language | --- |

**6.4. Tabular Summary**

To summarize the intentions of Studies 1-3, Table 4 compares various methodological and procedural intentions of each study.

Table 4. Principle differences and similarities of the studies herein proposed.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Study 1** | **Study 2** | **Study 3** |
| **Participants** | L2 learners of beginner, intermediate and advanced proficiencies | L2 learners of beginner, intermediate and advanced proficiencies | Heritage language speakers, with varying dominance of the heritage language |
| *Age* | 18-28 | 18-28 | 18-28 |
| *Educational background* | High school degree, some college | High school degree, some college | High school degree, some college |
| *Knowledge of a L3* | Little to none (maximally limited to 3 years of high school experience) | Little to none (maximally limited to 3 years of high school experience) | Little to none, depending on availability of participants |
| **Linguistic materials** | Translations of Hsu & Novick (2016), recorded by female native speaker of Mexican Spanish | Translations of Hsu & Novick (2016), recorded by female native speaker of Mexican Spanish | Translations of Hsu & Novick (2016), recorded by female native speaker of Mexican Spanish |
| **Cognitive control materials** | Attentional Network Task, presented after linguistic materials | Flanker trials (from ANT), interleaved within linguistic materials | Flanker trials (from ANT), interleaved within linguistic materials |
| **Conflict adaptation?** | No, correlational | Yes | Yes |
| **Other materials** | * Language background questionnaire * Segment of DELE (Torres & Sanz, 2016) | * Language background questionnaire * Segment of DELE (Torres & Sanz, 2016) | * Heritage language background questionnaire (Gollan, Starr & Ferreira, 2015; Torres & Sanz, 2016) * segment of DELE (Torres & Sanz, 2016) |

**Methodology notes**

Outliers

6000 ms maximum for all participants, 100 ms minimum for all participants; then, at individual level, 2.5 standard deviations from mean reaction time. Below minimum were to be removed (though there were no cases), above maximum were replaced with value equivalent to 2.5 times the standard deviation for the participant, or the maximum cutoff for all participants, whichever was lower (i.e. if SDx2.5 was outside of study limit, 6000 ms was used as the replacement, but if SDx2.5 = 5893, that was used).

Replaced data accounts for 2.54% of the total data points, well within the standard established by Jegerski (2014).

|  |  |
| --- | --- |
| 168(total removed) | 6600(total answered) |
| 0.02545455 |  |

well as data from subjects with performance accuracy below 60% or a reading-time average more than 2.5 standard deviations from the participant mean. (this is in Marijuan)

Exclusion:

Participant ~= 16 AND Participant ~= 19 AND Participant ~= 21 AND Participant ~= 22 AND Level ~= 1 AND Level ~= 3 AND JegerskiMcCormickStep3 = 1 AND Ambiguity = 1 !!!!!!!!!!!!!!!!! AND Participant ~= 10 (*Boxplots were really wide*) AND Participant ~= 15 (*Boxplots were really wide)* AND Participant ~= 8 *(Flanker Residual)* AND Participant ~= 5 *(Flanker Residual)*

Length of regions compared:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| average | ambig | 14.6 | 6.65 | 8.5 | 7.15 | 10.9 |
|  | unambig | 14.6 | 6.85 | 8.6 | 6.9 | 11.9 |
|  | group12unambig | 14.46 | 7.07 | 8.33 | 6.73 | 12.07 |
|  | group34unambig | 15 | 6.2 | 9.4 | 7.4 | 11.4 |

Region lengths (but used residuals)

|  |  |
| --- | --- |
| 1 | 19.05 |
| 2 | 10.95 |
| 3 | 9.711 |
| 4 | 10.48 |
| 5 | 13.58 |

**7. Conclusion**

The above-proposed studies will help us disentangle cognitive control’s complex relationship with L2 proficiency and with bilingual language dominance. Such research is timely, considering recent research in SLA, psycholinguistics and neuroimaging that suggests that cognitive control plays a differential role across L2 development and considering recent research in the ‘bilingual advantage’ literature that reconsiders the umbrella term ‘bilingual’ to study how distinct language profiles may possess distinct ‘advantages’ due to varying bilingual experiences.

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Chapter 3 methodology

Removed times greater than 2,500 ms.

Participants with accuracy <60%

Reading times more than 2.5 SDs from the participant mean

Then raw reading times were transformed (Why after ? I am not sure – Hofmeister; Jaeger, Fedorenko, Hofmeister & Gibson (2008); Jaeger, Fedorenko & Gibson (2010)

Residual reading times calculated – subtract the log-tranformed reading time of each stimuli against a number of predictors

Hofmeister

Self-paced reading tasks are employed for all of the experiments discussed here. In these comprehension experiments, subjects read sentences at their own pace on a computer screen (Just, Carpenter, & Woolley, 1982). Initially, they are presented with a screen of dashes separated by spaces, representing the words for that experimental item. With each press of a predefined key, a new word appears on the screen and the previous word disappears. Blocking of items into lists and randomisation within lists was automatically managed by the reading-time software, LINGER v. 2.94, developed by Doug Rohde (available at http://www.tedlab.mit.edu/dr/Linger/). Reading times were analysed with linear mixed-effects models, using the lme4 package in R (version 2.4.0). This method of statistical analysis not only avoids the loss of statistical power that comes with prior subject and item averaging (Pinheiro & Bates, 2000), but as Baayen (2004) points out, it also allows for a principled way of incorporating longitudinal effects and covariates into the analysis, as well as being free from the assumptions of constant covariance and sphericity. Markov chain Monte Carlo (MCMC) sampling (n25,000) was used to estimate conservative p-values for the fixed effects. Reading-time results were handled and analysed using the following method which borrows heavily from the analyses described in Jaeger, Fedorenko, Hofmeister, and Gibson (2008) and Jaeger, Fedorenko, and Gibson (2010). Unrealistic reading times (2,500 ms) were removed prior to further analysis, as well as data from subjects with performance accuracy below 60% or a reading-time average more than 2.5 standard deviations from the participant mean. Subsequently, raw reading times were log-transformed to normalise the data. Next, residual reading times were computed for each subject by regressing the log-transformed reading times from all stimuli (experimental items and fillers) against a number of predictors: (1) construction type; (2) word length; (3) the restricted cubic spline of the word position in the sentence; and (4) the log-transformed position of the trial in the experiment (for the specific implementation in R, see also http:// www.hlplab.wordpress.com/2008/01/23/modeling-self-paced-reading-dataeffects-of-word-length-word-position-spill-over-etc/). The first of these factors\*construction type\*takes into account the possibility that experimental items and fillers may impose unique processing loads based on their overall sentence complexity. For all three experiments described here, average reading times for the critical experimental items differed significantly from the baseline items (Experiment I: b.061, SE.004, t14.53, pB.0001; Experiment II: b.032, SE.005, t 6.71, pB.001; Experiment III: b.050, SE.003, t14.14, pB.0001). Similarly, word-length differences contribute to reading-time differences and are commonly controlled for in reading-time studies (Ferreira & Clifton, 1986). Unsurprisingly, reading times increase with longer word length in all three experiments (Experiment I: b.018, SE.001, t30.51, pB.0001; Experiment II: b.016, SE.001, t24.64, pB.0001; Experiment III: b .018, SE.001, t32.67, pB.0001). Participants also speed up drastically across trials; in fact, trial position emerges as the most significant predictor of reading times in the current studies (Experiment I: b.167, SE.003, t63.97, pB.0001; Experiment II: b.123, SE.003, t42.33, pB.0001; Experiment III: b.131, SE.002, t55.12, pB.0001). Lastly, word position has a clear nonlinear effect on reading times in all experiments, as Figure 1 illustrates for Experiment I (raw reading times are shown in Figure 1 to better convey the magnitude of word position effects, although logged reading times were used in the actual analysis). To capture these nonlinearities, the restricted cubic spline of this predictor was used to model the relationship between word position and reading times (Harrell, 2001; Harrell, Lee, & Pollock, 1998). These parameters are summarised in the multilevel model below used for each experiment: (3) logRTijb0b1Constructionib2Lengthib3log(ListPositioni)b4rcs (WordPositioni)bjoij Hence, log reading times for word i, read by subject j, are predicted by an intercept (b0), four parameters (b1 ... b4), a subject random effect (bj) and residual error (oij). All reading-time data from the experiment were employed (with the exception of practice items) in computations of these residual reading times, including filler items. The residuals of these models (residual log reading times) constitute the data discussed throughout this paper. After computing these residual log reading times and excluding reading times from incorrectly answered stimuli, data points more than 2.5 standard deviations from the mean at each word region for each experimental condition were removed. This process affected 2.9% of the data points in Experiment I, 3.0% of the data in Experiment II, and 2.6% of the data in Experiment III. Using this residualisation method, as opposed to raw reading times or including these reading-time predictors directly in the final models, has several advantages. First, each factor regressed out strongly influences reading times, as shown above. Secondly, regressing these predictors against reading times for all stimuli, including fillers, reduces the likelihood of collinearity. For instance, since two of the experiments described here manipulate sentence length and the word position of critical regions, word- position effects cannot be estimated on the basis of the experimental items alone without introducing strong collinearity between the predictors of word position and the primary experimental manipulation. Accordingly, better estimates of the effects of word position are achieved by using all experimental items, including fillers. The second major phase in analysing the data for each experiment involved regressing the residual log reading times at a particular word region against the complexity variable and the random effects of subjects and items. Because reading-time differences across conditions at a particular word region may reflect preexisting differences from a preceding word or region that have spilled over (Sanford & Garrod, 1989), I also treated reading times at the previous word as a fixed factor, in addition to the experimental manipulation of complexity. For analyses of multi-word regions, I employed the reading times from the word immediately preceding the region to estimate spillover effects. Note that all significant effects reported here remain significant (most effects even increase in size) with the use of multiple spillover variables (e.g., based on reading times at words n1, n2, n3, etc.) rather than one. In short, each of the mixed-effects models described within the experimental sections contained two fixed factors (complexity and spillover) and two random factors (subjects and items) regressed against the residual log reading times. For the comprehension question data, reaction time z-scores were computed for each subject. After removing z-scores more than 2.5 standard deviations from the mean, these z-scores were also analysed with linear mixed-effects models that included list position as a fixed effect and subjects and items as random effects. Questionanswer accuracies were evaluated using generalised linear mixed-effects models; however, there were no effects of accuracy in any of the experiments discussed here, so these models are not described.

1. Examples (1a-b), Ceutos & Mitchell (1998). [↑](#footnote-ref-1)
2. The authors call this variable executive function, a term that, like inhibitory control, has been used in the research to refer to the same psychological component (see Novick et al., 2014). Again, for the sake of consistency, I use ‘cognitive control’, given that its role in the current study will be to resolve conflict. [↑](#footnote-ref-2)
3. One study even found that bilinguals who began learning both languages at birth outperformed bilinguals who began learning their second language at age 3 on a Simon task, even though proficiency in both groups’ proficiency in both languages was equivalent (Struys, Mohades, Bosch & van den Noort, 2015). [↑](#footnote-ref-3)
4. It should be noted that the bilingual group had also reported comparable proficiency in a third language (beyond Spanish and Catalan) that they similarly learned in school. This presents a further difficulty for comparing Costa et al. (2008) and Torres & Sanz (2016). [↑](#footnote-ref-4)
5. Costa et al. (2008) and Torres & Sanz (2016) only include the labels of the poles of their Likert scale, so the choice of words is my own to reflect the numerical data presented and to reflect how the authors represented that data in their own descriptions, unless presented in quotes. [↑](#footnote-ref-5)