2018

Examination of the Mechanisms Driving Long-Range Prime-to-Target Structural Priming

Katherine Chia

FLORIDA STATE UNIVERSITY

COLLEGE OF ARTS AND SCIENCES

EXAMINATION OF THE MECHANISMS DRIVING LONG-RANGE PRIME-TO-TARGET STRUCTURAL PRIMING

By

KATHERINE CHIA

A Thesis submitted to the
Department of Psychology
in partial fulfillment of the
requirements for the degree of
Master of Science

2018

Katherine Chia defended this thesis on November 8, 2018.
The members of the supervisory committee were:

Michael P. Kaschak
Professor Directing Thesis

Walter R. Boot
Committee Member

Andrea Meltzer
Committee Member

The Graduate School has verified and approved the above-named committee members, and certifies that the thesis has been approved in accordance with university requirements.

ACKNOWLEDGMENTS

I would like to thank my advisor, Dr. Michael Kaschak, for always having an open door. His knowledge and kindness have been essential to my academic journey thus far. Additionally, I would like to thank my committee members, Dr. Wally Boot and Dr. Andrea Meltzer, for their support and feedback throughout my graduate career.

TABLE OF CONTENTS

LIST OF TABLES

ABSTRACT

Bock and Griffin (2000) presented two experiments demonstrating that *structural priming* (i.e., increased likelihood of producing a given syntactic form if you have just produced that form in another utterance) can be long-lasting. In their experiments, participants alternated between reading sentences aloud (where they read *prime* sentences aloud) and describing pictures (where the *target* pictures gave participants the opportunity to produce the same syntactic structure as was used for the prime sentence). The likelihood of describing the target picture with the same structure as the prime sentence was shown to be equally strong when the prime and target were presented in immediate succession (Lag 0) and when they were separated by up to 10 intervening filler sentences (Lag 10). This result has been taken as evidence for the claim that structural priming is the result of implicit learning within the language production system. The current project is aimed at taking a closer look at the factors that affect the persistence of structural priming across numerous filler items. Overall, our data provided mixed support for Bock and Griffin's (2000) claims. Although we found a robust priming effect at adjacent prime-target trials, our prime-target pairs that were separated by intervening trials were not significant. These findings suggest follow-up studies to clarify the effects of structural priming in a long-term setting.

CHAPTER 1

INTRODUCTION

Speakers can choose to deliver their thoughts in any number of ways. For instance, when describing a scenario in which a person is passing water to another person, they may say, "*Mike is passing Kat the water*" (double object construction; DO) or they may opt to say, "*Mike is passing the water to Kat*" (prepositional object construction; PO). While the two sentences have the same general meaning, which is that Mike is giving Kat water, the surface structure is different. Both dative constructions are acceptable, so it is intuitive to question why speakers chose to produce one over the other.

One factor that shapes syntactic choice is structural priming. First identified by Bock (1986), structural priming is the tendency to produce a recently encountered syntactic form over other options - such as using the passive construction over the active construction. In Bock's (1986) work, participants were presented with either DO or PO versions of the same sentences. For instance, they were given either 1) The rock star sold some cocaine to an undercover agent (PO) or 2) The rock star sold an undercover agent some cocaine (DO). After reading these sentences aloud, participants were instructed to describe a picture. The pictures in the study depicted a transfer event – an image of clown and a man with a hat could have been described as "*The clown gave the man a hat*" (DO) or "*The clown gave the hat to the man*" (PO). What Bock (1986) found was that when priming with a DO, participants were far more likely to produce a DO construction upon the opportunity to do so. They found the same effect for PO priming.

Structural priming is an extremely robust phenomena (see Mahowald et al., 2016, for a meta-analysis). It has been reported in language production (Pickering & Branigan, 1998), language comprehension (Kaschak & Glenberg, 2004), in the lab (Bock, 1986), and in naturally

occurring contexts (Levelt & Kelter, 1982; Chia et al., 2018). It can also be found in language acquisition (Brooks & Tomasello, 1999) and has been posited as a mechanism of language change (Bock & Griffin, 2000). Most studies of structural priming have involved language production (Pickering & Branigan, 1998; see Pickering & Ferreira, 2008, for a review), though there are a few reports of priming in language comprehension (e.g., Kaschak & Glenberg, 2004; Branigan, Pickering & McLean, 2005).

Ove the past decade, a theoretical consensus about structural priming has emerged. This consensus is called the two-mechanism account. That is, the basic priming effect is proposed to be driven by implicit learning processes, and with explicit memory mechanisms providing a boost to the strength of priming under certain conditions. There are multiple lines of evidence supporting the role of implicit learning in structural priming. First, structural priming appears to persist for long periods of time. It displays its effects when there are (at least) ten intervening trials separating the prime and target, as evidenced by Bock & Griffin (2000). Not only does structural priming seem to last long-term within an experiment, it has been documented to last for at least one week (Kaschak, Kutta & Schatschneider, 2011; Kutta & Kaschak, 2012).

A second line of evidence for implicit learning as the basis of structural priming generally is traced back to a paper by Ferreira et al. (2008). This study shows that its effects are even documented in people with anterograde amnesia (Ferreira et al., 2008). The significance of this was that the tested population demonstrated impaired explicit memory capabilities, whereas they had otherwise fully functional implicit memory performance. Their structural priming demonstration in the absence of explicit memory processes made a solid argument for structural priming as implicit learning.

A third line of evidence for implicit learning in structural priming is the inverse frequency effect. The inverse frequency effect is the finding that low-frequency constructions produce stronger priming than high frequency constructions. The narrative here is that frequent structures pose less of an impression on the language system and thus affect language production on a much smaller scale. Likewise, less frequent structures are far more impressionable and are thus reflected in a user's language production. However, support for this finding is limited, as others that have replicated Reitter et al., (2011)'s results did so in studies with multiple constructions. Subsequently, it is not clear whether the inverse frequency effect reported by Reitter et al. (2011) is the result of low frequency constructions, or of those mixed with other constructions.

Although there is a strong case for the role of implicit learning in structural priming, evidence for this claim does have some weaknesses. First, the study by Ferreira et al. (2008) had an extremely small sample size (n=4). Small sample sizes are acceptable for costly or timely experiments (such as those employing fMRI or EEG) or even special populations. However, one can argue that a sample size of 4 may be too small, even considering the circumstances. Additionally, the extent of amnesia is unclear. While the authors provide a table detailing years of education, source of amnesia, and age, only one measure was employed to indicate cognitive abilities. For this reason, using this study as a main argument for implicit learning is not the best.

Second, the inverse frequency account (Reitter et al., 2011) presents some flaws. An important characteristic of the lower-frequency structures is that they have lexical markers, such as "*by"* or *"to."* If a participant is producing these in a cumulative fashion, it may become evident. That is, the lexical marker may be clueing participants in, therefore (arguably)

producing an explicit memory effect. The explicit memory mechanism helps fill the holes that the implicit learning account presents.

The second part of the two-mechanism account of structural priming states that explicit memory is a boost to structural priming. It is suggested that explicitly memory's role in structural priming is that of a boost (Bock and Griffin, 2000, and Chang et al., 2006). The premise behind this is that explicit memory is most effective when the prime and target share the verb. This is because the repetition of the verb would act as a retrieval cue, which participants could use to produce their utterances. When looking at long-term structural priming, implicit learning is more significantly effective than explicit processes (Hartsuiker et al., 2008). The findings of Hartsuiker et al.'s (2008) study suggested that the short-term (explicit) lexical boost was short lived while the implicit structural priming persisted.

It is important to note that the case for explicit memory in structural priming is considerably weaker than the case for implicit learning. However, factors known to affect explicit memory have not been extensively explored. The study at hand study aimed to examine the role of explicit memory in structural priming more directly.

Present Studies

While prior studies heavily suggest that implicit learning is the mechanism driving structural priming, it is possible that other, more explicit factors might contribute to the persistence of the priming effect. Bock and Griffin (2000) reported in two experiments that structural priming can result in long lasting effects. In these experiments, participants were instructed to read *prime* sentences aloud and to indicate whether the sentences had occurred previously during the experiment. Additionally, they were presented with pictures and asked to describe them in a four second time window. Some of the pictures were *target* pictures and subsequently gave participants the opportunity to produce the primed dative. Bock and Griffin

(2000) found that participants were equally likely to produce the primed dative when presented with the picture immediately after the prime (Lag 0) as they were when presented with the picture after 10 intervening filler sentences (Lag 10). Their finding of long-lasting priming suggests that structural priming is the result of implicit learning. The current project aimed to examine whether other factors affected the persistence of structural priming across numerous filler items.

Schnur (2014) examined *semantic interference* in two different experiments. This paradigm is one in which picture naming becomes slower if the words are from the same semantic category. As an illustration, in the sequence *goat, cow, mouse,* responses to mouse are slower than they are to *goat* or *cow.* The aim of Schnur's (2014) study was see whether the accumulation of interference across trials was affected by lags (where lag is measured in the number of items that intervene between category members). If semantic interference persisted across long lags, it would not be unreasonable to posit that learning is the cause of semantic interference in naming. Schnur (2014) found that the semantic interference effect did not appear in the experiment where participants were only given longer lags between category members (e.g., lags between 8 and 50 trials). However, interference was found in an experiment where the long lags were accompanied by shorter lag trials (Lag 2). It appears that the persistence of the interference across long lags depends on having short lag trials in the experiment. This suggests the possibility that the short lag trials allow participants to notice the repetition of category items, and this awareness makes them sensitive to the repetition of category members across a longer lag.

Although Bock and Griffin (2000) posit that implicit learning is the mechanism behind long-range structural priming, it is conceivable to propose that explicit factors may contribute to

the persistence of the priming effect. Following Schnur (2014), Lag 0 items (wherein prime and target trials are presented consecutively), may alert speakers to the repetition of the double object and prepositional object datives (DO; *Kat gave Mike the pen,* PO; *Kat gave the pen to Mike)*. Therefore, upon presentation of the prime sentences (e.g., DO/PO or active/passive), speakers will learn that they will be asked to produce the primed structure at a later time (either immediately or within a few trials). If the findings by Schnur (2014) extend to structural priming, it is then appropriate to suggest that Bock and Griffin's (2000) findings regarding implicit learning's role in structural priming are not the whole story. Rather, explicit processes also contribute to persistent structural priming. If the Lag 10 priming seen in Bock and Griffin's (2000) study is driven by the presence of the Lag 0 trials, we should see that there is no Lag 10 priming in a version of the experiment where the Lag 0 trials are eliminated.

The initial design of our project involved two experiments. Experiment 1 was an attempt to replicate Bock and Griffin (2000) with a simplified design. Although Bock and Griffin (2000) primed their participants with active/passive and DO/PO alternations, we only looked at the DO/PO alternations. We did this for two reasons – 1) stronger priming was elicited with DO/PO alternations than with active/passive alternations, and 2) to shorten the duration of the experiment. Additionally, we only used Lag 0 and Lag 10 trials, whereas Bock and Griffin (2000) used Lag 0, Lag 4, and Lag 10. This was also done to shorten the duration of the experiment. Lastly, we presented our target pictures with verbs presented on them, whereas Bock and Griffin (2000) did not. This was done for two reasons – 1) to help participants produce utterances in the four second windows, and 2) to limit the production of "other" sentences. Bock and Griffin reported a relatively high percentage of "other" responses to their target items (~20% of trials). In our lab's experience, the verbs on target pictures greatly reduces the number of trials

that are eliminated. We expect to replicate the results of Bock and Griffin (2000) – structural priming will be equally strong in the Lag 0 and Lag 10 conditions.

Experiment 2 was identical to Experiment 1, except we removed the Lag 0 trials to see the persistence (or lack thereof) long term structural priming. In addition, we only used 12 of the 24 pictures per participant. If the Lag 0 trials are critical to seeing long-lasting structural priming, we expect that the removal of these trials will eliminate the Lag 10 priming in Experiment 2.

CHAPTER 2

METHODS FOR EXPERIMENT 1

Experiment 1: Replication of Bock and Griffin (2000)

Method

Sampling Plan and Participants. We used Frick's (1998) sequential sampling plan. After collecting an initial sample of 48 participants (12 in each of the 4 counterbalanced conditions), we planned to analyze the data. If the critical effects have $p<.01$ or $p>.36$, data collection will stop. After collecting an initial sample of 55 participants (we aimed for 12 in each of the 4 conditions), we found that our conditions were improperly counterbalanced. Therefore, we corrected this by collecting another round of participants, again aiming for 48 (12 in each condition) and gathered 58 participants' worth of data. Total, this resulted in 113 undergraduate participants. Because this sample size exceeded our planned maximum sample size, no further data collection was required. Participants were then only excluded if they did not perform the task correctly (e.g., did not produce sentences to describe the pictures). We eliminated 5 participants and subsequently ended up with 108.

Materials. The experiment employed the picture description materials used by Kaschak, Kutta, and Coyle (2014). These materials included 24 target pictures that elicited dative (DO or PO) productions, plus 24 control pictures that elicited intransitive constructions, 24 prime sentences to be read aloud (a DO and PO version for each prime) and 264 filler items that participants read aloud. The pictures Kaschak et al. (2014) used were the same ones used by Bock and Griffin (2000). However, as mentioned before, we chose to include a verb on each picture to constrain participants' utterances, and to avoid the high percentage of "other"

responses seen in Bock and Griffin's (2000) study. The E-Prime program used to run this experiment, along with the materials used, are available on OSF.

Procedure. Before beginning the experiment, participants were instructed to read an informed consent form that was approved by the Institutional Review Board of Florida State University. They were then given the opportunity to ask questions and to sign the consent form.

After signing the consent form, participants were randomly assigned to one of four conditions – DO Lag 0, DO Lag 10, PO Lag 0, or PO Lag 10. The experiment used a 2 (Prime type: DO vs. PO) x 2 (Lag 0, Lag 10) design. The experiment was counterbalanced so that the 24 critical prime-target pairs were presented equally often in each of the 4 cells of the design. The items in the experiment were presented in random order, with the structure of the experiment alternation between Lag 0 and Lag 10 trials. The E-Prime program used to conduct Experiment 1 is available on OSF.

Scoring and Analysis. The target completions in the experiment were scored as follows. The completions were scored as a DO if the completion was a noun phrase incorporating the direct object of the verb. The completions were scored as DO if they consisted of two noun phrases, first addressing the indirect object of the verb and the second addressing the direct object. Completions were scored as PO if they contained a noun phrase and prepositional phrase using the word "to," where the noun phrase denoted the direct object of the verb and the prepositional phrase denoted the indirect object of the verb. All other completions were scored as "other." This left a binary (PO=0, DO=1) coding of the target responses. We used a mixed models logistic regression to analyze the data. Participants and items were crossed random factors, and Prime (-1=PO Prime, 1=DO Prime), Lag (-1=0 Lag, 1=10 Lag), and the interaction of Prime x Lag were predictors. Following Barr et al. (2013), we planned to include the full

complement of random slopes in each analysis. In cases where the full model did not converge, we prioritized the inclusion of random slopes of Prime across participants and items, and only added further random slopes (e.g., the slope of Lag) if the more complex model would converge. The random effects structure of each model reported below is specified in the tables reporting the respective analyses.

CHAPTER 3

RESULTS AND DISCUSSION FOR EXPERIMENT 1

The mixed logit model predicting the log odds of producing a DO picture description is presented in Table 1, along with the raw and predicted means from the model. The two critical tests (the effect of Prime, and the Prime x Lag interaction) worked out as predicted. There was a main effect of Prime (p=0.006), with participants producing more DO picture descriptions following a DO prime than when following a PO prime. Additionally, there was no Prime x Lag interaction (p = .35), suggesting that the priming effect was of the same magnitude in the Lag 0 and Lag 10 conditions. Although this pattern replicates what was reported by Bock and Griffin (2000), it should be noted that our results are somewhat different than theirs. The effect of Prime was significant at Lag 0 (p= 0.014), replicating the original study. However, the effect of Prime was not close to significance in the Lag 10 condition (p=0.293), which is different than Bock and Griffin's (2000) finding of robust priming at Lag 10. Below, Tables 1-3 summarize the findings of Experiment 1.

Overall, our data provide mixed support for Bock and Griffin's (2000) claims. On the positive side, we observed a robust priming effect, and observed strong priming at Lag 0. On the negative side, our results suggest that priming was absent at Lag 10 (contrary to Bock and Griffin's, 2000, results). This may suggest that long-term lags are unstable or inconsistent. Although we failed to replicate the Lag 10 priming effect, we followed our preregistration and replicated Experiment 1 but without the Lag 0 condition. Doing so would allow us to see if taking away the Lag 0 trials reduced the small, non-significant hint of a priming effect in the Lag 10 condition.

Table 1: Mixed Logit Analysis of Experiment 1

Mixed Logit Model				
Predictor	**Coefficient**	**SE**	**t-value**	**p-value**
Intercept	1.599	0.266	6.012	<0.001
Prime	0.19	0.069	2.739	0.006
Lag	0.142	0.067	2.105	0.035
Prime x Lag	-0.079	0.085	-0.921	0.357

Raw and Estimated Means

	Raw Means		**Estimated Means**	
	Lag 0	**Lag 10**	**Lag 0**	**Lag 10**
DO Prime	0.79(.26)	0.79(.27)	0.85	0.86
PO Prime	0.73(.30)	0.76(.29)	0.77	0.84

Table 2: Mixed Logit Analysis of Experiment 1 - Lag 0

Mixed Logit Model				
Predictor	**Coefficient**	**SE**	**t-value**	**p-value**
Intercept	1.33	0.27	4.92	<0.001
Prime	0.256	0.104	2.467	0.014

Table 3: Mixed Logit Analysis of Experiment 1 - Lag 10

Mixed Logit Model				
Predictor	**Coefficient**	**SE**	**t-value**	**p-value**
Intercept	1.618	0.239	6.765	<0.001
Prime	0.096	0.092	1.051	0.293

CHAPTER 4

METHODS FOR EXPERIMENT 2

Experiment 2

Method

Participants. We collected data from 109 participants for Experiment 2. Our participants came from the same population as those from Experiment 1 – college undergraduates seeking course credit. We excluded participants if they 1) consistently produced the same dative – this would suggest they are not susceptible to priming and 2) if they did not complete their utterances within the four second production window. We ended up with 102 participants.

Materials. The materials were the same as Experiment 1, with the exception that participants only saw 12 of the prime sentences instead of 24. We organized this by separating the 24 target pictures into four groups of six. We subsequently ended up with four lists, which we called the A, B, C, and D blocks. Participants were randomly assigned to one of four conditions. Conditions one and three had blocks C and D. Conditions two and four had blocks B and A. We counterbalanced the dative alternations the sentences took and the Lags at which they were presented within the conditions. This ensured that all the stimuli were used at every Lag and with every prime. We did not include all 24 prime sentences as at the rate of Lag 10, the experiment would have surpassed the one hour time limit. However, across experiments, all 24 sentences were used.

Scoring. Responses were scored as in Experiment 1.

Design and Analysis. The data were analyzed in the same manner as in Experiment 1.

CHAPTER 5

RESULTS AND DISCUSSION FOR EXPERIMENT 2

Experiment 1

The mixed logit model predicting the log odds of producing a DO picture description is presented in Table 2. Participants did not show a priming effect in this experiment (p=.80). As in Experiment 1, priming was seen to be absent at Lag 10. Data for this are presented in Table 4.

Table 4: Mixed Logit Analysis of Experiment 2 with Raw and Estimated Means

Mixed Logit Model				
Predictor	**Coefficient**	**SE**	**t-value**	**p-value**
Intercept	1.456	0.354	4.111	<0.001
Prime	-0.026	0.109	-0.245	0.807

Raw and Estimated Means		
	Raw Means	**Estimated Means**
	Lag 10	**Lag 10**
DO Prime	0.77(.28)	0.81
PO Prime	0.77(.26)	0.81

CHAPTER 6

COMBINED ANALYSIS FOR EXPERIMENTS 1 AND 2

Combined Analysis

We conducted a combined analysis across the Lag 10 conditions from Experiments 1 and 2 to see if there was a Prime x Experiment interaction, indicating that the priming effect was different across experiments. This is presented in Table 5. The effect of Prime (p=0.522) was not significant, nor was the Prime x Experiment interaction (p=.456).

Table 5: Mixed Logit Combined Analysis

Mixed Logit Model				
Predictor	**Coefficient**	**SE**	**t-value**	**p-value**
Intercept	1.563	0.27	5.798	<0.001
Experiment	0.056	0.143	0.393	0.695
Prime	0.045	0.07	0.64	0.522
Prime x Experiment	0.057	0.077	0.747	0.456

CHAPTER 7

INTERIM DISCUSSION

These experiments were an attempt to test the mechanisms that lead to persistent structural priming. Bock and Griffin (2000) suggested that structural priming is persists up to 10 trials between the prime and picture targets. This finding is typically taken as support for the implicit learning account of structural priming. However, our results suggest that persistent structural priming may not be as robust as reported by Bock and Griffin (2000). Because we failed to find Lag 10 priming in Experiment 1, we were unable to find convincing evidence that removing the Lag 0 trials from the experiment would eliminate longer-range structural priming. The next step in our project is to replicate the first two experiments, but using a long lag that we are more confident will allow us to replicate the structural priming effect.

We surveyed the small literature reporting persistent structural priming effects and found that labs find priming out to Lag 4 trials and in some cases, Lag 6 trials (e.g., Hartsuiker et al., 2008; Bock et al., 2007). Therefore, we conducted Experiments 3 and 4. Experiment 3 had Lag 0 and Lag 3 trials. We expected to see long-term priming (Lag 3). We decided to run these experiments simultaneously due to time constraints. In Experiment 4, we took away the Lag 0 trials.

CHAPTER 8

METHODS FOR EXPERIMENT 3

Experiment 3

The third experiment aimed to establish structural priming at the immediate and long-term level by using a Lag that has been proven reliable (Lag 3). We choose Lag 3 after surveying the literature and finding consistent success at this "shorter" long-range delay (Ferreira et al., 2008; Hartsuiker, 2008; Bernolet et al., 2016; Bock & Griffin, 2000; Bock et al., 2007).

Method

Participants. We followed our preregistered sample plan, which can be found in OSF. In total, we collected data from 100 Florida State University undergraduates. However, we did two runs of Experiment 3. In the first run, we realized that some experimenters were giving participants examples of how to conjugate words to describe pictures. This first run yielded 56 participants. We then decided to perform a second run in which experimenters were instructed to not give examples in order to avoid accidental priming. This run totaled 44 participants. No difference was found between these participant pools, and so they were collapsed for the purposes of analyzing the data from this experiment. All students received course credit for their participation. Participants were only excluded if they did not perform the task correctly (i.e., read the sentences and conjugated the verbs).

*Materials***.** Experiment 3 used the same materials as Experiments 1 and 2.

Procedure. The procedure and instructions were the same as Experiment 1 with a minor change – instead of Lag 0 and Lag 10 trials, participants saw Lag 0 and Lag 3 trials. Additionally, the second run of Experiment 3 omitted examples of conjugation. Participants were told they would see a series of sentences on the computer screen, and that they had to read them

aloud within a four second window. After each sentence was read, the experiment automatically went to the next screen. On this screen, there was a message that asked, “Have you seen this before?” to which they had to respond using the “y” or “n” keys. This part of the experiment was to ensure the participants were paying attention to the sentences as opposed to passively participating.

The participants were also presented with pictures that had verbs on them. They were told to describe the pictures by conjugating the verb at the top of the screen. They also saw the “Have you seen this before?” message after every picture. Participants continued the experiment until the program flashed a “Goodbye” message. They then informed the experimenter and were dismissed.

Scoring. Responses were scored as they were in Experiments 1 and 2.

Design and analysis. The data were analyzed in the same manner as Experiment 1.

CHAPTER 9

RESULTS AND DISCUSSION FOR EXPERIMENT 3

The mixed logit model predicting the log odds of producing a DO target completion for this experiment, along with the raw and estimated means, is presented in Table 6. As described earlier, we collected data in two runs in an effort to correct a potentially problematic aspect of our instructions. Preliminary analyses revealed that the performance in both runs was essentially the same, and both sets of data were analyzed as a single experiment. Although participants produced more DO descriptions after receiving a DO prime, the effect of Prime was not significant in this experiment (p=0.157). The non-significant priming is likely due to the high number of DO productions observed. Our participants were close to ceiling for DO production, which attenuated the priming effect.

Like Experiment 1, the Prime x Lag interaction was not significant (p=0.356). Parallel to Experiment 1, our long-range trials (in this case, Lag 3), did not yield significance either.

Table 6: Mixed Logit Analysis of Experiment 3 with Raw and Estimated Means

Mixed Logit Model				
Predictor	**Coefficient**	**SE**	**t-value**	**p-value**
Intercept	1.949	0.3	6.504	<0.001
Prime	0.127	0.09	1.415	0.157
Lag	0.075	0.092	0.817	0.414
Prime x Lag	-0.084	0.091	-0.923	0.356
Raw and Estimated Means				
	Raw Means		**Estimated Means**	
	Lag 0	**Lag 3**	**Lag 0**	**Lag 3**
DO Prime	0.81(.27)	0.80(0.29)	0.92	0.92
PO Prime	0.78(0.30)	0.81(0.26)	0.88	0.91

CHAPTER 10

METHODS FOR EXPERIMENT 4

Experiment 4

We ran Experiments 3 and 4 concurrently in order to maximize the influx of participants in the beginning of the Fall term. Therefore, like Experiment 3, we conducted two different runs of the study - one in which the experimenters gave the subjects verbal examples, and one in which they did not. As in Experiment 3, the performance from both runs was essentially the same, and so all of those data are treated as a single experiment.

Method

Participants. 75 undergraduate psychology students participated in Experiment 4 for partial course credit. This is counting runs 1 and 2. Like the past experiments, participants were only excluded if they did not perform the task correctly (i.e., read the sentences and conjugated the verbs). After exclusions, we ended up with 72 participants.

Materials. The materials were the same as those used in Experiments 1, 2, and 3.

Procedure. The procedure of this experiment was like Experiment 2, except that the long-term lag in this study was three intervening trials instead of ten.

Scoring. Responses in this experiment were scored as they were in Experiments 1, 2, and 3.

Design and analysis. Like the experiments prior to this one, the analysis of this experiment had Prime and Lag as predictors of the log odds of producing a DO target completion.

CHAPTER 11

RESULTS AND DISCUSSION FOR EXPERIMENT 4

The mixed logit models predicted the log odds of producing a DO target completion are presented in Table 7. The effect of Prime was not significant (p=0.289). The results of this experiment align with those of Experiment 2. That is, long range priming did not occur, especially in the absence of subsequent prime-target trials.

Table 7: Mixed Logit Analysis of Experiment 4 with Raw and Estimated Means

Mixed Logit Model				
Predictor	**Coefficient**	**SE**	**t-value**	**p-value**
Intercept	2.105	0.278	7.593	<0.001
Prime	0.145	0.137	1.061	0.289
Raw and Estimated Means				
	Raw Means	**Estimated Means**		
DO Prime	0.89(.17)	0.93		
PO Prime	0.84(.21)	0.93		

CHAPTER 12

COMBINED ANALYSIS FOR EXPERIMENTS 3 AND 4

Lag 3 was not significant in either Experiment 3 or Experiment 4. However, we conducted a combined analysis across the Lag 3 conditions from Experiments 3 and 4 to see if there was a Prime x Experiment interaction, indicating that the priming effect was different across experiments. The model and results for this analysis are presented in Table 8. Like in Experiments 1 and 2, there was no effect of Prime (p=0.103).

Table 8: Mixed Logit Analysis of Lag 3 Across Experiments 3 and 4
Mixed Logit Model

Predictor	**Coefficient**	**SE**	**t-value**	**p-value**
Intercept	2.076	0.26	7.986	<0.001
Experiment	0.163	0.143	1.136	0.258
Prime	0.141	0.087	1.63	0.103
Prime x Experiment	0.023	0.081	0.277	0.782

CHAPTER 13

GENERAL DISCUSSION

We undertook this project in order to take a closer look at the factors that affect the persistence of structural priming across numerous filler items. Bock and Griffin (2000) presented two experiments demonstrating that structural priming could be long lasting. They reported that interlocutors were equally likely to demonstrate structural priming when recently presented with a given syntactic form as when given the opportunity to produce ten intervening trials later. However, Schnur (2014) suggests that short lags alert the participants to the presence of repeated categories in a task. Subsequently, they are more prone to expect an opportunity to generate the same structures on upcoming trials. With this in mind, Bock & Griffin's (2000) account would not fully explain long-term structural priming. Schnur (2014) would suggest that more explicit processes are a component behind persistent structural priming – not just the implicit processes posited by Bock and Griffin (2000).

With Experiment 1, we first aimed to replicate Bock & Griffin (2000)'s original results. We expected to find equally strong priming in Lag 0 and Lag 10 conditions – evidence that implicit learning is a strong component behind structural priming. We reported a robust effect of Prime (p=0.006), but upon closer examination, found that only the Lag 0 condition was significant (p=0.014), and that the Lag 10 trials, while trending, did not yield the expected results. In subsequent a subsequent iteration of this design (Experiment 3) we did not see reliable priming at Lag 3. Here, we sketch an alternative account for why priming may be inconsistent beyond Lag 0 in our experiments.

Upon closer examination of past reports of persistent structural priming, we noticed a trend – our study was lacking elements others utilized. It appears that other studies ask

participants to engage with the sentences in a deeper way. For instance, Ferreira et al. (2008) and Bock and Griffin (2000) reported priming out to Lag 10; however, their participants listened to a sentence, uttered it, then described a picture. Hartsuiker et al. (2008) reported priming out to Lag 6 in their Experiment 4; however, their participants "chatted" with a confederate in either a virtual chatroom form or in person. Bernolet et al. (2016), Hartsuiker et al. (2008) – in Experiment 3, Bock & Griffin (2000) – in Experiment 1, and Bock et al. (2007) all report priming out to Lag 2 or Lag 4. These studies either asked their participants to engage with the stimuli on a deeper level than we did.

In Bock et al. (2007) participants were told to describe what was happening in each picture and to repeat each sentence. They were then told to study the sentences well enough to recognize them the next day. It is reasonable to assume participants developed methods to remember the sentences verbatim in this instance – thus deeply engaging with their stimuli. Therefore, we believe that different depth of processing or attention for the prime sentences may yield different rates of priming. The extent to which a participant is instructed to engage with a prime may be predictive of how well they remember it.

Our second aim was to see whether taking away the immediate trials affected priming. Although priming was observed in Lag 0 but not in Lag 10 trials in Experiment 1, we conducted Experiment 2, (as per our pre-registration), and omitted the adjacent prime-target pairs. Like Experiment 1, we failed to find an effect of Prime in our Lag 10 trials. Likewise, in Experiment 4, we did not observe an effect of taking the Lag 0 trials away. Because Experiments 1 and 3 did not establish long term priming, we were unable to observe the effects of omitting Lag 0 trials on long-range priming.

An important note to make is that we observed priming in Experiment 1 in the Lag 0 trials, yet we did not in the Lag 0 trials of Experiment 3. This raises questions about the consistency of structural priming. One explanation may be the unusually high rate of DO productions that we collected. Generally, American English speakers will naturally produce a higher rate of DO productions (~60%, as reported by Kaschak, Kutta, and Jones, 2011). However, we observed an unusually high rate of DO productions, suggesting that our participants had a much naturally higher DO production tendency. This may have quashed the expected effects.

Our findings suggest that maybe attention to the prime sentences is more important for priming effects than is typically indicated. Perhaps there are other conditions that are important to witness these effects. As proposed earlier, maybe we must attend to or process sentences in a deep enough way to truly exhibit priming. A future direction would be to incorporate some of the elements that other studies have reported. These may help the previously reported effects resurface.

APPENDIX A

DOUBLE OBJECT PRIMES

A rock star sold an undercover agent some cocaine.

Mozart wrote his wife a song.

The ambitious father taught his 3 year old son the alphabet.

The bored teen passed the cute guy a note.

The clerk issued the new typist an office key.

The cocktail waitress served the tired executive a martini.

The corrupt inspector offered the bar owner a deal.

The credit card company mailed the student an application.

The deadbeat tenant owed the landlord 6 months' rent.

The dictator bought the terrorist a Rolls Royce.

The driver sheepishly handed the police officer his license.

The foundation is giving the university several million dollars.

The governess made the princess a pot of tea.

The graduate students baked the professor a cake.

The indulgent mother promised her daughter a puppy.

The governess made the princess a pot of tea.

The judge awarded the plaintiff a hundred thousand dollars.

The legislature is sending the governor a bill legalizing capital punishment.

The lifeguard tossed the struggling swimmer a rope.

The little girl read the old woman a short story.

The management company is renting the CIA three sites of offices.

The team owner told the columnist an offensive joke.

The toddler timidly fed the rabbit a carrot.

The waitress took the customers a tray of appetizers.

APPENDIX B

PREPOSITIONAL OBJECT PRIMES

A rock star sold some cocaine to an undercover agent.

Mozart played a song to his wife.

The ambitious father taught the alphabet to his 3 year old son.

The bored teen passed a note to the cute guy.

The cheerleader showed the seat to her boyfriend.

The clerk issued an office key to the new typist.

The cocktail waitress served a martini to the tired executive.

The corrupt inspector offered a deal to the bar owner.

The credit card company mailed an application to the student.

The deadbeat tenant owed 6 months' rent to the landlord.

The dictator gave the Rolls Royce to the terrorist.

The driver sheepishly handed his license to the police officer.

The foundation is giving several million dollars to the university.

The governess gave a pot of tea to the princess.

The graduate students gave the cake to the professor.

The indulgent mother promised a puppy to her daughter.

The judge awarded a hundred thousand dollars to the plaintiff.

The legislature is sending a bill legalizing capital punishment to the governor.

The lifeguard tossed a rope to the struggling swimmer.

The little girl read a short story to the old woman.

The management is renting three suites of offices to the CIA.

The team owner told an offensive joke to the columnist.

The toddler timidly fed a carrot to the rabbit.

The waitress took ta tray of appetizers to the customers.

APPENDIX C

IRB CONSENT FORM

Informed Consent Form

I freely and voluntarily and without element of force or coercion, consent to be a participant in the research project entitled, "Memory and Language Processing." This research is being conducted by Dr. Michael Kaschak at the Department of Psychology, Florida State University. I understand that the purpose of this research project is to understand the ways that specific kinds of experience affect the way that we subsequently process language. I understand that if I participate in this study, I will be asked to perform one of the following tasks that are checked off below:

_____ Reading or listening to short stories or sentences

_____ Completing a series of sentence stems or describing pictures

_____ Learning a made-up language

_____ Taking a memory test for materials presented in the experiment

_____ Judging the grammaticality of sentences

I understand that these tasks will require me to provide behavioral responses (e.g., button pressing, speaking, or writing sentences), and may involve the recording of the eye movements that I make while performing the task.

I understand that I must be at least 18 years of age in order to participate. The total time commitment for the study will be between 30 and 60 minutes, and I will be compensated by receiving either 1) a credit point toward my research requirement in General Psychology, or 2) extra credit points (if participating for a course other than General Psychology). I understand that my participation is completely voluntary, and I may stop participation at any time. If I decide to stop participation, I will still be entitled to the research credit or extra credit point. All data collected from me will be confidential to the extent allowed by law and will not be connected to me by name or other identifying information. In addition, my name will not appear on any of the results. No individual responses will be reported in any presentations or publications that come from this work. Only group findings will be reported. I understand that all data relevant to the study will be kept in a locked file cabinet or on a password-protected computer in the researcher's laboratory for 10 years (until September 2027).

I understand that the experiment constitutes only minimal risk to me.

I understand that there are benefits for participating in this research project. First, I may gain insight into how different kinds of experience shape the way I learn, understand, and use language. I will also be providing researchers with valuable insight into these issues.

I understand that this consent may be withdrawn at any time without prejudice, penalty, or loss of benefits to which I am otherwise entitled. I have been given the right to ask and have answered any inquiry concerning the study. Questions, if any, have been answered to my satisfaction.

I understand that I may contact Dr. Michael Kaschak, Florida State University, Department of Psychology, [redacted] for answers to questions about this research or my rights as a participant. Group results will be sent to me upon my request. If I have questions about my rights as a participant in this research, or if I feel I have been placed at risk, I can contact the Chair of

Initials: _____

APPENDIX D

IRB MEMORANDUM

Florida State
UNIVERSITY

Office of the Vice President For Research
Human Subjects Committee
P. O. Box 3062742
Tallahassee, Florida 32306-2742
(850) 644-8673 · FAX (850) 644-4392

RE-APPROVAL MEMORANDUM

Date: 02/16/2018

To: Michael Kaschak <kaschak@psy.fsu.edu>

Address: Department of Psych

Dept.: P

From: Thomas L. Jacobson, Chair

Re: Re-approval of Use of Human subjects in Research:
Language Adaptation

Your request to continue the research project listed above involving human subjects has been approved by the Human Subjects Committee. If your project has not been completed by 02/13/2019 , you are must request renewed approval by the Committee.

If you submitted a proposed consent form with your renewal request, the approved stamped consent form is attached to this re-approval notice. Only the stamped version of the consent form may be used in recruiting of research subjects. You are reminded that any change in protocol for this project must be reviewed and approved by the Committee prior to implementation of the proposed change in the protocol. A protocol change/amendment form is required to be submitted for approval by the Committee. In addition, federal regulations require that the Principal Investigator promptly report in writing, any unanticipated problems or adverse events involving risks to research subjects or others.

By copy of this memorandum, the Chairman of your department and/or your major professor are reminded of their responsibility for being informed concerning research projects involving human subjects in their department. They are advised to review the protocols as often as necessary to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

Cc:
HSC No. 2018.22920

***Author's name is not on the protocol because the protocol dates from prior to her arrival to the lab. Additionally, her contribution to the project in question was intellectual and did not involve interaction with the participants, making it unnecessary to include her on the protocol.

APPENDIX E

CONSENT FORM

Informed Consent Form

I freely and voluntarily and without element of force or coercion, consent to be a participant in the research project entitled, "Language Processing." This research is being conducted by Katherine Chia, a graduate student at the Department of Psychology, Florida State University. I understand that the purpose of this research project is to understand the ways that specific kinds of experience affect the way that we subsequently process language.

I understand that these tasks will require me to provide behavioral responses (e.g., reading and describing pictures).

I understand that I must be at least 18 years of age in order to participate. The total time commitment for the study will be between 30 and 60 minutes, and I will be compensated by receiving either 1) a credit point toward my research requirement in General Psychology, or 2) extra credit points (if participating for a course other than General Psychology). I understand that my participation is completely voluntary, and I may stop participation at any time. If I decide to stop participation, I will still be entitled to the research credit or extra credit point. All data collected from me will be confidential to the extent allowed by law and will not be connected to me by name or other identifying information. In addition, my name will not appear on any of the results. No individual responses will be reported in any presentations or publications that come from this work. Only group findings will be reported. I understand that all data relevant to the study will be kept in a locked file cabinet or on a password-protected computer in the researcher's laboratory for 10 years (until September 2028).

I understand that the experiment's risks are audio recording. If I partake in this study, I am aware that my responses to the experiments' stimuli will be stored in the lab and will only be accessible by experimenters for data analysis.

I understand that there are benefits for participating in the research project. First, I may gain insight into how different kinds of experience shape the way I learn, understand, and us language. I will also be providing researchers with valuable insight into these issues.

I understand that this consent may be withdrawn at any time without prejudice, penalty, or loss of benefits to which I am otherwise entitled. I have been given the right to ask and have answered any inquiry concerning the study. Questions, if any, have been answered to my satisfaction.

I understand that I may contact Katherine Chia, Florida State University, Department of Psychology, _____, for answers to questions about this research or my rights as a participant. Additionally, I can contact her major professor, Dr. Michael Kaschak, at _____. Group results will be sent to me upon my request. If I have questions about my rights as a participant in this research, or if I feel I have been placed at risk, I can contact the Chair of the Human Subjects Committee, Institutional Review Board, through the Office of the Vice President for Research, at (850)644-8633.

Initials: _____

APPENDIX F

IRB MEMORANDUM

Florida State
UNIVERSITY

Office of the Vice President for Research
Human Subjects Committee
Tallahassee, Florida 32306-2742
(850) 644-8673 · FAX (850) 644-4392

APPROVAL MEMORANDUM

Date: 10/24/2018

To: Katherine Chia

Address:

Dept.: PSYCHOLOGY DEPARTMENT

From: Thomas L. Jacobson, Chair

Re: Use of Human Subjects in Research
Examination of the Mechanisms Driving Long-Range Prime-to-Target Structural Priming

The application that you submitted to this office in regard to the use of human subjects in the proposal referenced above have been reviewed by the Secretary, the Chair, and two members of the Human Subjects Committee. Your project is determined to be Expedited per 45 CFR § 46.110(6) and has been approved by an expedited review process.

The Human Subjects Committee has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval does not replace any departmental or other approvals, which may be required.

If you submitted a proposed consent form with your application, the approved stamped consent form is attached to this approval notice. Only the stamped version of the consent form may be used in recruiting research subjects.

If the project has not been completed by 10/23/2019 you must request a renewal of approval for continuation of the project. As a courtesy, a renewal notice will be sent to you prior to your expiration date; however, it is your responsibility as the Principal Investigator to timely request renewal of your approval from the Committee.

You are advised that any change in protocol for this project must be reviewed and approved by the Committee prior to implementation of the proposed change in the protocol. A protocol change/amendment form is required to be submitted for approval by the Committee. In addition, federal regulations require that the Principal Investigator promptly report, in writing any unanticipated problems or adverse events involving risks to research subjects or others.

By copy of this memorandum, the chairman of your department and/or your major professor is reminded that he/she is responsible for being informed concerning research projects involving human subjects in the department, and should review protocols as often as needed to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

This institution has an Assurance on file with the Office for Human Research Protection. The Assurance Number is IRB00000446.

Cc: Michael Kaschak
HSC No. 2018.25722

REFERENCES

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of memory and language*, *68*(3), 255-278.

Bernolet, S., Colleman, T., & Hartsuiker, R. J. (2014). The "sense boost" to dative priming: Evidence for sense-specific verb-structure links. *Journal of Memory and Language*, *76*, 113-126.

Bienvenue, B., & Mauner, G. (2003, March). Exposure effects for infrequent syntactic structures alter sentence comprehension. Poster presented at the Sixteenth Annual CUNY Conference on Human Sentence Processing, Boston, MA.

Bock, J. K. (1986). Syntactic persistence in language production. *Cognitive psychology*, *18*(3), 355-387.

Bock, K., Dell, G. S., Chang, F., & Onishi, K. H. (2007). Persistent structural priming from language comprehension to language production. *Cognition*, *104*(3), 437-458.

Bock, K., & Griffin, Z. M. (2000). The persistence of structural priming: Transient activation or implicit learning?. *Journal of experimental psychology: General*, *129*(2), 177

.

Branigan, H. P., Pickering, M. J., Liversedge, S. P., Stewart, A. J., & Urbach, T. P. (1995). Syntactic priming: Investigating the mental representation of language. Journal of Psycholinguistic Research, 24, 489– 506.

Branigan, H. P., Pickering, M. J., & McLean, J. F. (2005). Priming prepositional-phrase attachment during comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *31*(3), 468-481.

Brooks, P., & Tomasello, M. (1999). How Children Constrain Their Argument Structure Constructions. Language, 75(4), 720-738. doi:10.2307/417731

Chang, F., Dell, G. S., & Bock, K. (2006). Becoming syntactic. *Psychological review*, *113*(2), 234.

Chia, K., Axelrod, C., Johnson, C., Bressler, M., Cooperman, H., Chu, A., ... & Folsom, S. (2018). Structural Repetition in Question Answering: A Replication and Extension of Levelt and Kelter (1982). *Discourse Processes*, 1-22.

Hartsuiker, R. J., Bernolet, S., Schoonbaert, S., Speybroeck, S. and Vanderelst, D. (2008). Syntactic priming persists while the lexical boost decays: Evidence from written and spoken dialogue. *Journal of Memory and Language* 58(2): 214–238.

Ferreira, V. S., Bock, K., Wilson, M. P. and Cohen, N. J. (2008). Memory for syntax despite amnesia. *Psychological Science* 19(9): 940–946.

Frick, R. W. (1998). Interpreting statistical testing: Process and propensity, not population and random sampling. Behavior Research Methods, Instruments, & Computers, 30(3), 527-535.

Kaschak, M. P., & Glenberg, A. M. (2004). This construction needs learned. *Journal of Experimental Psychology: General*, *133*(3), 450.

Kaschak, M. P., Kutta, T. J., & Coyle, J. M. (2014). Long and short term cumulative structural priming effects. *Language, cognition and neuroscience*, *29*(6), 728-743.

Kaschak, M. P., Kutta, T. J., & Jones, J. L. (2011). Structural priming as implicit learning: Cumulative priming effects and individual differences. *Psychonomic bulletin & review*, *18*(6), 1133-1139.

Kutta, T. J., Kaschak, M. P., Porcellini, A., & Jones, J. L. (2017). Implicit and explicit memory factors in cumulative structural priming. *Collabra: Psychology*, *3*(1).

Kaschak, M. P., Kutta, T. J., & Schatschneider, C. (2011). Long-term cumulative structural priming persists for (at least) one week. Memory & cognition, 39(3), 381-388.

Kutta, T. J., & Kaschak, M. P. (2012). Changes in task-extrinsic context do not affect the persistence of long-term cumulative structural priming. Acta psychologica, 141(3), 408-414.

Levelt, W. J., & Kelter, S. (1982). Surface form and memory in question answering. *Cognitive psychology*, *14*(1), 78-106.

Mahowald, K., James, A., Futrell, R., & Gibson, E. (2016). A meta-analysis of syntactic priming in language production. *Journal of Memory and Language*, *91*, 5 – 27.

Pickering, M. J., & Branigan, H. P. (1998). The representation of verbs: Evidence from syntactic priming in language production. *Journal of Memory and language*, *39*(4), 633-651.

Pickering, M. J., & Ferreira, V. S. (2008). Structural priming: A critical review. Psychological bulletin, 134(3), 427.

Rayner, K., Carlson, M., & Frazier, L. (1983). The interaction of syntax and semantics during sentence processing: Eye movements in the analysis of semantically biased sentences. *Journal of Verbal Learning and Verbal Behavior*, *22*, 358–374.

Reitter, D., Keller, F. and Moore, J. D. (2011). A computational cognitive model of syntactic priming. *Cognitive science* 35(4): 587–637.

Schnur, T. T. (2014). The persistence of cumulative semantic interference during naming. *Journal of Memory and Language*, *75*, 27-44.

BIOGRAPHICAL SKETCH

Katherine Chia is a Cognitive Psychology Ph.D. student at Florida State University. Her advisor is Dr. Michael Kaschak. Katherine's research focuses on language processes, specifically, language acquisition and language comprehension. Katherine grew up in Orlando, Florida and attended Florida State University, graduating cum laude with a Bachelor of Science (B.S.) degree in Psychology and a minor in Biology, with the distinction of Honors in the Major for her undergraduate thesis, *Massed vs Spaced Presentation in Cumulative Structural Priming.*