8-2018

Priming Sentence Comprehension in Older Adults

Emily Hosokawa
Purdue University

PRIMING SENTENCE COMPREHENSION IN OLDER ADULTS

by

Emily Hosokawa

A Thesis

Submitted to the Faculty of Purdue University

In Partial Fulfillment of the Requirements for the degree of

Master of Science

Department of Speech, Language, & Hearing Sciences

West Lafayette, Indiana

August, 2018

THE PURDUE UNIVERSITY GRADUATE SCHOOL
STATEMENT OF COMMITTEE APPROVAL

Dr. Jiyeon Lee, Chair
Department of Speech, Language, & Hearing Sciences
Dr. Laurence Leonard
Department of Speech, Language, & Hearing Sciences
Dr. David Kemmerer
Department of Speech, Language, & Hearing Sciences and Psychology

Approved by:

Dr. Keith Kluender
Head of the Graduate Program

Dedicated to the Purdue Speech-Language Pathology Class of 2018

ACKNOWLEDGMENTS

The author would like to thank Dr. Holly Branigan for the use of stimuli and her advice regarding experimental design. The author would also like to recognize Dr. Jiyeon Lee, Dr. Laurence Leonard, Dr. David Kemmerer and Grace Man for their guidance, support and advice throughout the process.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Author: Hosokawa, Emily, A. MS
Institution: Purdue University
Degree Received: August 2018
Title: Priming Sentence Comprehension in Older Adults
Major Professor: Jiyeon Lee

Syntactic priming is thought to reflect ongoing language learning processes throughout the life span. However, little is known on if and how the mechanisms of syntactic priming change in aging. This study examined whether syntactic priming influences sentence comprehension in healthy older adults and whether such effects occur independently of, or in conjunction with, lexically specific (verb) information. We further examined if older adults show persisting priming effects. Twenty older adults completed a written sentence-picture matching task involving the interpretation of prepositional phrases (*the chef is poking the solider with an umbrella*) that were ambiguous between high and low attachment in immediate (0-lag, Experiment 1) and delayed (2-lag, Experiment 2) priming. After reading a prime sentence with a particular interpretation, older adults tended to interpret an ambiguous prepositional phrase in a target sentence in the same way. The priming effect persisted over two intervening fillers. However, the priming effect was not enhanced by verb overlap between a prime and a target sentence, unlike what has been shown in young adults. These results show that implicit error-based abstract structural priming is preserved and persists in aging, whereas explicit memory-based lexically specific priming is absent in sentence comprehension by older adults

CHAPTER 1: INTRODUCTION

Language users draw on sources of linguistic and non-linguistic information to successfully produce and comprehend sentences within constraints of cognitive mechanics (Altman & Steedman, 1988; Bock, 1986; Bock & Ferreira, 2014; Frazier & Rayner, 1982; Trueswell, Tanenhaus, & Garnsey, 1994; Trueswell, Tanenhaus, & Kello, 1993). Syntactic repetition (or syntactic priming) is one source of information that facilitates sentence processing in both children and young adults (Branigan & McLean, 2016; Branigan, Pickering, & McLean, 2005; Pickering, Branigan, & McLean, 2013; see Pickering & Ferreira, 2008 for review). That is, language users adapt their future production and comprehension preferences based on previously encountered syntactic structures (primes). Syntactic priming is viewed to reflect life-long experience-based language learning or tuning processes (Chang, Dell, & Bock, 2006; Chang, Janciauskas, & Fitz, 2012). As yet, little is known about if and how the mechanisms of syntactic priming are affected by aging. This study investigates whether and how syntactic priming influences comprehension of sentences with an ambiguous prepositional phrase in healthy older adults. Specifically, we examine whether older adults show priming effects independently of, or in conjunction with, lexically specific information and if their priming effects persist over time.

Syntactic priming, or the tendency to repeat structure across otherwise unrelated sentences, is pervasive in the domain of written and spoken sentence production across various syntactic structures (Bock, 1989; Bock & Loebell, 1990; Bock & Griffin, 2000; Branigan, Pickering & Cleland, 2000; Man, Branigan, & Lee, in preparation; Pickering & Branigan, 1998; see Pickering & Ferreira, 2008 for review). For example, speakers who heard passive sentences (e.g., *the boy was bit by the dog*) under the guise of a sentence recall task are more likely to use passive sentences in subsequent generation of their own sentences, rather than active sentences (Bock, 1986; Bock & Griffin, 2000; Bock, Dell, Chang, & Onishi 2007). The priming effect was found to be greater in dialogue-based tasks compared to monologue-based tasks, presumably because the participants tend to process the primes to a greater depth in a conversational setting (Branigan et al., 2000; 2007; Branigan & McLean, 2016; Cleland & Pickering, 2003; Haywood, Pickering & Branigan, 2005). In line with the view that syntactic priming reflects life-long language learning, syntactic priming has been observed in children as young as 3-4 years old through adults with and without disorders (Bencini & Valian, 2008; Branigan & McLean, 2016; Savage, Lieven, Theakston, & Tomasello, 2006; Shimpi, Gamez, Huttenlocher & Vasilyeva, 2007 for children; Cho-Reyes, Mack, & Thompson, 2016, Hartsuiker & Kolk, 1998; Lee & Man, 2017; Saffran & Martin, 1997 for aphasia; Ferreira, Bock, Wilson, & Cohen, 2008 for amnesic patients). Additionally, priming persists over multiple intervening fillers and different sessions (Kaschak, Kutta, Schatschneider, 2011; Savage et al., 2006; Shin & Christianson, 2012).

A distinction has been made between lexically specific and independent priming. While priming occurs without any lexical overlap between the prime and target sentences (abstract priming), studies have found that priming is significantly enhanced when a lexical head such as a verb is repeated between the prime and target sentences (Branigan et al., 2000; Hartsuiker, Bernolet, Schoonbaert, Speybroeck, & Vanderelst, 2008; Pickering and Branigan, 1998; Branigan & McLean, 2016; Rowland, Chang, Ambridge, Pine & Lieven, 2012; Cleland & Pickering, 2003). This enhanced priming effect caused by lexically specific primes is called the *lexical boost.* For example, Pickering and Branigan (1998) found that young adults were more likely to produce a double object (DO) dative sentence following a DO prime compared to a prepositional dative (PD) prime in a written sentence completion task, and that this effect was much larger when the verb was repeated between the prime and target compared to when it was not repeated. They posited that when the same verb was used, there is additional activation of the lemma (verb) and its link to the syntactic combinatorial nodes (e.g. *V NP NP*), thus, leading to larger priming effects, while only the combinatorial node information was primed without verb repetition.

Importantly, however, the lexical boost tends to dissipate relatively quickly, while abstract priming persists (Bock & Griffin, 2000; Branigan & McLean, 2016; Branigan, Pickering, & Cleland, 1999; Hartsuiker et al., 2008; Levelt & Kelter, 1982). For example, Hartsuiker et al. (2008) found that young adults were more likely to use a PD or DO construction after reading a PD or DO prime, respectively, in a written dialogue task. This priming effect became significantly enlarged when the verb was repeated between the prime and the target sentence. Then, the authors varied the lag between the prime and target such that either no fillers (0-lag), two fillers, or six fillers intervened. Hartsuiker et al. (2008) found a robust lexical boost at Lag 0 in both written and spoken sentence production. However, the lexical enhancement of priming rapidly decayed such that there was no lexical boost at later lags. Importantly, the participants still showed lexically independent priming over 2- and 6-lags, suggesting that it is more long-lived than the lexical boost.

Given the difference in the time course between abstract priming and the lexical boost, different cognitive mechanisms have been suggested to underlie these two types of priming (Bock, Loebell, & Morey, 1992; Bock, Dell, Chang, & Onishi, 2007; Chang et al., 2006; 2012). Chang and colleagues, for example, in their dual-path model, proposed that abstract priming is a consequence of prediction error-based weight changes in long-term implicit memory (Chang et al., 2000; 2006, 2012; see also Fine & Jaeger, 2013). Priming (learning) happens when the model makes changes in its connection weights as a result of an error (discrepancy) between what was predicted and the actual utterance that it encounters. For example, if a DO structure was heard when the model predicted a PD structure, this prediction error caused the model to adjust connection weights in the syntactic representations, creating small but lasting bias on future syntactic choices. On the other hand, the lexical boost is attributed to short-term activation of item-specific representations in explicit memory. That is, the repeated lexical head (verb) serves as a retrieval cue for short-term explicit memory, accounting for a large but ephemeral 'boost' in the priming. Further evidence for this dissociation is that the lexical boost is absent or reduced in individuals whose ability to form, store, and retrieve explicit memories is not yet fully developed. For example, production priming studies found that children who are 3-6 years old show an absent or reduced lexical boost, compared to young adults (Peter, Chang, Pine, Blything, & Rowland, 2015; Rowland et al., 2012; see also Man, Branigan, & Lee., in preparation for similar evidence in older adults; cf. Branigan & McLean, 2016). However, these children still showed significant lexically independent priming, which relies on an implicit learning mechanism.

The empirical evidence for the dissociation between lexically specific and independent priming has been especially less clear in the comprehension literature. On one hand, studies have consistently found evidence for lexically specific priming during sentence comprehension (Arai, van Gompel & Scheepers 2007; Branigan et al., 2005; Ledoux, Traxler, & Swaab, 2007; Traxler & Tooley, 2008). However, only a subset of studies has demonstrated lexically independent priming in comprehension (Ledoux et al., 2007; Pickering et al., 2013; Thothathiri & Snedeker, 2008; Traxler, 2008). For example, Branigan et al. (2005) examined syntactic priming during comprehension of sentences with an ambiguous prepositional phrase (PP) such as *the artist is poking the clown with the gun.* The PP either modified the verb (*poke*; high attachment) or the object noun phrase (*the clown*; low attachment). The young adult participants read a sentence and were asked to select a picture that matched the sentence meaning. In the prime trial, the pictures were displayed such that only one interpretation of the PP was possible. In the target trial, participants read a new sentence with an ambiguous PP and were then free to choose from two pictures that matched either interpretation. Branigan et al. (2005) found that participants demonstrated priming by being more likely to select the syntactic interpretation that they saw on the previous priming trial. Importantly, the priming effect was significant only when the target and prime shared the verb, but not when different verbs were used between the prime and target. However, Pickering et al. (2013) repeated this paradigm with young adults using more sensitive statistical analysis and did in fact find evidence for lexically independent priming as well as a lexical boost effect. Contrary to production studies that have found that the lexical boost rapidly decays, Pickering et al. (2013) also found that the lexical boost persisted over two intervening fillers. These studies with young adults demonstrate that while lexically specific priming has consistently been found in the comprehension priming literature, lexically independent priming effects are far less consistent.

Additionally, surprisingly little is known on whether and how syntactic priming changes in healthy aging. Various aspects of cognition decline in aging. Specifically, explicit cognitive control such as working memory, inhibition, and explicit learning of new information are well documented to decline with age (Craik, & Bialystok, 2006; Daselaar, Fleck, Dobbins, Madden, & Cabeza, 2006; Mattay, Fera, Tessitore, Hariri, Berman, Das, S., Meyer-Lindenberg, Goldberg, Callicott, & Weinberger, 2006; Van Hooren, Valentijn, Bosma, Ponds, Van Boxtel, & Jolles, 2007). In contrast, implicit, subconscious, memory systems are considered to be relatively preserved through aging (Graf, 1990; Light & Singh, 1998; Mather, 2010; Monti, Gabrieli, Reminger, Rinaldi, Wilson, & Fleischman, 1996; Nyberg, Backman, Erngrund, Olofsson & Nilsson, 1996). In line with this pattern of preservation and decline of different memory systems, Fleischman, Wilson, Gabrieli, Bienias, & Bennett (2004) tracked 140 older adults over four years on a set of explicit memory vs. implicit memory tests (e.g. stem completion task). While there was a significant annual decrease in scores on explicit memory tasks, implicit memory scores remained robust and constant in older adults.

Similarly, syntactic processing has been shown to be reduced in older adults compared to younger adults (Gordon, Hendrick, & Levine, 2002; Obler, Fein, Nicholas, & Albert, 1991; Kemtes & Kemper, 1997). For example, Kemtes and Kemper (1997) compared younger and older adults' online and offline comprehension of sentences that are temporarily ambiguous between the main verb and relative clause interpretations (e.g., *Several angry workers warned about low wages decided to file complaints)* using a noncumulative, moving window reading task. The participants then answered a comprehension question related to the sentence. Additionally, the authors administered a battery of working memory tests to both groups and created composite memory scores that separated participants into high, medium and low span memory groups. The older adults did not differ from younger adults on on-line reading times, however, they were significantly less accurate on off-line follow up questions. The authors suggested that age-related working memory limitations affect only off-line tasks but not on-line activation of syntactic representations as such (see also Davidson, Zacks & Ferreira, 2003).

Some researchers have suggested that as a compensation for age-induced cognitive decline, older adults tend to rely on 'good-enough' parsing strategy during sentence comprehension, whereby individuals do not always process all available information in a sentence (e.g., lexical, syntactic, etc.). For example, Christianson, Williams, Zack and Ferreira (2006) tested both young and older adults' interpretations of garden path sentences (e.g., W*hile Anna dressed the baby played in the crib*) in a sentence reading task. They then assessed participants' interpretation of the sentence with follow up comprehension questions (e.g., *Did Anna dress herself?*). For non-garden path sentences, which require a superficial syntactic interpretation, older and younger adults did not differ in accuracy of follow up questions. However, for garden path sentences, which requires disambiguation, older adults showed a significantly lower accuracy compared to the younger adults. The authors found a marginally significant correlation between older adults' reading span measures (an indicator of working memory) and their accuracy on the follow up garden path questions. These results suggest that working memory constraints forced the older adults to rely on their "good enough" initial (incorrect) interpretation of the garden path sentence without necessarily resolving the syntactic ambiguity of the sentence, different from young adults who fully disambiguated the sentences. Given some of the differences in syntactic processing observed between older and younger adults, we may expect that comprehension priming changes with age as well.

Only a few studies specifically examined syntactic priming in sentence production of older adults. Virtually no published data exist on comprehension-to-comprehension priming in older adults. The findings to date from production studies show the priming effects become less consistent with aging. For example, Altmann and colleagues (Altmann, Kemper, Mullin, & Mathews, 2004), replicating the monologue-based production priming task used in Bock & Loebell (1990), found that older adults did not show reliable priming for datives but a small priming effect ($p = .05$) for transitive sentences. The older control participants tested in Cho-Reyes et al. (2016)'s aphasia study showed significant priming effects on dative structures, whereas those tested in Hartsuiker and Kolk (1998) failed to show significant priming effects despite reliable priming effects seen in their aphasic cohort. In contrast, Hardy, Messenger, and Maylor (2017) found that older adults showed a comparable lexical boost and lexically independent priming as young adults in a scripted dialogue priming task wherein participants heard a syntactic structure from a confederate and then immediately described their own card. However, Hardy et al. did not examine whether these priming effects persisted over intervening fillers. When Man and colleagues (Man et al., in prep) extended Hardy et al.'s study by adding dative structure and a 2-lag condition, their older adults show lexical boost for transitives, but not for datives at 0-lag. In the 2-lag condition, no lexical boost was found even in transitives and only abstract priming persisted for both structures. Together, Man et al. suggested that the lexical boost becomes reduced with aging as shown in children (Peter et al., 2015; Rowland et al., 2012), possibly attributed to reduced explicit memory in older adults, whereas the implicit abstract priming remains stable in aging.

Hence, there is evidence to hypothesize that the mechanisms of syntactic priming in older adults may be qualitatively different from those seen in young adults or children, possibly modulated by age-related changes in cognition, task differences, and target syntactic structures. Systematic investigation of syntactic priming in older adults may help to identify the conditions in which syntactic repetition is most facilitative for older adults and to refine existing theories of implicit language learning. The findings may also inform development of treatment studies using syntactic priming for older adults with acquired language disorders. For example, while the clinical implications of syntactic priming in individuals with stroke-induced aphasia are emerging (Cho-Reyes et al., 2016; Hartsuiker & Kolk, 1998; Lee & Man, 2017; Saffran & Martin, 1997; Verryt, Bogaerts, Cop, Bernolet, De Letter, Hemelsoet, Santens, & Duyck, 2013), they stand to benefit from more in-depth exploration of priming in healthy aging.

The purpose of this study was to examine effects of lexically specific and independent priming during comprehension of sentences with an ambiguous prepositional phrase in older adults. Experiment 1 examined these priming effects when there was no filler between the prime and target (0-lag). In Experiment 2, two fillers were embedded between a prime and a target (2-lag), thereby examining the persistence of the structural priming effects. The same group of healthy older adults participated in both experiments, with the order of the experiments counterbalanced. Based on a dual path model of structural priming (Chang et al., 2006) and given the documented dissociation between implicit and explicit memory in healthy aging, we predicted that older adults would demonstrate preserved abstract syntactic priming effects not only at immediate priming (Experiment 1) but also over intervening fillers (Experiment 2) due to their intact implicit memory mechanisms. However, we did not expect a larger priming effect for lexically specific priming compared to lexically independent priming, that is, no lexical boost due to decreased explicit memory mechanisms in aging.

CHAPTER 2: EXPERIMENT 1

Experiment 1 examined the effect of verb overlap on syntactic priming in comprehension when there is no intervening filler between the prime and target (0-lag). Using a written sentence to picture matching task (Pickering et al., 2013), comprehension of sentences with an ambiguous prepositional phrase (PP) was examined. A 2 (verb type: same vs. different) x 2 (prime type: high vs. low attachment) design was used with the verb type and prime type as within-subject factors.

Methods

Participants. Twenty older adults (7 males, 13 females) were recruited from the Greater Lafayette areas. An informed consent was obtained from the participants and they were compensated for their time. All participants were between ages 61-83 years old (mean age (SD) = 73.75 years (7.17)) and had received at least 12 years of education (mean years of education (SD) = 16.95 (2.95)). All participants passed a hearing screening at 40 dB at 500, 1000, and 2000 Hz in at least one ear and reported normal or corrected-to-normal vision. Only the participants who scored within normal limits for their age on the Cognitive Linguistic Quick Test (CLQT; Helm-Estabrooks, 2001) were included in the study (mean Composite Rating Score (SD) = 3.98/4.0 (.061)).

Additionally, participants completed the Corsi block-tapping test (Kessels, van Zandvoort, Postma, Kappelle, & de Haan, 2000) and picture-pointing span test (DeDe, Ricca, Knilans, & Trubl, 2014). The Corsi block tapping test is a nonverbal working memory test that requires participants to view an array of squares on a screen that light up in a specific sequence. The participants are asked to select the squares in the same order (forward span) or opposite (backward span) that they just viewed. The test begins with two squares and works up to eight squares. The test is discontinued once the participant has missed two consecutive trials. The Picture Pointing Test assesses one's verbal working memory by asking the participant to point to target pictures that match to a set of heard words in the same (forward span) or opposite (backward span) order. The test starts with two words and ends with eight words; participants move to next span of words if they point to all of the correct pictures on at least three out of five trials for a given span. Lastly, the participants completed the Shipley's Vocabulary Test (Shipley, 1940). The older participants' scores on these tests were compared with the scores from young adults from Lee et al (under review). Our older adults showed significantly lower scores on all four memory measures compared to young adults (*ts* (38) < -.2.55, *p*s <.05), in line with previous studies showing impaired working memory in older adults (Graf, 1990; Light & Singh, 1998; Mather, 2010; Monti et al, 1996; Nyberg et al., 1996). In contrast, older adults showed significantly higher scores on the Shipley's Vocabulary Test compared to young adults, consistent with the previous literature showing increased vocabulary knowledge in aging (Burke & Shafto, 2008; Kemper & Summer, 200; Verhaegan, 2003).

Table 1: Older participants' scores on memory and vocabulary tests.

	Older Adults	Young Adults*
Test (maximum score)	Mean(SD)	Mean(SD)
Picture pointing span test		
Forward span (8)	4.92(.61)	5.60(.99)
Backward span (8)	3.84(.80)	4.85(1.18)
Corsi block-tapping test		
Forward span (9)	4.50(.65)	5.70(.63)
Backward span (9)	4.80(.63)	5.82(.90)
Shipley's Vocabulary Test (40)	38.05(8.49)	31.75(2.84)

*Young adults (n=20)' scores are from Lee Lab's database.

Stimuli. Both linguistic and visual stimuli were adapted from Pickering et al. (2013). Six unique verbs (*hit, poke, prod, injure, hurt,* and *thump*) were used to create the prime and target sentences. Each verb was repeated 8 times with different sets of nouns, resulting a total of 48 sentences with a prepositional phrase (e.g., *the clown is hitting the ballerina with the umbrella*). The first 24 sentences were directly taken from Pickering et al. (2013). An additional 24 sentences were created by rearranging existing nouns from those original 24 sentences. Corresponding action-describing, black-and-white picture stimuli were prepared. The same sentence was used once as a prime and once as a target.

In addition, a total of 96 fillers were prepared. Filler sentences included a mix of 48 transitives (29 in active voice and 19 in passive voice), 29 intransitives, and 19 datives (10 prepositional dative and 9 double object structures). Each filler sentence was repeated once, resulting in a total of 192 fillers. Two fillers preceded a prime and two fillers followed a target, but they did not appear in between the prime and the target. Thus, each prime-target pair was associated with four filler items.

Two lists were created for Experiment 1. 48 experimental items (48 prime and target pairs) comprised each list. Within each list, the verb was repeated between the prime and the target for half of the prime-target pairs (same verb: e.g., *the swimmer is thumping the clown with the book - the teacher is thumping the ballerina with the umbrella*). Different verbs were used for the other 24 prime-target pairs (e.g., *the swimmer is thumping the clown with the book -The doctor is hitting the teacher with the sword*). The order of the same vs. different verb pairs was counterbalanced across the lists (e.g., same verb for items 1-24 for list 1 and different verb for items 25-48 for list 2). In addition, within the same or different verb prime-target pairs, the first 12 primes were designated as high attachment interpretation, in which the PP modifies the verb and the second 12 were low attachment where the PP modifies the object noun. Items within a list were pseudo-randomized such that no more than three same-verb or three different-verb items were presented consecutively.

Procedure. A sample experimental trial is illustrated in Figure 1. A written sentence picture matching task was used. Participants silently read a sentence with an ambiguous PP and then viewed two pictures. For a prime sentence, one picture was disambiguated for either a high attachment (HA) or low attachment (LA) interpretation and one matched neither interpretation. With this set up, a particular (HA or LA) syntactic interpretation could be forced for the prime sentence. Then, the participants read a target sentence, which was paired with two pictures that matched both interpretations. The subject was then free to choose either picture. It was considered that the participant's syntactic interpretation was 'primed' if the participant selected a target picture that had the same interpretation as the prime (e.g., HA as exemplified in Figure 1) as opposed to the picture of the alternative interpretation (e.g., LA).

Stimuli were presented on a 20-inch monitor using Experiment Builder stimuli presentation software (SR Research). Participants were instructed to silently read the sentences on the screen. The written sentence was presented on the screen for up to 7 seconds. Once they understood its meaning (or after 7 seconds), the participants pressed any key on the keyboard to advance to the next slide. Then, two pictures were presented on the screen and participants hit the '1' key to select the left side picture and the '3' key to select the right picture. No time limit was provided for the presentation of the picture stimuli. Participants were instructed to answer as quickly and accurately as possible. A fixation cross appeared on the screen for 500 milliseconds with a simultaneous pure tone (100 milliseconds) at the beginning of each experimental or filler item in order to help participants distinguish between items. Participants completed 8 practice items before the start of the experiment. In addition, the participants were offered a rest break every 72 items to avoid fatigue. The accuracy and reaction time of participants' responses were recorded using Experimental Builder. Each participant received both list 1 and 2 in two separate sessions with at least 2 weeks apart between the sessions. The order of list presentation was counterbalanced across the participants.

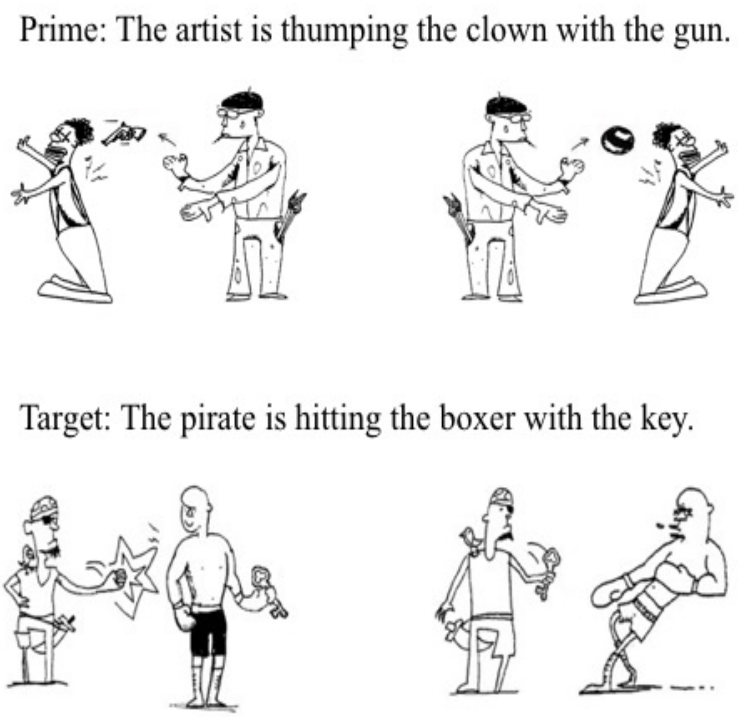


Figure 1: An example of an experimental item. The prime sentence is disambiguated for a high attachment interpretation.

Data Analysis. Each participant completed 96 target items, 24 in each of the four priming conditions: HA same verb, LA same verb, HA different verb, and LA different verb prime conditions. We removed trials where a participant chose the wrong picture for the prime sentence. In addition, we removed the trials where a participant took longer than 10 seconds or shorter than 500 milliseconds to select a picture for the prime sentence. This was done to minimize inclusion of trials where participants accidentally hit a response key (i.e., RT < 500 milliseconds) or trials in which they were distracted or used strategic choice (i.e., RT > 10 seconds). The remaining responses were then coded according to whether the participant chose the high vs. low attached picture for the target sentence. Since target response is a binary variable ("1" for HA vs. "0" for LA response), the responses were analyzed using logistic mixed effects models to compare probability of HA responses across different prime conditions (*lme 4* package; Bates, Maechler, Bolker, & Walker, 2014; Jaeger, 2008). We included prime and verb and the interaction between prime and verb as fixed factors in the model. By-participant and by-item random effects on the prime and verb were also included to account for associated variability in the data. ANOVA analyses were run to perform model comparison with $\alpha = .05$ to determine whether each fixed effect and interactions contributed to the model fit.

Results and discussion

Twenty-five trials (1.3% of the data, out of total 1920 trials) were removed because the responses were made outside of the reaction time range mentioned above or experimental errors. Participants correctly identified the prime picture on 96% (1828/1895) of the remaining trials.

The results of the logistic mixed-effects models are summarized in Table 2. The mean percentages of HA response produced under different priming conditions are presented in Figure 2. The significant priming effect significantly improved the model fit (χ^2 (1) = 5.31, p = .02), indicating that participants were more likely to make a HA response following HA primes compared to LA primes in general. However, there was no significant effect of verb (χ^2 (1) = 1.33, p = .24). Importantly, the interaction between prime and verb was not significant (χ^2 (1) = 0.72, p = .39). The priming effects were not different between when the verb was repeated (M (SE) = 56%

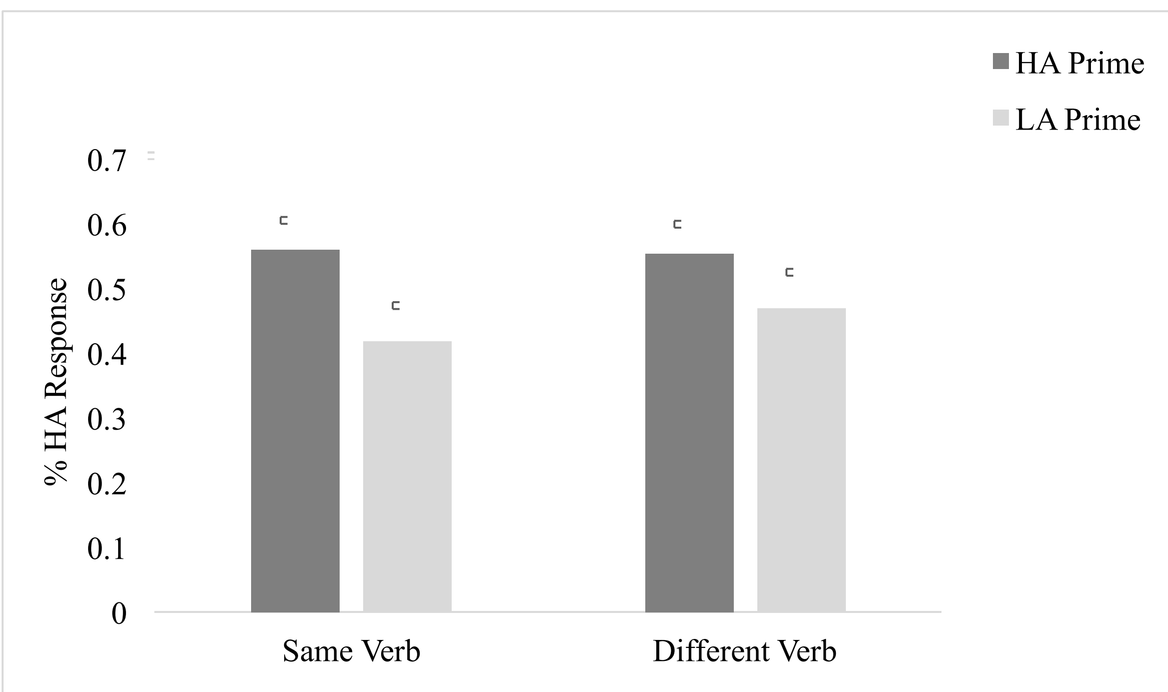
(4) vs. 42% (5)) and when different verbs were used between a prime and a target sentence (M (SE) = 55% (4) vs. 47% (5)).

Table 2: Summary of logistic mixed effects models for Experiment 1 (0-lag).

Variables	Log-odds estimate	SE	Wald's *Z*
(intercept)	.0356	.287	0.124
prime	.2094	.243	1.272*
verb	-.3980	.289	-1.373
prime x verb	.3179	.374	0.848

Note. The z-test statistics with asterisks indicate the fixed factors that significantly improved model fit after ANOVA model comparison (** *p* =.001, * *p* <.05).

Figure 2: Priming results in Experiment1 (0-lag)



In summary, Experiment 1 explored whether older adults would demonstrate immediate priming effects, and if so, would the magnitude of priming be greater for prime-target pairs that used the same verb. We found that older adults did demonstrate immediate priming effects for both same verb and different verb primes, with no difference in magnitude of priming based on verb type, thus, no lexical boost.

CHAPTER 3: EXPERIMENT 2

The purpose of experiment 2 was to examine whether older adults demonstrate persisting syntactic priming over two intervening filler items during sentence comprehension.

Methods

Participants. The same twenty older adults from Experiment 1 completed Experiment 2. The order of the experiments was counterbalanced across the participants with at least 2 weeks apart between experiments.

Stimuli. The same experimental items from Experiment 1 were used in Experiment 2. Filler and experimental stimuli were rearranged such that two fillers interceded between a prime and a target, creating a 2-lag condition. The total number of experimental and filler items remained the same between Experiment 1 and Experiment 2.

Procedure. As in Experiment 1, two lists were used over the course of two sessions administered approximately two weeks apart (see Stimuli section under Experiment 1 for a description of the lists). The same experimental procedures were followed.

Data Analysis. The same data coding and statistical analysis were performed as in Experiment 1.

Results and discussion

Out of a total of 1920 trials, 48 trials (3.4% of the data) were removed due to experimental errors or because they were associated with either too fast (< 500 milliseconds) or too long (> 10 secs) response times. Among the remaining trials, participants chose the correct pictures for the prime sentences in 95% of the time.

The results of the logistic mixed-effects models are summarized in Table 3. The mean percentages of HA response produced under different priming conditions are presented in Figure

3. The priming effect significantly improved the model fit, similar to the results from Experiment 1 (χ^2 (1) = 21.98, p < .001). However, neither the main effect of verb (χ^2 (1) = 1.18, p = .28) nor the interaction between prime and verb (χ^2 (1) = 1.92, p = .16) was significant. The participants were more likely to make HA responses following HA primes compared to LA primes whether the verb was repeated or not between a prime and target sentence (same verb: M (SE) = 60% (5) vs. 50% (6); different verb M (SE) = 60% (5) vs. 51% (5)).

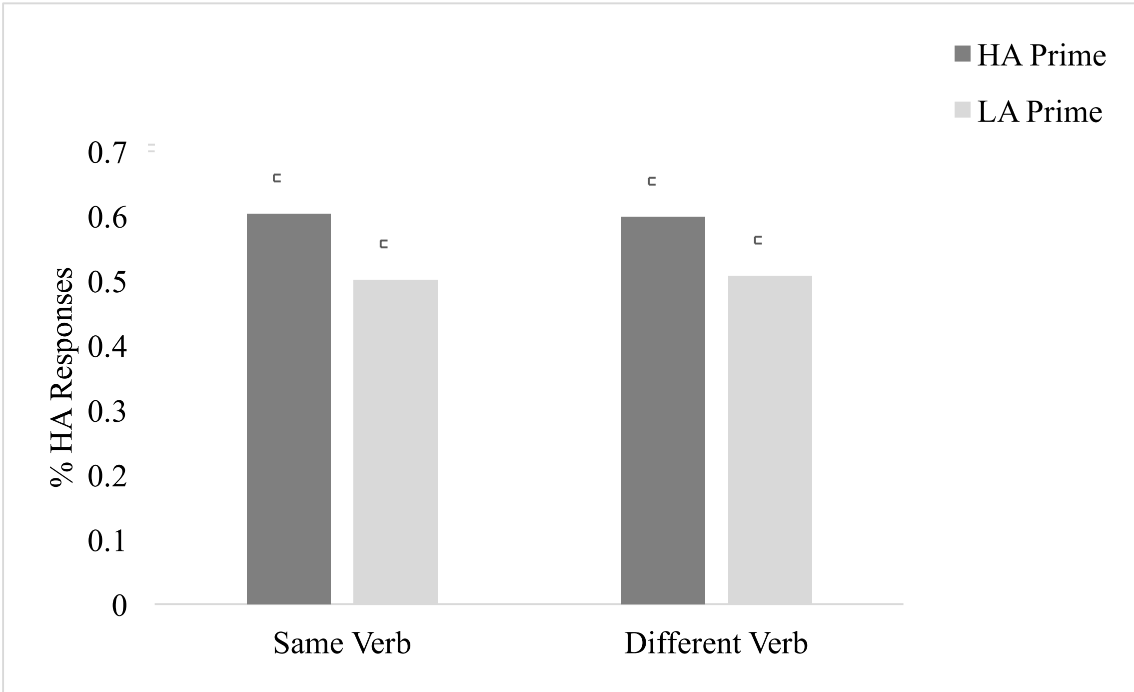
In summary, the results of Experiment 2 showed that older adults demonstrate persistent priming effects over two filler sentences. However, this priming effect did not differ significantly as an effect of verb overlap between primes and targets.

Table 3: Summary of logistic mixed effects models for Experiment 2 (2-lag).

Variables	Log-odds estimate	SE	Wald's *Z*
(intercept)	-.1036	.227	-0.456
prime	.3639	.144	2.517**
verb	-.2505	.142	-1.755
prime x verb	.2766	.199	1.389

Note. The z-test statistics with asterisks indicate the fixed factors that significantly improved model fit after ANOVA model comparison (** p =.001).

Figure 3: Priming Results from Experiment 2 (2-lag)



CHAPTER 4: GENERAL DISCUSSION

The purpose of the current study was to investigate syntactic priming in comprehension with older adults. Specifically, we examined whether and how older adults' prior experience in syntactic comprehension affects interpretation of a sentence with an ambiguous prepositional phrase and how this process is modulated by lexical information, i.e., verb overlap between prime and target sentences. In Experiment 1, the priming effects were examined when the target sentence was presented immediately after the prime (0-lag), whereas in Experiment 2, the time course of these priming effects was examined over two intervening filler utterances (2-lag). Within the theoretical framework of the dual path model of structural priming (Chang et al., 2006; 2012), we hypothesized that older adults would not demonstrate the lexical boost, due to age-related decline in explicit memory, whereas their abstract syntactic priming would be preserved due to their relatively preserved implicit memory mechanisms.

Consistent with our prediction, the older adults showed significant abstract structural priming in both experiments. They were more likely to choose a high attachment interpretation after being primed with a high attachment choice, not only when the target immediately followed the prime (Experiment 1) but also when two filler sentences intervened between prime and target sentences (Experiment 2). These results suggest that ability to extract abstract syntactic information from the prime sentence and re-use it for future comprehension of sentences remains preserved in older adults. The findings are consistent with previous research suggesting that the processing of syntactic representations as such is not affected by age-associated changes in explicit cognitive control (Davidson et al., 2003; Kemets & Kemper, 1997).

The significant abstract priming effect seen in our older adults is also in line with the previous comprehension studies in young adults and children that have found evidence for structural priming in the absence of lexical overlap (Pickering et al., 2013; Sheepers & Crocker, 2004; Thotharathi & Snedeker, 2008; Traxler, 2008). Additionally, the current results from our older adults in a sentence comprehension task also align well with very recent sentence production studies that have found preserved abstract priming in older adults at both immediate (Hardy et al., 2017; Man, et al., in prep) and longer-term priming conditions (Man et al., in prep). Putting the pieces together, it appears that abstract priming is not only emergent from an early state of language development around ages of 3-4 years (Bencini & Valian, 2008; Branigan & McLean, 2016; Savage et al., 2006; Shimpi et al. (2007); Thothathiri & Snedeker, 2008) but also it persists into the aging system. This supports the idea of abstract structural priming as a long-term language learning mechanism that potentially relies on implicit memory mechanisms, and should thus be preserved throughout the lifespan (Chang et al., 2006; 2012; Fine & Jaeger, 2013; Pickering & Ferreira, 2008).

Interestingly; however, our older adults did not show the lexical boost in either experiment. That is, older adults did not demonstrate greater priming when the verb was repeated between the prime and the target, as compared to when different verbs were used between the prime and target. These findings contrast with previous studies that have found a robust lexical boost in young adults in both comprehension and production, at least when the target immediately followed the prime (Arai et al., 2007; Branigan et al., 2005; Ledoux et al., 2007; Pickering et al., 2013; also see Pickering & Ferreira, 2008 for a review). For example, Branigan et al. (2005) found that young adults showed the lexical boost at 0-lag but not at 2-lag in their sentence comprehension experiments. In a later study, the same group of researchers (Pickering et al., 2013) found that young adults showed the lexical boost even over two intervening fillers. Notably, the current study used the same sentence stimuli and task as these two studies. Thus, the lack of lexical boost in our older participants is most likely due to age-related changes in cognition, more specifically reduced activation in explicit memory, rather than differences in experimental stimuli or tasks. If lexical boost is an effect of a short-term memory trace for the lexical item (Chang et al., 2006; 2012), we should expect to see a reduced or absent lexical boost in groups of individuals who have weaker explicit memory systems. Similarly, previous studies examining lexical boost between children of 3-6 years of age and young adults have failed to find a reliable lexical boost effect in children during production of dative sentences, whose explicit memory is not fully developed (Peter et al., 2015; Rowland et al., 2012; but see Branigan & McLean, 2016).

The absence of lexical boost seen in our older adults is partially consistent with the two recent production priming studies with older adults (Hardy et al., 2017; Man et al., in prep). Hardy et al. (2017) suggested that lexically specific priming is stable in aging, based on the significant lexical boost that older adults showed during production of passives. However, Man et al. (in prep) found that the lexical boost varies as an effect of target structure in older adults, when the effect was examined across different target sentence structures. Their older adults showed a lexical boost effect only in passives but not in double-object sentences. Hence, Man et al. (in prep) proposed that lexically specific priming is not an automatic mechanism in older adults who have reduced explicit memory, different from young adults. However, older adults could still use lexical information to compensate for increased syntactic demands associated with lower frequency structures such as passives (see also Altmann et al., 2004).

One reason for why older adults showed the lexical boost, at least for passive targets, in these production studies could be due to the interactive nature of a dialogue-based task that both studies used. In Hardy et al., (2017), the participant took turns with the experimenter describing picture cards to each other with the goal being to find matching picture cards. Increased magnitude of priming has been reported in dialogue tasks compared to monologue tasks, due to increased depth of encoding prime sentences in an interactive communicative setting (Branigan et al., 2000; 2007; Garrod & Pickering, 2004). There is a strong tendency for interlocutors to align at various levels of linguistic representations in a dialogue to facilitate information processing (Garrod & Pickering, 2004 for review). Therefore, it is possible that in the context of a dialogue paradigm that requires interaction, Hardy et al.,'s older adults have kept their syntactic system highly activated, devoting more attention to prime sentences. This might have led to greater use of the lexically specific information in the sentences than in a solitary task used in our current study.

Additionally, in our comprehension-based task, older adults might have relied on an underspecification, or 'good enough' strategy as a compensation for their cognitive limitations (Swets et al., 2008; Christianson et al., 2008). For example, Christianson et al. (2008) showed that older adults are prone to shallow comprehension of garden path sentences by relying on initial syntactic parsing rather than fully committing to re-analysis of the sentence using verb information. The increased use of this less-than-complete parsing was seen more frequently in older adults with lower working memory scores than those with higher working memory scores. Because our experimental task did not obligate older adults to use the lexical-semantic information of the verb in the prime sentences, it is possible that they were prone to use incomplete processing of the prime as a compensation for age-related limitations in explicit cognitive control (Buckner, 2004; Mather, 2010; Nyberg et al., 1996; Light & Singh, 1987). Specifically, our older adults might have relied primarily on the syntactic attachment information of the prepositional phrase of the prime (whether it is attached to the verb or the object noun) to draw a plausible meaning of the sentence and find a matching picture, rather than exhaustively encoding both structural and verb information of the prime sentence.

Given that present findings are the first evidence showing dissociation between lexical boost and abstract syntactic priming during sentence comprehension with older adults, this study leaves several open questions that warrant future investigation. One direction is to investigate how task complexity may influence the lexical boost. For example, if our comprehension paradigm obligated the participants to use both the syntactic and the lexical-semantic information in order to disambiguate the foil from the true picture, might the older adults have processed the lexical information more in depth and demonstrated the lexical boost? Another question is whether creating a more dialogue-like comprehension task in which the participant is interacting with an experimenter or confederate would increase the likelihood of finding the lexical boost in older adults. Lastly, existing theories of structural priming are not explicit on what specific cognitive construct of explicit memory truly supports the lexical boost. Identifying the relationship between various explicit memory measures such as working and short-term memory tests, and older adults' lack of reliance on lexical boost in comprehension priming was beyond the scope of the present study.

In conclusion, our study sheds light on the interaction between the mechanisms of structural priming and aging. Similar to previous production studies across different age groups and past comprehension studies with children and young adults, our older adult participants demonstrated preserved long-term, abstract priming (Ledoux et al., 2007; Pickering et al., 2013; Thothathiri & Snedeker, 2008; Traxler, 2008). This novel evidence is consistent with an account of abstract structural priming as implicit language learning, which is preserved in aging. However, there was an absence of the lexical boost in our older adults, in line with the view that any lexical boost is supported by explicit memory processes, which are known to be impaired in aging (Graf, 1990; Light & Singh, 1998; Mather, 2010; Monti et al, 1996; Nyberg, 1996). It was also suggested that older adults' greater reliance on abstract structural information rather than lexical information may serve as a compensation for their reduced cognition within the underspecification account of syntactic processing (Christianson et al., 2006; Sanford & Graesser, 2006; Swets et al., 2008)

REFERENCES

Altmann L.J.P., Kemper, S., Mathews, A., & Mullin, D. A. (2004). Syntactic priming in older adults; Poster presented at the *10th Cognitive Aging Conference*; Atlanta, GA.

Altmann, G., & Steedman, M. (1988). Interaction with context during human sentence processing. *Cognition*, *30*(3), 191-238.

Arai, M., Van Gompel, R. P., & Scheepers, C. (2007). Priming ditransitive structures in comprehension. *Cognitive psychology*, *54*(3), 218-250.

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2014). lme4: Linear mixed-effects models using Eigen and S4. *R package version*, *1*(7), 1-23.

Bencini, G. M., & Valian, V. V. (2008). Abstract sentence representations in 3-year-olds: Evidence from language production and comprehension. *Journal of Memory and Language*, *59*(1), 97-113.

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., & Ferreira, V. S. (2014). Syntactically speaking. In *The Oxford handbook of language production*.

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

Bock, K., & Loebell, H. (1990). Framing sentences. *Cognition*, *35*(1), 1-39.

Bock, K., Loebell, H., & Morey, R. (1992). From conceptual roles to structural relations: Bridging the syntactic cleft. *Psychological review*, *99*(1), 150-171.

Branigan, H. P., & McLean, J. F. (2016). What children learn from adults' utterances: An ephemeral lexical boost and persistent syntactic priming in adult–child dialogue. *Journal of Memory and Language*, *91*, 141-157.

Branigan, H. P., Pickering, M. J., & Cleland, A. A. (2000). Syntactic co-ordination in dialogue. *Cognition*, *75*(2), B13-B25.

Branigan, H. P., Pickering, M. J., & Cleland, A. A. (1999). Syntactic priming in written production: Evidence for rapid decay. *Psychonomic Bulletin & Review*, *6*(4), 635-640.

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.

Branigan, H. P., Pickering, M. J., McLean, J. F., & Cleland, A. A. (2007). Syntactic alignment and participant role in dialogue. *Cognition*, *104*(2), 163-197.

Buckner, R. L. (2004). Memory and executive function in aging and AD: multiple factors that cause decline and reserve factors that compensate. *Neuron*, *44*(1), 195-208.

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

Chang, F., Dell, G. S., Bock, K., & Griffin, Z. M. (2000). Structural priming as implicit learning: A comparison of models of sentence production. *Journal of psycholinguistic research*, *29*(2), 217-230.

Christianson, K., Williams, C. C., Zacks, R. T., & Ferreira, F. (2006). Younger and older adults'" good-enough" interpretations of garden-path sentences. *Discourse Processes*, *42*(2), 205-238.

Cleland, A. A., & Pickering, M. J. (2003). The use of lexical and syntactic information in language production: Evidence from the priming of noun-phrase structure. *Journal of Memory and Language*, *49*(2), 214-230.

Cho-Reyes, S., Mack, J. E., & Thompson, C. K. (2016). Grammatical encoding and learning in agrammatic aphasia: Evidence from structural priming. *Journal of Memory and Language*.

Craik, F. I., & Bialystok, E. (2006). Cognition through the lifespan: mechanisms of change. *Trends in cognitive sciences*, *10*(3), 131-138.

Daselaar, S. M., Fleck, M. S., Dobbins, I. G., Madden, D. J., & Cabeza, R. (2006). Effects of healthy aging on hippocampal and rhinal memory functions: an event-related fMRI study. *Cerebral cortex*, *16*(12), 1771-1782.

Davidson, D. J., Zacks, R. T., & Ferreira, F. (2003). Age preservation of the syntactic processor in production. *Journal of Psycholinguistic Research*, *32*(5), 541-566.

DeDe, G., Ricca, M., Knilans, J., & Trubl, B. (2014). Construct validity and reliability of working memory tasks for people with aphasia. *Aphasiology*, *28*(6), 692-712.

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

Fine, A. B., & Florian Jaeger, T. (2013). Evidence for implicit learning in syntactic comprehension. *Cognitive Science*, *37*(3), 578-591.

Fleischman, D. A., Wilson, R. S., Gabrieli, J. D., Bienias, J. L., & Bennett, D. A. (2004). A longitudinal study of implicit and explicit memory in old persons. *Psychology and aging*, *19*(4), 617-625.

Frazier, L., & Rayner, K. (1982). Making and correcting errors during sentence comprehension: Eye movements in the analysis of structurally ambiguous sentences. *Cognitive psychology*, *14*(2), 178-210.

Garrod, S., & Pickering, M. J. (2004). Why is conversation so easy?. *Trends in cognitive sciences*, *8*(1), 8-11.

Gordon, P. C., Hendrick, R., & Levine, W. H. (2002). Memory-load interference in syntactic processing. *Psychological science*, *13*(5), 425-430.

Graf, P. (1990). Life-span changes in implicit and explicit memory. *Bulletin of the Psychonomic Society*, *28*(4), 353-358.

Hardy, S. M., Messenger, K., & Maylor, E. A. (2017). Aging and syntactic representations: Evidence of preserved syntactic priming and lexical boost. *Psychology and aging*, *32*(6), 588-597.

Hartsuiker, R. J., Bernolet, S., Schoonbaert, S., Speybroeck, S., & 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.

Hartsuiker, R. J., & Kolk, H. H. (1998). Syntactic facilitation in agrammatic sentence production. *Brain and language*, *62*(2), 221-254.

Haywood, S. L., Pickering, M. J., & Branigan, H. P. (2005). Do speakers avoid ambiguities during dialogue?. *Psychological Science*, *16*(5), 362-366.

Helm-Estabrooks, N. (2001). *Cognitive Linguistic Quick Test: Examiner's Manual*. Psychological Corporation.

Jaeger, T. F. (2008). Categorical data analysis: Away from ANOVAs (transformation or not) and towards logit mixed models. *Journal of memory and language*, *59*(4), 434-446.

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.

Kessels, R. P., Van Zandvoort, M. J., Postma, A., Kappelle, L. J., & De Haan, E. H. (2000). The Corsi block-tapping task: standardization and normative data. *Applied neuropsychology*, *7*(4), 252-258.

Light, L. L., & Singh, A. (1987). Implicit and explicit memory in young and older adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *13*(4), 531-541.

Lee, J., & Man, G. (2017). Language recovery in aphasia following implicit structural priming training: a case study. *Aphasiology*, *31*(12), 1441-1458.

Ledoux, K., Traxler, M. J., & Swaab, T. Y. (2007). Syntactic priming in comprehension: Evidence from event-related potentials. *Psychological science*, *18*(2), 135-143.

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

Man, G., Branigan, H., Lee, J., (in preparation). Priming sentence production in older adults: evidence for preserved abstract priming and variable lexical boost.

Mather, M. (2010). Aging and cognition. *Wiley Interdisciplinary Reviews: Cognitive Science*, *1*(3), 346-362.

Mattay, V. S., Fera, F., Tessitore, A., Hariri, A. R., Berman, K. F., Das, S., ... & Weinberger, D. R. (2006). Neurophysiological correlates of age-related changes in working memory capacity. *Neuroscience letters*, *392*(1-2), 32-37.

Monti, L. A., Gabrieli, J. D., Reminger, S. L., Rinaldi, J. A., Wilson, R. S., & Fleischman, D. A. (1996). Differential effects of aging and Alzheimer's disease on conceptual implicit and explicit memory. *Neuropsychology*, *10*(1), 101-113.

Nyberg, L., Bäckman, L., Erngrund, K., Olofsson, U., & Nilsson, L. G. (1996). Age differences in episodic memory, semantic memory, and priming: Relationships to demographic, intellectual, and biological factors. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *51*(4), P234-P240.

Obler, L. K., Fein, D., Nicholas, M., & Albert, M. L. (1991). Auditory comprehension and aging: Decline in syntactic processing. *Applied psycholinguistics*, *12*(4), 433-452.

Peter, M., Chang, F., Pine, J. M., Blything, R., & Rowland, C. F. (2015). When and how do children develop knowledge of verb argument structure? Evidence from verb bias effects in a structural priming task. *Journal of Memory and Language*, *81*, 1-15.

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), 427–459. http://doi.org/10.1037/0033-2909.134.3.427

Pickering, M. J., McLean, J. F., & Branigan, H. P. (2013). Persistent structural priming and frequency effects during comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *39*(3), 890-897.

Rowland, C. F., Chang, F., Ambridge, B., Pine, J. M., & Lieven, E. V. (2012). The development of abstract syntax: Evidence from structural priming and the lexical boost. *Cognition*, *125*(1), 49-63.

Saffran, E. M., & Martin, N. (1997). Effects of structural priming on sentence production in aphasics. *Language and Cognitive Processes*, *12*(5-6), 877-882.

Sanford, A. J., & Graesser, A. C. (2006). Shallow processing and underspecification. *Discourse Processes*, *42*(2), 99-108.

Savage, C., Lieven, E., Theakston, A., & Tomasello, M. (2006). Structural priming as implicit learning in language acquisition: The persistence of lexical and structural priming in 4-year-olds. *Language Learning and Development*, *2*(1), 27-49.

Scheepers, C., & Crocker, M. W. (2004). Constituent order priming from reading to listening: A visual-world study. *The on-line study of sentence comprehension: Eyetracking, ERP, and beyond*, 167-185

Shimpi, P. M., Gámez, P. B., Huttenlocher, J., & Vasilyeva, M. (2007). Syntactic priming in 3- and 4-year-old children: Evidence for abstract representations of transitive and dative forms. *Developmental psychology*, *43*(6), 1334-1345.

Shin, J. A., & Christianson, K. (2012). Structural priming and second language learning. *Language Learning*, *62*(3), 931-964.

Shipley, W. C. (1940). A self-administering scale for measuring intellectual impairment and deterioration. *The Journal of Psychology*, *9*(2), 371-377.

Swets, B., Desmet, T., Clifton, C., & Ferreira, F. (2008). Underspecification of syntactic ambiguities: Evidence from self-paced reading. *Memory & Cognition*, *36*(1), 201-216.

Thothathiri, M., & Snedeker, J. (2008). Syntactic priming during language comprehension in three-and four-year-old children. *Journal of Memory and Language*, *58*(2), 188-213.

Traxler, M. J. (2008). Lexically independent priming in online sentence comprehension. *Psychonomic Bulletin & Review*, *15*(1), 149-155.

Traxler, M. J., Pickering, M. J., & Clifton Jr, C. (1998). Adjunct attachment is not a form of lexical ambiguity resolution. *Journal of Memory and Language*, *39*(4), 558-592.

Traxler, M. J., & Tooley, K. M. (2008). Priming in sentence comprehension: Strategic or syntactic?. *Language and Cognitive Processes*, *23*(5), 609-645.

Trueswell, J. C., Tanenhaus, M. K., & Garnsey, S. M. (1994). Semantic influences on parsing: Use of thematic role information in syntactic ambiguity resolution. *Journal of memory and language*, *33*(3), 285.

Trueswell, J. C., Tanenhaus, M. K., & Kello, C. (1993). Verb-specific constraints in sentence processing: Separating effects of lexical preference from garden-paths. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *19*(3), 528-553.

Van Hooren, S. A. H., Valentijn, A. M., Bosma, H., Ponds, R. W. H. M., Van Boxtel, M. P. J., & Jolles, J. (2007). Cognitive functioning in healthy older adults aged 64–81: a cohort study into the effects of age, sex, and education. *Aging, Neuropsychology, and Cognition*, *14*(1), 40-54.

Verhaeghen, P. (2003). Aging and vocabulary score: A meta-analysis. *Psychology and aging*, *18*(2), 332-339.

Verreyt, N., Bogaerts, L., Cop, U., Bernolet, S., De Letter, M., Hemelsoet, D., & Duyck, W. (2013). Syntactic priming in bilingual patients with parallel and differential aphasia. *Aphasiology*, *27*(7), 867-887.