'Click on the bigote largo': Comprehension of novel sentence structures in English-Spanish bilinguals

DAVID NAHMIAS[1], DAN GRODNER[1] & MALATHI THOTHATHIRI[2]

[1]Swarthmore College, [2]George Washington University

Department of Psychology, Swarthmore College
500 College Ave. Swathmore, PA 19081 United States

Abstract

There have been numerous studies on how syntactic structures in two native languages are represented and separated in the brain. Previous studies have shown that monolingual subjects abstract to general syntactic structures (Thothathiri & Snedeker, 2008). Furthermore, it has been shown that bilinguals represent syntactic structures independent of language since a syntactic structure in the first language was able to prime the use of a similar syntactic structure in the second language (Koostra, van Hell & Dijkstra, 2010). Finally, it has also been found that bilinguals access both languages' vocabulary simultaneously when faced with a phonetically ambiguous scenario (Canseco-Gonzalez et al., 2010). This study aimed to see how well English-Spanish bilinguals integrate syntactic structures from two different languages. We wanted to know if bilinguals can use syntactic structures from both languages to represent a new syntactic structure that has features of both languages but yet does not exist in either language. The first experiment tested this by priming subjects with a new syntactic structure "Click on the bigote largo," a code-switched sentenced that because of Spanish syntax had the order of the adjective-noun pair. This is the reverse order of what an initially English sentence would be expected to have. The second experiment also introduced an alternate syntactic structure "Click on the antigua casa," a code-switched sentence that still held the syntactic structure of a typical initially English sentence that would have adjective-noun pair. For the critical trials we created a phonetically, and thus syntactically, ambiguous scenario where the initial cohort following "Click on the ..." would refer to both an English adjective-noun pair and a Spanish noun-adjective pair. We

predicted that subjects would be primed by whatever sentence structure they heard previously and would thus initially look at the item with the initial cohort that corresponded to the primed syntactic structure regardless of what the actual target item was. For the first experiment our results confirmed our hypothesis for the code-switched critical trials. Subjects initially looked at the English target when primed with fully English sentences as opposed to the actual code-switched target and looked directly at the code-switched target when primed with code-switched sentences. The second experiment, though with fewer subjects, suggests that when primed with the novel code-switched sentence with an adjective-noun order target, subjects more often looked at the English target than the code-switched target regardless of what the target actually was. Further results inline with the current results of the second experiment would confirm our hypothesis.

1. Introduction

Sentence structures and syntactic representations in the brain have been studied in a variety of ways and numerous results and discoveries have been made as to how people represent syntactic structures. It was shown by Thothathiri & Snedeker (2008) that subjects abstracted to more general sentence structures rather than storing specific syntactic elements of sentences. When subjects were primed with various sentences using different verbs that represented essentially the same action they showed a priming effect for sentences with the same structure. Though the words themselves were different it was shown that subjects understood the sentence in terms of what it meant and abstracted to a general sense of 'giving' or 'passing' allowing a previous sentence of similar structure to prime a later sentence.

It has also been shown by Koostra, van Hell & Dijkstra (2010) that with different languages that share similar syntactic structures participants preferred to repeat the same syntactic structure in the second language rather than change syntactic structures from the first language showing that both languages were being accessed. Furthermore, this seems to suggest that syntactic representation is independent of language. They concluded that one language's syntactic structure could prime the subject to use that same syntactic structure in the second language. This was further shown by Weber & Indefrey (2009) physiologically when they found under fMRI analysis that

different languages were using the same part of the brain. This meant that for bilinguals that had learned both languages at an early age both languages were being accessed from the same part of the brain.

Finally, Canseco-Gonzalez et al. (2010) found that bilinguals have what could be considered a master vocabulary of both languages being accessed at all times. This was demonstrated by presenting subjects with two nouns in different languages that shared overlapping cohorts. When the initial cohort was said subjects accessed all possible words, in both languages, that shared the initial cohort being uttered until there was no longer an ambiguity of which item, in one of the languages, was the target.

In this article we use the findings of these previous studies and investigate whether bilinguals represent both languages' structures separately or as one large syntax that can be manipulated and mixed together.

2. Experiment I

The first study looked at this question by priming subjects with certain syntactic structures that do not exist in either language but are rather novel sentence structures that are a result of code-switching. In English the describing adjective is said before the noun it is describing, for example 'big cookie.' However, in Spanish this order is reversed and the describing adjective is said after the noun, for example 'galleta grande (cookie big).' We created a syntactic structure of an initially English sentence that code-switched into a Spanish noun-adjective pair. We looked to see if this novel structure could be primed and therefore was being created by the subjects as a legitimate syntactic structure. We tracked subjects' eye movements, a common practice for experiments like this (Canseco-Gonzalez et al., 2010), to record subjects' online comprehension. We used the obtained data as a means of determining if this novel sentence structure was being primed and thus was being created in subjects' mind (Thothathiri & Snedeker, 2008).

We hypothesized that when the prime and target type were the same syntactic structure, both fully English or both code-switched, subjects would look directly at the target object since they would be primed with similar sentences with either the adjective or the noun being said first, depending on the type of sentence. This would follow the repetition suppression effect described by Weber & Indefrey (2009). However, when the primes differed from the target we hypothesized that subjects would first look at the object with the initial cohort that would follow the structure of the prime sentences and

then once the region of ambiguity had passed they would look at the target object. This would follow the cohort effect described by Canseco-Gonzalez et al. (2010).

2.1. Methods

2.1.1. Participants

Twenty-four subjects (20 female, Mean age = 19 year) participated. Participants were chosen based on their knowledge and experience with both English and Spanish. Each subject was first asked to fill out an online survey that asked them at what age they had first learned each language and how often they spoke each language. The average age for first learning English and Spanish was 2. The oldest age of acquisition for both languages was 6. Our criteria regarding who was selected for the experiment followed closely the selection criteria of Conseco-Gonzalez et al. (2010) which were based on the critical period hypothesis of language acquisition. However, only 20% of subjects reported speaking Spanish more than 10 hours a week which meant that most if not all subjects mostly spoke English day to day.

2.1.2. Design

Subjects were first familiarized with all the individual images used in the experiment. Each with the image, its English, adjective noun label, and its code-switched, noun adjective label.

Each participant received 64 trials of which 16 were critical, 32 were primes and 16 were fillers. The experiment was set up with four different types of conditions:

- Two English primes and an English target
- Two code-switched primes and an English target
- Two English primes and a code-switched target
- Two code-switched primes and a code-switched target.

The two prime-target relationship design was adapted from Thothathiri & Snedeker (2008) since a priming effect was seen when two priming sentences were used. Each participant received all four conditions throughout the experiment. However, four different lists were made which counterbalanced which condition each critical trial was. Lists only varied with auditory stimuli, the order of the trials' images remained the same for all participants. Participants were randomly assigned to a list at the beginning of the experiment, though were equally distributed across the four lists for a total of six

participants per list. Finally, order within the lists was pseudo-random and only the prime-prime-target relationship was controlled for.

2.1.3. Materials

The EyeLink II system was used to track subjects' eye movements. The software ExBuilder, designed by Edward Longhurst was used to compile the experiment. We displayed both visual and auditory stimuli simultaneously on a computer and tracked subjects eye movements relative to the images locations and audio offsets for each trial.

Stimuli were selected under various phonological and semantic constraints. 16 pairs of English adjectives and Spanish nouns that shared the same initial cohort were found. Each of these words, both the adjectives and nouns had to be easy to depict visually in order for them to be included in the experiment. Furthermore, English adjectives were only chosen if a contrasting adjective could depict the same object the critical English adjective was describing. In each trial, the English target had a contrasting object so that the adjective did not seem unnecessary and was distinguishing between two objects (Brown Schmidt & Konopka, 2008). Within each trial only two objects of the four depicted item's adjectives or nouns, in both English and Spanish, could share the same initial critical cohort of that trial. This ensured that the initial cohort could only refer to one of those items' adjective or noun. Finally, each image was only used once for a total of 256 images used.

Auditory Stimuli   The audio stimuli were prerecorded by an English-Spanish bilingual. Each phrase began with "Click on the..." after which the adjective-noun or noun-adjective pair was said. The English continuation would be "Click on the big cookie" while the Spanish, code-switched, continuation would be "Click on the bigote largo. (mustache long)" Each of the priming trials were recorded targeting the same object in the trial and varied only between their English and Spanish labels. However, the filler trials' audio remained constant for all participants. The time at which the initial cohort of interest was uttered from when the trial began was recorded for data analysis.

Visual Stimuli   Each trial had four individual pictures which were combined to be each in the corners of a three by three white square on a black background. The center square had a red dot that the subject clicked on

before hearing the auditory stimuli. There was then a smaller transparent red box that appeared over the item that the subject clicked on. Each trial, filler, prime and target visually shared an identical design.

Sample Target Stimuli:
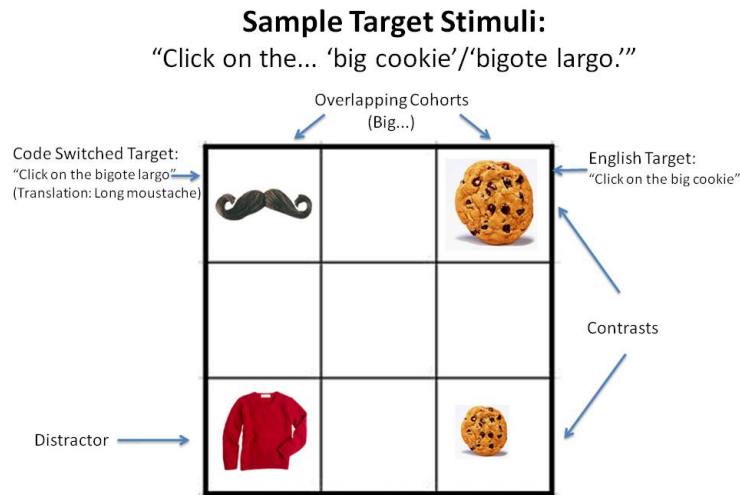"Click on the... 'big cookie'/'bigote largo.'"

Figure 1: This is a sample critical trial which shares the same design as all trials except for the phonetic manipulation of the target items which is only present in critical trials.

2.2. Results

The data was acquired by EyeLink II and ExBuilder. A file of what type of trial each trial was, a file of what type of object was in each location for each trial and a file of the time when the initial cohort of each target was said were compiled together. This returned an average ratio of subjects looking at a particular item with respect to the elapsed time of the trial.

$$\text{DV} = \frac{\text{looking time to target}}{(\text{looking time to target} + \text{competitor})}$$

Furthermore, the critical time for where we analyzed our data was 200-400ms after t=0, when the initial critical cohort was uttered.

The figures show the ratio of subjects looking at each of the images through each type of critical trial. All the data was shifted by various amounts so that where it is labeled 'big' or 'bigote' the initial cohort of the phonetically ambiguous word began for each of the critical trials. We are therefore able to compare all the critical trials with one time scale. Finally, note the region of interest is highlighted in each figure.
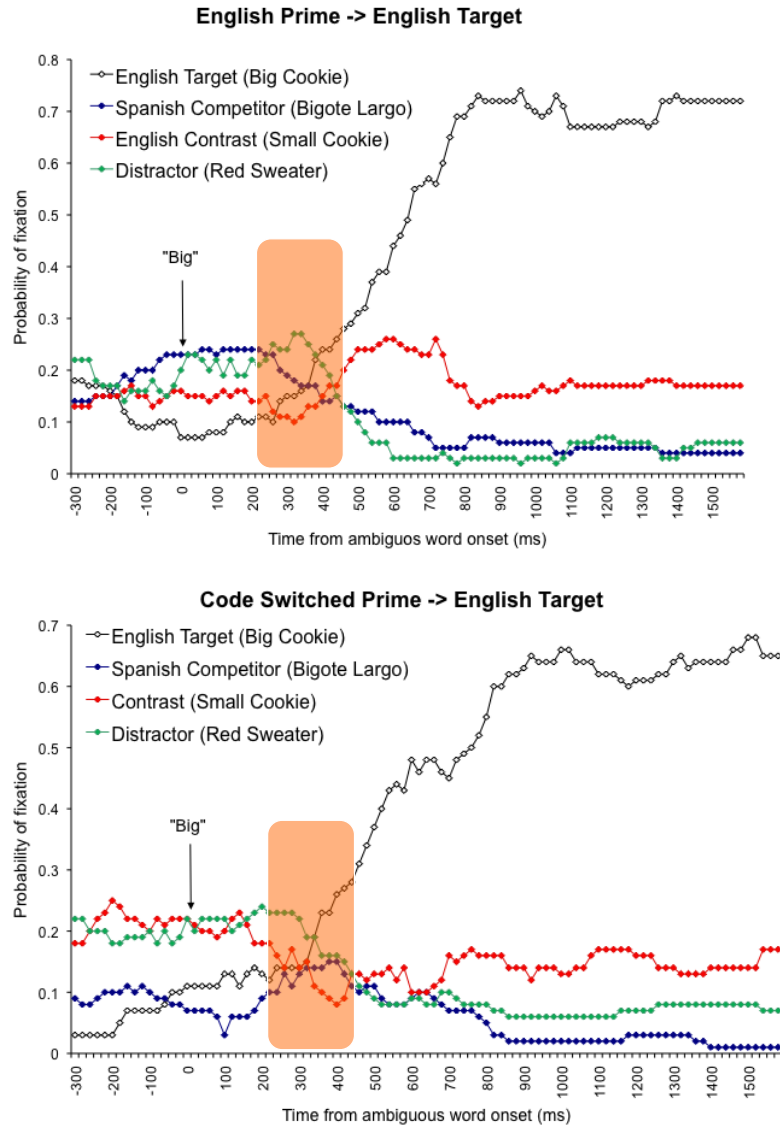
6

Figure 2: This figure shows that there was no priming effect for English target sentences as there was no significant difference between the ratio of subjects looking at different objects between English and code-switched primes.

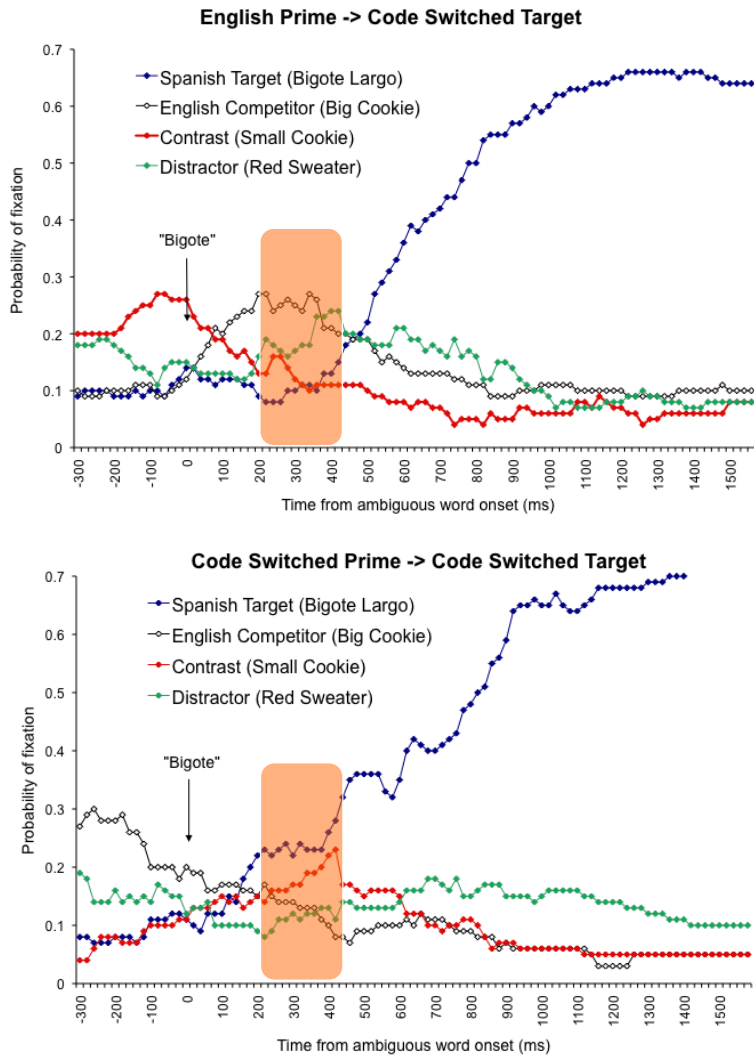## 2.2.2. Code Switched Targets

Figure 3: This figure shows that there was a priming effect for code-switched targets since there was a significant difference between the ratio of subjects looking at different objects between English and code-switched primes. It was found that subjects looked at the target object with greater frequency in the code-switched primed targets than in English primed targets from 200-400ms.

The results of this experiment suggest that there is in fact some priming effect occurring, though only for the code-switched targets. However, since it is only present in the code-switched targets it is possible then that it is only code-switching that is being primed rather than the novel syntactic structures. Experiment II looks to disambiguate between these two possibilities.

3. Experiment II

The second study looked at this question by creating a syntactically rare scenario that would disambiguate whether we were priming code-switching or specific syntactic structures in the results from Experiment I. Rather than having only fully English sentences or code-switch sentences with the more common noun-adjective order, we introduce code-switched sentences where an adjective-noun order is used, for example "Click on the antigua casa (old house)." The purpose of doing this is to see if we can prime a usually fully English sentence with a code-switched sentence that shares the same syntactic structure of the adjective-noun order.

Similar to our hypothesis of Experiment I, we hypothesized that when the prime and target shared syntactic structures, either both with adjective-noun order or both with noun-adjective order, subjects would look directly at the target object. However, when the prime's syntactic structure differed from the target we hypothesized that subjects would first look at the object with the initial cohort that would follow the structure of the priming sentences and then once the region of ambiguity passed they would look at the target object. These hypotheses follow from the same reasons as cited in Experiment I.

3.1. Methods

3.1.1. Participants

Sixteen subjects (8 female, Mean age = 19 year) participated. Participants were chosen under the same criteria as Experiment I and again only 20% of subjects reported speaking Spanish more than 10 hours a week which meant that most if not all subjects mostly spoke English day to day.

3.1.2. Design

Subjects were again first familiarized with all the individual images used in the experiment. However, in this experiment, there were four different

familiarization conditions, one for each different conditions. For the familiar-ization each image had the image, its English, adjective noun label, and its code-switched, either noun adjective or adjective noun label, which depended on what was being used in that particular condition. This was done so that that item would be labeled exactly as it would be referred to.

Each participant received 64 trials of which 16 were critical, 32 were primes and 16 were fillers, similar to Experiment I. However, Experiment II was set up with four different types of conditions:

- Two code-switched adjective-noun primes and an English target
- Two code-switched noun-adjective primes and an English target
- Two code-switched adjective-noun primes and a code-switched target
- Two code-switched noun-adjective primes and a code-switched target.

Furthermore, all fillers were changed to fully English so that not all fully English trials were critical trials. The rest of the design details follow from Experiment I.

3.1.3. Materials

32 new primes were carefully chosen for Experiment II with the adjective noun pairs describing the object able to be said both in the more common Spanish noun-adjective order as well as in the less common but acceptable Spanish adjective-noun order. All critical trials and fillers remained the same between Experiment I and Experiment II and all stimuli and other design specifications followed the same constraints as Experiment I.

Auditory Stimuli The audio stimuli were all again prerecorded by a Spanish-English bilingual using similar guidelines from Experiment I.

Visual Stimuli The visual stimuli, besides the change in individual pictures for the 32 prime trials, remained the same between Experiment I and Experiment II.

3.2. Results

The procedure and model for analyzing the data as well as what is shown in the figures below is the same as in Experiment I. Again, note the region of interest is highlighted in the figures.
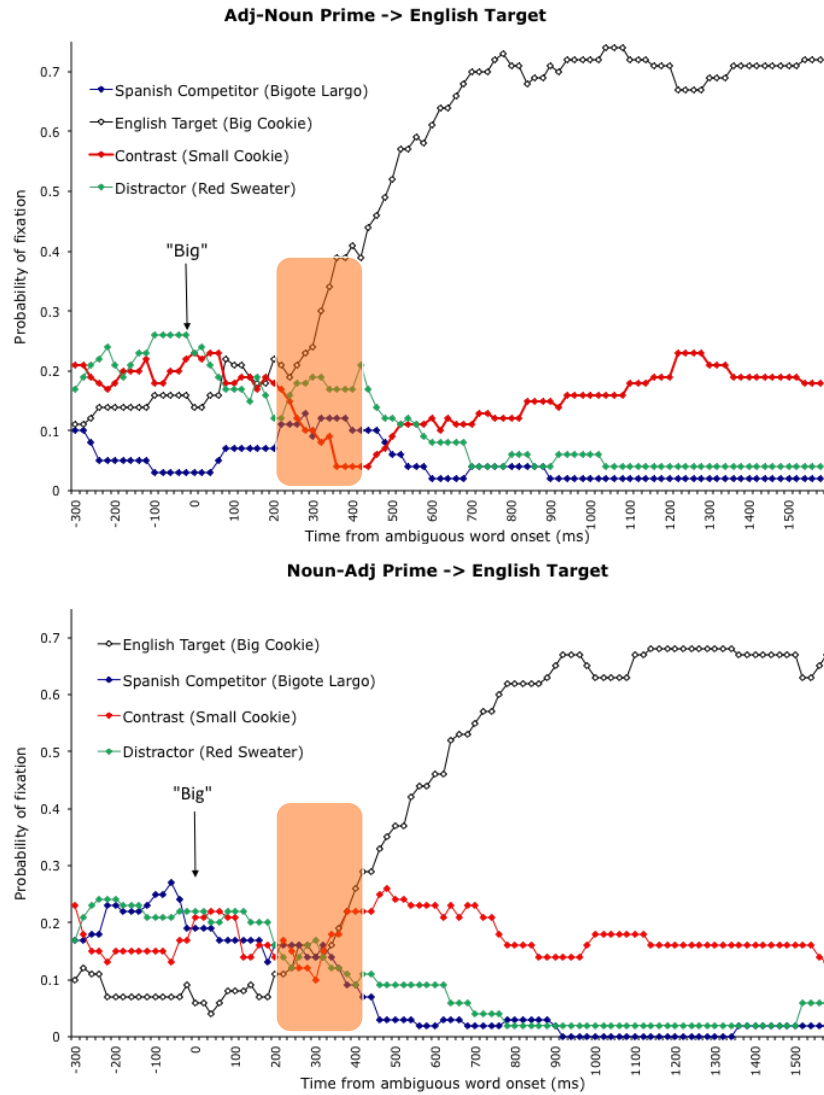
3.2.1. English Targets

Figure 4: This figure suggests that there may be a priming effect since subjects looked at the target more often when there was an Adj-Noun prime which is of the same syntactic structure as the English target.
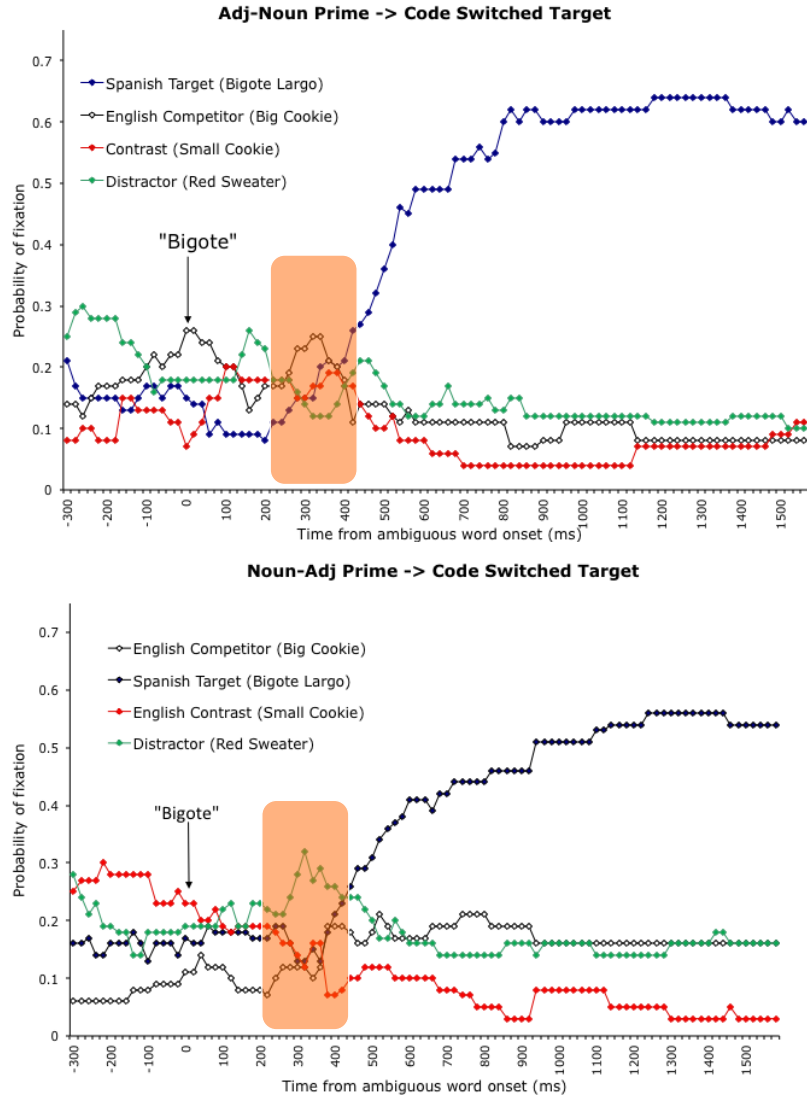
11

3.2.2. Code-Switched Targets

Figure 5: This figure suggests that there may be a priming effect since subjects looked at the target more often when there was a Noun-Adj prime which is of the same syntactic structure as the Code-Switched target.

The results of this experiment suggest that subjects looked more often at the target with the initial cohort that shared the same syntactic structure as the priming sentences. This would mean that the results in Experiment I were priming syntactic structures, not code-switching.

4. General Discussion

4.1. Conclusion

The results of Experiment I showed that although there were no significant results for English target trials, there were significant results for code-switched targets. This shows that sentence structures created out of phrases from multiple languages can be primed. This is concluded because of how priming of these novel sentence structures influences real-time sentence comprehension of code-switched target sentences. However, with regard to the English target trials there are two possibilities. Since each sentence began with "Click on the..." it is possible that an English continuation was always primed with this initial part of the sentence in English for every trial. Furthermore, the subjects were greeted and given instructions entirely in English which could have also affected the results of the experiment. Another possibility is that subjects might be English dominant bilinguals and may be less susceptible to English priming effects. However, the results not only do not show a priming effect they instead seemed to show a reverse priming effect which cannot be explained from the data.

The results of Experiment II suggest that subjects looked more frequently during the region of interest at the object matching the syntactic structure of primed objects than the competing target with the same initial cohort. Since only 16 subjects participated in this experiment the results are not yet conclusive. Further investigation and experimentation is needed to confirm whether a significant priming effect is occurring. However, based off the current results it would seem that it the syntactic structure of the prime trials are priming the subject for the critical trials. Furthermore, there is a lot of noise in the data currently which can be seen for example in the Noun-Adj Prime → Code Switched Target case where the object with highest ratio of subjects are looking at the distractor item during the region of interest. Though when comparing the ratio of subjects looking at the two competing targets that shared the initial cohort the target that shared syntactic structure with the prime was higher, it was not the highest of all the objects which is what would be expected.

13

When considering the results of these two experiments together there are some significant results. In Experiment I, trials with code-switched targets were found to have a significant priming effect which left the question as to whether only code-switching itself was being primed or if abstract syntactic structures were being primed. From the preliminary results of Experiment II, it would seem that it is in fact abstract syntactic structures not tied to any specific language that are being primed. Since all the primes are code-switched if any difference is found between them then it is not possible to say that code-switching was being primed in Experiment I. This would mean that results in Experiment I indicate that subjects were being primed by syntactic structures. A possibility for why the English primes in Experiment I, which are the only English primes across both Experiments, are not effective is a ceiling effect. Given that the majority of the participates predominately English speakers in day-to-day life it becomes more difficult to prime them with English sentences.

To summarize, these results indicate that much like it has been shown that bilinguals access both their English and Spanish vocabulary when faced with a phonetically ambiguous scenario (Canseco-Gonzalez et al., 2010) subjects access both English and Spanish syntactic structures simultaneously for online comprehension of code-switched sentences and use a novel sentence structure. These results confirm the results from Koostra, van Hell & Dijkstra's (2010) since syntactic structures seem to also be independent of language here. Just as subjects abstracted to general syntactic structures in monolingual studies (Thothathiri & Snedeker, 2008), subjects in this study also abstracted and created a novel sentence structure by using sentence structures from both English and Spanish. This shows that not only are syntactic structures developed and accessed in the same region of the brain (Weber & Indefrey, 2009), they also can be mixed and are not necessarily independent of each other. This means that multilingual sentences are represented and processed similarly to unilingual sentences.

4.2. Future Directions

In order to confirm the suggested results from Experiment II more subjects should be tested under the conditions of Experiment II. Afterwards, once the new data is combined with the current data it may be the case that the noise of the current data will be less pronounced and it will be more clear what priming effects, if any, are occurring.

Furthermore, to confirm the results of the code-switched targets from Experiments I & II and possibly explain the lack of significant results from English targets trials a third experiment could be conducted. Experiment I would be modified so that the initial part of the sentence "Click on the..." would be said in Spanish, "Haz click en el..." after which the sentence could either continue in Spanish or code-switch into English. Furthermore, we would control for gender information provided by Spanish determiners (el v. la), by exclusively using noun phrases that are grammatically male in Spanish. Additionally, in recent research, it has been found that the code-switch order from English to Spanish is less common and that code-switching from Spanish to English may be more natural for Spanish-English bilinguals (Valdés, 2012). This newly proposed experiment will require the replacement of four target trials from Experiment I.

We would predict one of two possible results. Either based on the results of Experiment I the code-switch targets would show a strong priming effect as before and the monolingual target sentences, in this case fully Spanish sentences, if there are no priming effect would show that code-switched sentences are more easily primed and that monolingual sentences cannot be primed in this way. Or based on the results of Experiment II, there will be weaker priming results throughout the experiment since if it is the case that it is more natural to code-switch from Spanish to English then it may be less novel and thus harder to prime, as seen with English targets in Experiment I and noun-adjective primed targets in Experiment II.

Acknowledgments

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