**Second language proficiency and the role of cognitive control**

**in the revision of L2 syntactic garden-paths**

**Abstract**

In a recent study, Pozzan and Trueswell (2015) found that adult learners of a second language (L2) at an intermediate proficiency level have difficulty abandoning initial interpretations of syntactic garden-path sentences, much the same as those difficulties observed with children in their native language (Trueswell, Sekerina, Hill and Logrip, 1999). This processing difference in children has been associated with immature cognitive skills (Choi and Trueswell, 2010; Novick, Trueswell, and Thompson-Schill, 2005; Woodard, Pozzan, and Trueswell, 2016). Similar difficulty has also been observed in patients with impaired cognitive skills due to brain damage (Novick, Kan, Trueswell, and Thompson-Schill, 2009). Pozzan and Trueswell (2015) propose that the domain-general cognitive abilities involved in garden-path recovery, which are either immature in the case of children or impaired in the case of patients, may likewise be diminished for language learners of low proficiency levels when processing the L2, resulting in the similar findings among the three populations. They base this suggestion on the higher recruitment of the brain structures related to cognitive control (namely the LIFG and other prefrontal structures) that has been observed during low-proficiency language processing, as compared to first language (L1) and high-proficiency L2 processing, which do not show the same level of recruitment (Abutalebi, 2008). However, due to the limited scope of the study, Pozzan and Trueswell (2015) are not able to make this claim beyond speculation. The current study looks to answer several of the questions that emerge from their important contribution.

**Introduction**

Many sources of information must be coordinated and processed during the online interpretation of sentences by a healthy adult in his or her first language (L1), a process that only becomes more difficult in other populations that must coordinate this information while dealing with certain handicaps, such as impaired cognitive skills as a result of brain damage (in the case of patients) or immature cognitive skill development (in the case of children).

Several studies that have found decreased performance by children on language processing experiments have attributed it to their immature domain-general cognitive skills (Choi and Trueswell, 2010; Novick et al., 2005; Woodard et al., 2016). However, the issue arises that children are developing their linguistic system while their cognitive skills develop. Recent research attempting to tease apart results associated with their emerging language skills from those associated with protracted maturation of prefrontal cortical has led to questions concerning the interaction of these two systems. Following a rich strand of research that utilizes the visual world paradigm to understand language processing through participant behavior and eye movements, Pozzan and Trueswell (2015) question whether the differences seen in child processing of syntactic garden-paths is better explained as a L1 learner phenomenon or as a result of this incomplete prefrontal development observed in children. They reason that L1 and adult L2 learners will obtain similar results if these differences are a learner phenomenon, while children will differ from adults (both native and L2 speakers) if these differences relate to immature cognitive skills.

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 (1-referent vs 2-referent visual world). In this incarnation of the visual world, each scene presented to the participant was divided into four quadrants, each quadrant containing either the target referent, a nontarget competitor referent, the correct goal, or an incorrect goal (see Fig. 1)

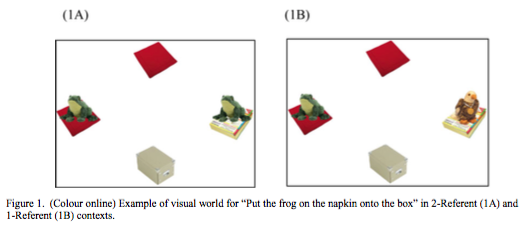


Figure 1. From Pozzan and Trueswell (2015). Example of visual world for "Put the frog on the napkin onto the box" in 2-Referent (1A) and 1-Referent (1B) contexts.

Participants were presented with a temporarily ambiguous sentence, as in (1), or an unambiguous sentence, as in (2):

1. Put the frog on the napkin onto the box.
2. Put the frog that’s on the napkin onto the box.

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. To aid in reaching this appropriate interpretation, participants can use referential cues that Pozzan and Trueswell incorporated into their design. In the case of the 1-referent condition (i.e. 1B), the use of the definite article is effectively required and so does not provide any clues to disambiguation, but in the case of the 2-referent condition (i.e. 1A), the definite article is atypical (in both Italian and English) unless followed by modifying information, so the definite article can serve as a hint that the subsequent information will modify the noun, not serve as a goal.

The results obtained were mixed: L2 adults’ act-out and eye-movement data reflected increased consideration of the incorrect goal, the same patterns observed in children in terms of the difficulty they presented in the abandonment of incorrect parses in temporarily ambiguous sentences once the disambiguating information became available (Trueswell et al., 1999), while the native adults are far superior in reanalyzing the structure at this point. However, L2 adults used the referential context to aid their processing, similar to native adults and “in sharp contrast with the pattern observed for children” (Pozzan and Trueswell, 2015, p. 7). The use of referential context to aid interpretation in the 2-referent conditions may relate to L1-transfer, given that in both English and Italian the use of a definite article (“Put the frog…”) would be anomalous without modifying information to indicate a specific target, but it may also relate to increased sensitivity to contextual information that children do not utilize (Pan & Felser, 2011), a question that remains for future research.

Although the researchers found that adult L2 learners behaved like children in terms of their increased consideration of the incorrect goal, and therefore, their ability to abandon initial interpretations upon reaching the disambiguating information, the study only involves one proficiency level: intermediate (as assessed by the oral comprehension subtest of the Michigan Test of English Language Proficiency). Therefore, this decreased ability for revision at one particular stage of L2 development may be the result of task difficulty for the intermediate learner. The authors suggest an alternate possible explanation by relating their findings to neuroimaging data from Abutalebi (2008), who found increased activity of the LIFG and other prefrontal structures involved in cognitive control during processing of a non-native, non-proficient language, which could suggest that the L2 speakers involved in Pozzan and Trueswell’s study may have shown revision difficulties similar to populations with immature or impaired cognitive skills because their own cognitive skills may have been engaged to the point of depletion, resulting from processing a non-highly proficient L2. A differential role of other cognitive functions has been observed in behavioral studies, as well. For example, the facilitative effects of executive function and phonological short term memory on the automatization of L2 grammatical structures have been shown to diminish as proficiency level increases (Serafini & Sanz, 2015)

Conflict detection has been shown to trigger sustained cognitive control; for example, the Stroop effect can be lessened for an incongruent trial if it is is preceded by another conflict trial as opposed to a congruent/nonconflict trial (Freitas, Bahar, Yang, and Banai, 2007; Kerns, Cohen, MacDonald, III, Cho, Stenger, and Carter, 2004). This pattern has also been observed in adults’ performance on cross-task conflict adaptation tasks, where recovery from an incorrect interpretation due to syntactic ambiguity is facilitated when the language-comprehension trial is preceded by a conflict Stroop trial (Hsu and Novick, 2016). A different pattern has been observed in children: while conflict adaptation has been found within cognitive control tasks (e.g. incongruent Stroop trial preceding incongruent Stroop trial), in a cross-task design, recovery from syntactic misanalysis is less likely following an incongruent Stroop trial (Huang, Gerard, Hsu, Kowalski, and Novick, 2016). The authors suggest this may be due either to the depletion of immature cognitive control resources or to task difficulty fatigue.

The current study develops out of these findings that cognitive-control engagement can be manipulated by altering the type of conflict of a preceding trial. By introducing varying proficiency levels and a cross-task conflict adaptation paradigm, we can determine whether conflict-control engagement can account for the non-native-like findings observed in Pozzan and Trueswell (2015). Given that the LIFG and other prefrontal structures are significantly less engaged during highly proficient L2 processing than during non-highly proficient L2 processing (Abutalebi, 2008), the conflict adaptation paradigm should result in a triggering of sustained cognitive control for near-natives, resulting in improved performance on a language-comprehension trial that follows an incongruent Stroop trial. Meanwhile, if cognitive control is already engaged for beginner and intermediate learners, performance should not improve to the same extent following incongruent trials, and in fact, may decrease following these trials due to depletion of resources or fatigue, as observed in children in Huang et al. (2016). However, if the differences observed between native and intermediate L2 speakers in Pozzan and Truewswell (2015) relate exclusively to proficiency-related task difficulty, all groups should behave similarly when exposed to the cross-task conflict adaptation.

**Research Questions**

1. Does cognitive control engagement during trial *n*-1 differentially affect online revision abilities (as measured by eye-movement) of distinct proficiency levels during the processing of a syntactic garden-path sentence?
2. Does cognitive control engagement during trial *n*-1 differentially affect distinct proficiency levels’ final interpretation of syntactic garden-path sentence (as measured by actions toward the incorrect goal)?

**Experimental Investigation**

**Method**

***Participants***

Data will be collected from participants at four levels of Spanish proficiency: (1) native Spanish speakers whose L2 is English[[1]](#footnote-1); (2) near-native L2 speakers of Spanish whose L1 is English and who use Spanish on daily basis in their professional and/or personal lives; (3) students enrolled in Intermediate Spanish 2 at Georgetown University, whose L1 is English; and (4) students enrolled in Beginner Spanish 2 at Georgetown University, whose L1 is English. Spanish was chosen because its word order in these sentences corresponds to that of English and Italian, including the prepositional phrase attachment ambiguity. It was chosen over Italian in order to ensure a large sample size and this wide array of learner proficiency.

***Materials and Procedures***

To test whether cognitive-control engagement affects distinct proficiency levels differentially during the processing of syntactic garden-paths, the design of the task will incorporate a cross-task conflict adaptation paradigm, following Hsu and Novick (2016), pseudorandomly interleaving a Stroop task with a language-comprehension task involving syntactic ambiguity, similar to the task used in Pozzan & Trueswell (2015). This task requires that participants listen to an imperative sentence relating to a simultaneously-presented scene shown on a computer screen and that they carry out the action as instructed. Like other studies in this strand, such as Pozzan and Trueswell (2015) and Hsu and Novick (2016), the current study will measure (1) final interpretations of the trial sentences by considering participants’ placement of the target within the visual world; and (2) online processing of the sentences by recording eye movements during presentation of the sentence. Importantly, some of the sentences contain a syntactic structure that results in a temporary ambiguity, while the remainder does not contain any ambiguity. With the study design’s pseudorandom interleaving, each critical trial is preceded by a Stroop trial.

Figure 2: Experimental Protocol

*Stroop task.*Following Hsu & Novick’s (2015) cross-task conflict adaptation paradigm, the Stroop task used will separate representational conflict and response conflict. This follows from Milham, Banich, Webb, Barad, Cohen, Wszalek, and Kramer (2001), who found that the involvement of areas of the brain involved in attentional control differs according to the type of conflict, and so, since response conflict may engage mechanisms that are not involved in the representational conflict encountered in the language task, it is important to separate the two types of conflict.

Participants will first be trained to use a three-button mouse to respond to the Stroop trials, where each button represents an ink color (blue, green, or yellow). Participants will then respond to 144 Stroop trials (72 congruent and 72 incongruent trials) before beginning the interleaved Stroop and language-comprehension trials. In the congruent Stroop trials, participants are presented with a color name in the corresponding ink color (“blue” in blue ink, “green” in green ink, or “yellow” in yellow ink), and they must respond by clicking the button that corresponds to the ink color presented. It is in the incongruent trials where the separation of representational and response conflicts is paramount. Here, only response-ineligible color names are used (“brown”, “orange”, and “red”), though they are presented in the same ink colors as the congruent trials. In other words, the response options never vary.

*Language-comprehension task.*Participants will be presented with a visual world and will be instructed to move the target referent to the correct goal (see Fig. 2). The 2-referent condition included in Pozzan and Trueswell (2015) will not be included in the current study, as it was observed that adults in their study used referential context to aid in processing, regardless of proficiency level

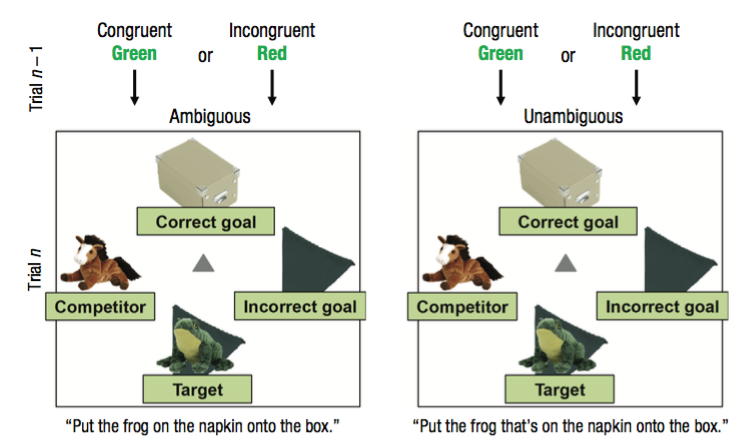


Figure 3. From Hsu and Novick (2015). Experimental design. Visual worlds had a target (here, "frog") and a nontarget competitor (here, "horse"). Although Pozzan and Trueswell (2015) incorporated a 1-referent condition (such as the scene shown) and a 2-referent condition (see Figure 1A), the current study removes the referential context condition, as it was observed that adults use referential context regardless of proficiency level.

Corresponding to the scene in Figure 2, a temporarily ambiguous Spanish sentence is provided in (3) and an unambiguous sentence in (4):

1. Pon la rana en la servilleta en la caja.

Put the frog on the napkin on the box.

1. Pon la rana que está en la servilleta en la caja.

Put the frog that is on the napkin on the box.

As seen in Figure 2, there is both an empty napkin and a napkin on which a frog is seated. Therefore, in the case of sentence (3), listeners temporarily interpret the modifier “*en la servilleta*” incorrectly as a goal. However, the disambiguating prepositional phrase “*en la caja*” triggers a reanalysis of the structure of the sentence, a revision of their initial interpretation. Within this particular paradigm, eye movements to the goal (here, *la caja*) have robustly been shown to be delayed due to the initial incorrect interpretation of the modifier (here, *the napkin*), compared to those sentences that do not have this temporary ambiguity, such as (4) (Hsu and Novick, 2016; Novick, Thompson-Schill, & Trueswell, 2008; Spivey, Tanenhaus, Eberhard, and Sedivy, 2002, among many others). As mentioned above, children (Trueswell et al., 1999) and L2 learners of intermediate proficiency (Pozzan & Trueswell, 2015) have been shown to have more difficulty revising this initial interpretation than native adults, both in the behavioral and eye-tracking data.

Following the tokens used by Hsu and Novick (2016), the participants will hear both the ambiguous (*x* = 24) and unambiguous (*x* = 24) sentences, as well as interspersed filler sentences (*x* = 48). These fillers would (a) also follow Stroop trials and (b) contain imperative instructions, but importantly, contrary to the ambiguous sentences, (c) the first postnominal prepositional phrase *would be* the goal and not a modifier. These three characteristics would contribute to preventing participants from learning during the exposure that the first prepositional phrase is a modifier (See Fine, Jaeger, Farmer, & Qian, 2013). An example of a filler is included in (5):

1. Pon el caballo en la caja.

Put the horse on the box.

Following previous studies using this paradigm, item locations (e.g., target, competitor, incorrect goal, correct goal) and item ambiguity will be counterbalanced.

*Interleaved Stroop-to-sentence sequences****.*** During the test phase, either a congruent or incongruent Stroop item (trial *n* − 1) will precede either an ambiguous or unambiguous sentence (trial *n*). The counterbalancing of these items will result in 12 trials for each of the four conditions in this two by two design. However, additional filler Stroop and language-comprehension trials will prevent the participants from predicting task type. The interleaving of the Stroop and language-comprehension tasks will allow for the observation of whether detection of conflict initiates and sustains cognitive control during the subsequent language-comprehension task, especially when revision of an incorrect initial interpretation is necessary in an ambiguous sentence trial.

**Hypothesized Results and Discussion**

Given Abutalebi’s (2008) finding that structures related to cognitive control are not engaged for highly proficient L2 speakers or native speakers as they are for non-proficient speakers, it is my prediction that the two higher-proficiency groups will perform similarly in each condition, and that the Stroop-conflict detection will activate cognitive control for the subsequent trial, thus improving recovery from misinterpretation of ambiguous sentences. However, according to the extant data, there are three likely results that may be obtained for the beginner and intermediate participants. To facilitate discussion, each of these hypothetical situations will be discussed separately.

*“Depletion” of Cognitive Control.* Given the recruitment of the LIFG and other prefrontal structures observed by Abutalebi (2008) during the processing of a non-proficient L2, the demands of using an L2 at these lower proficiency levels may result in a carryover effect, a refractory period during which cognitive control resources available to the participants are effectively temporarily depleted by the high cognitive load. This would relate to the results obtained in child processing by Huang and colleagues (2016). An interaction would be observed between Stroop congruency on trial *n*-1 and proficiency level, as hypothetically depicted in Figure 4.

Figure 4

*“Maximally Engaged” Cognitive Control.* This alternate possible set of results assumes that cognitive control of low proficiency participants is engaged throughout the study due to the use of the L2, and so preceding incongruent Stroop trials would not result in improved recovery from misanalysis for these participants. Therefore, hypothetically, an interaction would be observed between Stroop congruency on trial *n*-1 and proficiency level, as the high proficiency groups would perform better following incongruent Stroop trials, as depicted in Figure 5, while the low proficiency groups would not perform differently under the two conditions.

Figure 5

*“Heightened Engagement” of Cognitive Control.* This final alternative would show that cognitive control engagement can be manipulated to aid recovery from misinterpretation for each proficiency level (See Fig. 6). This finding would suggest that the increased consideration of the incorrect goal in Pozzan and Trueswell (2015) is a reflection of proficiency level and not overloaded cognitive control. Each proficiency level would respond to the cross-task manipulation similarly, and so perform similarly under both ambiguous conditions.

Figure 6

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1. Although Pozzan & Trueswell (2015) used monolingual speakers of English as their native speaker group, given the current design, it would be more appropriate to use native Spanish speakers who use English as an L2. The use of highly-proficient bilinguals in both the near-native (L1-English, L2-Spanish) and native (L1-Spanish, L2-English) groups would ensure comparability between the two groups: any differences in performance should relate to differences in proficiency, rather than to cognitive control differences associated with bilingualism. [↑](#footnote-ref-1)