STRUCTURAL PRIMING IN APHASIA USING A BLOCKED STIMULUS DESIGN

by

Ellis Farr

A Thesis

Submitted to the Faculty of Purdue University

In Partial Fulfillment of the Requirements for the degree of

Master of Science

Department of Health and Human Sciences

West Lafayette, Indiana

August 2020

THE PURDUE UNIVERSITY GRADUATE SCHOOL
STATEMENT OF COMMITTEE APPROVAL

Dr. Jiyeon Lee, Chair
Department of Health and Human Sciences

Dr. Laurence B. Leonard
Department of Health and Human Sciences

Dr. David Kemmerer
Department of Health and Human Sciences

Approved by:
Dr. Jiyeon Lee

Dedicated to my father who has helped me in all things great and small.

ACKNOWLEDGMENTS

My immeasurable gratitude is extended to all individuals who contributed in one way or another to make this study possible.

Dr. Jiyeon Lee, supervisor of this study, for her support, encouragement, and time dedicated to this project.

The members of the committee, **Dr. Laurence B. Leonard** and **Dr. David Kemmerer**, for sharing their expertise in their own field as seen in their way of correction and ideas shared.

The sincerest thanks go to all participants in this study for giving their time and efforts towards the field of research and educational advancements.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Purpose. Sentence production is impaired in many persons with aphasia (PWA). Structural priming, a speaker's tendency to re-use a previously heard sentence structure, has been shown to facilitate sentence production in PWA. Man et al. (2019), however, found that PWA showed significant priming only in transitive sentences but not in dative sentences when these two different types of sentences were presented in an alternating manner within a session [Man, G., Meehan, S., Martin, N., Branigan, H., Lee, J. (2019). Effects of Verb Overlap on Structural Priming in Dialogue: Implications for Syntactic Learning in Aphasia. *Journal of Speech, Language, and Hearing Research, 62*, 1933-1950]. This study sought to examine whether presenting transitive vs. dative stimuli in a blocked format would yield more consistent priming effects in PWA.

Methods. Twelve PWA and twelve healthy older adults (HOA) completed a dialogue-like priming task, where participants took turns describing pictures with the experimenter. Importantly, each participant received two blocks of transitive and dative priming. In addition, we repeated verbs between prime and target items for half of each block to test if lexical overlap boosts priming, i.e., lexical boost. We measured how often the participant re-used the same syntactic structure they heard the experimenter produce previously when they described their own picture.

Results. HOA showed significant priming and lexical boost in the transitive block and significant priming in the dative block, replicating Man et al. (2019). PWA, showed near significant priming in the transitive block. Importantly, the priming effect became significant when the verb was repeated between prime and target, indicating lexical boost. However, PWA failed to show priming in the dative block.

Discussion. Using a blocked stimulus design only modulated lexically-mediated priming in transitives for PWA, different from Man et al. (2019). Findings suggest that while it is feasible to use structural priming to ameliorate sentence production deficits in PWA, the presentation of target stimuli would likely not influence outcomes.

INTRODUCTION

Structural Priming. Structural priming, the tendency to repeat structures that an individual has already used or observed before, is extremely prevalent in language learning and processing in healthy individuals (Chang, Dell, & Bock, 2006; Ferreira & Bock, 2006; Mahowald, James, Futrell, & Gibson, 2016; Pickering & Ferreira, 2008). Recently there has been attention directed towards using structural priming as a means to facilitate sentence production in people with aphasia (PWA). However, little research has been conducted to systematically assess what mechanisms of structural priming are preserved and what experimental factors modulate strength of priming in PWA. Without this knowledge established, effective use of structural priming for syntactic rehabilitation with PWA is limited. This study aims to address the gap in literature by assessing if using a blocked presentation of syntactic structures with and without verb overlap in a comprehension-to-production dialogue task will lead to significant structural priming in PWA.

It has been well-established that structural priming occurs at multiple linguistic representations. For example, the ability for an individual to be primed for specific syntactic structures does not have to depend on thematic role similarities, prosodic patterns, or conceptual repetition. This suggests that priming can occur when structural frames are the only overlapping similarities. In other words, the order of constituents is determined regardless of lexical information (i.e. *abstract priming*; Bock, 1989; Bock & Loebell, 1990). For example, a prepositional-object dative (PO) is more likely to be produced after a prepositional-object dative, as opposed to a double-object dative (DO), regardless of what preposition is present in the initial prime. In other words, an individual would be more likely to produce the sentence "The woman brought a cake to her boss" after hearing the sentence "The woman baked a cake for her boss" and not "The woman baked her boss a cake". This shows that phrasal combinatorial nodes are sufficient to influence future productions of a speaker, regardless of lexical similarities between the prime and the target sentence (Bock & Loebell, 1990). However, later studies indicate that although the occurrence of structural priming does not depend on lexical information, lexical similarities do increase the degree of structural priming (Hartsuiker, Bernolet, Schoonbaert, Speybroeck, & Vanderelst, 2008; Pickering & Branigan, 1998; Scheepers, Raffray, & Myachykov, 2017). This phenomenon is known as *lexical boost*.

Researchers suggest that structural priming is a mechanism that aids in language learning. Several theories have been proposed on the relationship between structural priming and learning (Bock et al., 2007; Chang, Dell, & Bock, 2006; Chang, Janciauskas, & Fitz, 2012; Fine & Jaeger, 2013; Reitter, Keller, & Moore; 2011). The dual-path model proposed by Chang et al. (2006; 2012) argues that structural priming is a result of error-based implicit learning, where an expected structure is deemed as "correct" and an unexpected structure is deemed as "incorrect". In this model each word in an utterance is processed in a strictly incremental order. Before a prime is presented, the structure of the expected response is based on previous experiences. Once the prime is presented, and it does not match the expected structure, the speaker's expectations are shifted to match the prime and thus increases the likelihood of a correct response in the future. This adjustment of the speaker's expectations based on the experience with a structure is stored in implicit long-term memory. Moreover, this model explains that the greater the error, or lower frequency that a structure occurs, the greater the priming effect, as it leads to a greater shift in expectations. This, in turn, leads to a greater level of learning. However, according to the dual-path model, lexical boost is processed in the short-term memory, and thus only lives long enough to influence the next exposure to a structure. In other words, when a target sentence is being planned, overlapping lexical information (e.g., verb) acts as a cue to the memory of a prime and creates a bias for the speaker to repeat a structure. Jaeger and Snider (2013) build upon this model, suggesting that the degree of adaptation after a prime is dependent on a prediction error made by listener when processing the prime, thus the goal of abstract priming is to minimize the number of prediction errors.

Reitter and colleagues (2011) have come up with another theory for the link between learning and structural priming. They claim that both mechanisms of priming instead are tied to declarative memory. In their computational cognitive model, the language processor is faced with the task of deciding the formulation of an utterance (i.e. active vs. passive). In the model, a retrieved structural representation spreads activation to surrounding, related representations. This activation somewhat decays with time, but repeated retrieval of a specific structure changes the overall pattern of activations, which results in lasting effects over time. In other words, lexical and non-lexical structures can be primed through a single related grammatical category. Lexical boost, however, depends strictly on spreading activation from lexical items to related syntax, thus influencing only subsequent use of an item. Although Chang and Reitter's models have

discrepancies in the cognitive processes that influence structural priming, both agree that abstract structural priming operates separately from lexical similarities, though shared lexical information does influence the degree of structural priming in a normal system.

Syntactic Deficits in PWA. The inability to map meaning onto syntactic representation is prevalent in PWA (Saffran et al., 1989). Complex grammatical structures requiring individuals to think critically about event relationships within a sentence (e.g. who is doing what to whom) prove to be especially challenging to comprehend and produce in both fluent and non-fluent aphasia (Caramazza & Berndt, 1985; Caramazza & Miceli, 1991; Lee & Thompson, 2011a; 2011b; Lee, Yoshida, & Thompson, 2015; Maher, Chatterjee, Rothi, & Heilman 1995; Miceli, Silveri, Romani, Caramazza, 1989; Saffran, Schwartz, & Marin, 1980a; Thompson, Faroqi-Shah, & Lee, 2015). Example sentences include semantically reversible sentences, sentences with non-canonical word order (e.g. passive vs. active) and sentences with complex argument structures (e.g. datives vs. transitives) (Bastiaanse & Zonneveld, 2005; Cho-Reyes & Thompson, 2012; Howard, 2001, 2004, & 2007; McAllister, Bachrach, Waters, Michaud, & Caplan, 2009; Saffran, Schwartz, & Marin, 1980a; Saffran, Schwartz, & Marin, 1980b; Thompson, 2003; Thompson, Lange, Schneider, & Shapiro, 1997; Webster, Franklin, Lee & Thompson, 2004). Although the precise cause remains unclear, a possible explanation for the deficits in PWA is that the syntactic representations for these sentences are preserved but accessing them is what proves to be challenging (Bastiaanse & Van Zonneveld, 2004; Bock & Levelt, 1994; Lee & Thompson, 2004).

Finding ways to amend these mapping deficits in PWA has been an important subject in experimental and intervention studies. For example, the Mapping Therapy and the Treatment of Underlying Forms (TUF) are both built around the idea of teaching PWA to use syntactic rules to rebuild the mapping between underlying semantic representations (agent vs. theme) and surface level syntactic representations (subject vs. objects) (Rochon, Laird, Bose, & Scofield, 2005; Schwartz, Saffran, Fink, Meyers, & Martin, 1994; Thompson & Shapiro, 2005; Thompson, Shapiro, Kiran, & Sobecks, 2003).

Structural Priming in PWA. Recent studies have found that structural priming has a potential to aid PWA in re-mapping semantic representations onto syntactic representations. For example, studies by Hartsuiker & Kolk (1998) and Saffran & Martin (1997) found that PWA were more likely to produce more syntactically complex, non-canonical sentences that are often absent from their speech after being exposed to prime sentences. Thus, PWA demonstrate improved

production in relatively complex syntactic structures following structural priming. However, the types of sentences that PWA could be primed for varied across the two studies. Hartsuiker & Kolk (1998) found priming effects in PWA with agrammatic aphasia for both datives and transitives, whereas Saffran & Martin (1997) found priming effects only for transitives and not datives in mixed aphasia types.

More recently, studies have found 'longer-term' priming effects in PWA. A study by Cho-Reyes and colleagues (2016) found that agrammatic PWA showed priming effects that endured over a set of four intervening trials for dative sentences. Moreover, in a case study by Lee & Man (2017) found that an individual with agrammatic aphasia showed priming effects for prepositional-object datives that were maintained at four weeks post training. These lasting effects suggest that abstract priming may be a result of learning and not simply repetition.

Although the results of previous studies are promising, they do not provide concrete knowledge that allows structural priming to be guaranteed as a rehabilitation technique for syntactic comprehension and production in PWA. For example, we are not certain that a comprehension-to-dialogue task leads to significant structural priming in PWA. Recent studies (Cho-Reyes et. al. 2016; Hartsuiker & Kolk, 1998; Lee & Man, 2017; Saffran & Martin, 1997; Yan et. al, 2018) used single speaker production tasks to assess structural priming in PWA. A study by Lee, Man, Ferreira, and Gruberg (2019) found that PWA exhibited a priming effect in a comprehension-to-dialogue task if they orally repeated the prime sentences they heard and not if they only listened to the primed sentences. These results follow the trend that production increases the level of syntactic priming. Additionally, we are unsure whether a lexical boost is present in PWA. In a study by Lee, Hosokawa, Meehan, Nadine, and Branigan (2019) both PWA and healthy older adults (HOA) did not exhibit an increased degree of structural priming after being presented with sentences with similar lexical content in a comprehension task, however both groups did show evidence of abstract structural priming. A single study (Yan et. al., 2018) exists that shows lexical boost in PWA during a sentence production task, however this study only observed transitive sentences, and they used a single-speaker production task with repeated exposure to prime sentences. These conflicting studies demonstrate that further research is required to determine if abstract priming for both datives and transitives is preserved in PWA, as well as if lexical boost is present in PWA.

In the most recent study by Man et al. (2019), they utilized a collaborative picture-matching task (modified from a study in 2016 by Branigan and McLean), where the experimenter and participant took turns describing pictures to assess if structural priming is present in aphasia. The results of this study indicated that PWA showed successful priming for only transitives in a dialogue-like task simply by listening to their conversational partner's productions of primes. However, these results are at odds with previous findings, as other studies did find abstract priming for datives (Yan et. al 2018; Lee et. al., 2019), while Man et. al. did not. One possibility for these conflicting findings may be due to experimental design. In Man et. al.'s study, the two target structures were mixed amongst each other during stimuli presentation. It is likely that prediction error-based learning mechanisms and/or pragmatic saliency explain why this presentation format would cause a lack of priming effect in datives. For example, passives have a greater level of prediction error, as they occur much less frequently in the English language, when compared to actives; whereas DO and PO datives occur almost equally, so there is a smaller level of prediction error, and thus less learning. In terms of pragmatic saliency, the difference between actives and passives is relatively great, as the subject of the sentence changes based on the structure. This leads to a large shift in attention between the two sentence types. The difference between DO and PO sentences is much smaller, as only the direct object and indirect object switch locations. The large levels of error-based learning and pragmatic saliency in transitives may overtake the smaller levels found in datives. In fact, there is some evidence that PWA showed successful priming for datives when they were the only structure presented in the experiment (Cho-Reyes et al., 2016; Lee & Man, 2017).

Additionally, Man et. al. did not observe reliable lexical boost in PWA. This is at odds with Yan et al. (2018) that did find lexical boost in PWA. It is still to be determined if this is due to deficits in spreading activation of lexical information or difficulties holding information in the short-term memory in PWA. Another possibility may be that the complex nature of the task is to blame. For example, as stated earlier, non-canonical, complex sentence production and comprehension prove to be exceptionally challenging for PWA, and thus require great attention to the task at hand. This may lead to less cognitive capacity available to assess lexical similarities in PWA. However, the exact cause of this lack of lexical boost is still to be determined and therefore requires additional research beyond the scope of this study to fully assess.

The purpose of this study is to investigate the effect of a blocked stimulus design on structural priming of transitive and dative targets in PWA in a dialogue-like comprehension-to-production task. Specifically, we ask if ordering stimulus in a blocked presentation will increase the likelihood of priming for both sentence structures (datives and transitives). We will use the same stimuli in Man et al.'s study to assess this, but we will instead group all transitive targets together (i.e., passives[1] and actives) and all dative targets together (i.e., DO and PO). It is predicted that PWA will show priming for both datives and transitives when the stimuli are presented in blocked formatting. If PWA show structural priming for both sentence types, then our sub-question is to examine if PWA show lexical boost, similar to that seen in Yan et al. (2018). Thus, it is predicted that if lexically specific immediate priming is preserved in PWA, then the likelihood of priming will increase when a prime sentence and target sentence share the same verb. Determining the effects of stimuli order could have clinical implication for complex sentence production rehabilitation in PWA. If it is found that blocking stimuli leads to abstract priming in PWA, clinicians should consider blocking structures during syntactic training to be more effective during therapy and maximize outcomes.

[1] Although passive sentences do not have the 'transitive' argument structure due to the lack of the direct object, we use the term 'transitive' to include passive structures to follow the current literature on structural priming.

METHODS

Participants. The experiment consisted of 12 PWA (7 females, 5 males, age 39-84 years, years of education: 12-18 years) and 12 HOA (9 females, 3 males, age 64-81 years, years of education: 12-20 years). All participants were monolingual, native English speakers with no reported history of neurological or psychological disorders prior to stroke that would affect their communication. All participants reported normal or corrected-to-normal vision and passed a hearing screening at 500Hz, 1000HZ, and 2000Hz at 40 dB in at least one ear. HOA participants had their cognitive-linguistic abilities screened using the Cognitive Linguistic Quick Test (CLQT; Helm-Estabrooks, 2001). All HOA scored within normal limits for their age range, as indicated by Clinical Severity Rating (range: 3.8-4.0/4.0). This suggests that there were no significant age-related deficits in their attention, memory, executive functioning, language, and visuospatial skills. Participants were compensated for their time and provided with informed consent prior to the study. All HOA and PWA were tested at Purdue University and its satellite location in Indianapolis.

All PWA had a diagnosis of aphasia following a left CVA at least 6 months prior to participation in the study. A battery of cognitive-linguistic tests was administered to PWA, as seen in Table 1.

Table 1. Language testing results for PWA.

PWA	WAB-R			NAVS						
	AQ (100)	Fluency (10)	AC (10)	VNT (100)	VCT (100)	ASPT (100)	SPPT_C (100)	SPPT_NC (100)	SCT_C (100)	SCT_NC (100)
A1	69.6	5	8.7	73	100	100	13	0	93	27
A2	77	6	8.8	50	100	94	80	7	80	60
A3	70.3	8	5.25	80	100	69	13	0	60	33
A4	93.1	9	9.85	95	100	100	100	100	100	100
A5	85	8	9.3	95	100	100	93	80	80	73
A6	87.7	8	9.55	83	100	94	100	68	93	87
A7	96.2	9	10	100	100	100	100	100	100	80
A8	75.2	6	8.5	82	95	69	33	20	60	53
A9	96.2	10	10	100	100	100	100	100	100	100
A10	94.4	9	9.2	100	100	100	100	93	100	100
A11	73	4	8.5	16	90	56	53	60	86	80
A12	84.6	6	9.1	100	100	97	93	80	100	93
Mean	83.6	7.3	8.9	81	99	90	73	59	88	74
SD	10.3	1.8	1.3	26	3	16	35	41	15	25

Note: AC = Auditory Comprehension, VNT = Verb Naming Test, VCT = Verb Comprehension Test, ASPT = Argument Structure Production Test, SPPT_C = Sentence Production Priming Test (Canonical), SPPT_NC = Sentence Production Priming Test (Non-canonical), SCT_C = Sentence Comprehension Test (Canonical), SCT_NC = Sentence Comprehension Test (Non-canonical); WAB-R = Western Aphasia Battery-Revised, NAVS = Northwestern Assessment of Verbs and Sentences.

The tests included the Western Aphasia Battery Revised (WAB-R; Kertez, 2006) and the Northwestern Assessment of Verbs and Sentences (NAVS; Thompson, 2011). Given the nature of the experimental task, participants had to obtain a score or 60 or more on the WAB-R, indicating mild-moderate fluent or non-fluent aphasia. Additionally, they must have scored at least a 5/10 on the Auditory Comprehension section of the WAB-R, and 80% on the on the Verb Comprehension Test (VCT) and above chance level on the comprehension of canonical sentences of the Sentence Comprehension Test (SCT_C) on the NAVS to indicate relatively intact comprehension of single words and simple sentences. Participants also scored at least 4/10 on the Fluency section of the WAB-R, and 50% correct on the Verb Naming Test (VNT) and the Argument Structure Production Test (ASPT) on the NAVS that indicated a preserved ability to produce at single words and least some canonical sentences.

Materials and Design. A 2 (group) x 2 (target type) x 2 (prime type) x 2 (verb type) design was used, with the three predictors (target, prime and verb types) being within-participant factors. For transitive stimuli, a set of 48 target sentences and 48 prime sentences and corresponding black-and-white line drawings were taken from Man et al. (2019). The pictures consisted of an animal and a human completing one of 6 actions (*bite, chase, kiss, lift, push, pull*). Each of the 6 actions were used 8 times in the target sentences and 8 times in the prime sentences with different agents and themes. Each transitive target picture was paired once with an active prime and once with a passive prime. Additionally, half of the prime-target pairs had the same verb and half had a different verb. Dative stimuli followed the same design with 48 target sentences and 48 prime sentences. The pictures contained an animate agent and goal and an inanimate theme completing one of 6 actions (*give, hand, offer, sell, show, throw*). Each of the 6 actions were used 8 times in the target sentences and 8 times in the prime sentences. Similar to the transitive stimuli, each dative target picture was paired once with a double-object prime and once with a prepositional-object prime. Half of the prime-target pairs also had the same verb and half had a different verb. The nouns and verbs were written on the picture cards for both the targets and primes in order to minimize the effect of word retrieval errors of PWA.

Additionally, 192 filler cards were interspersed throughout the deck so that 4 fillers occurred in between every target-prime card pair. Fillers consisted of intransitive sentences with matching pictures. Of the fillers, 31 identical picture cards in the experimenter and participants' card deck were used as "Bingo" items. "Bingo" items were present to ensure that the participant

was attending to the task. The pictures were printed on 4 1/2 x 3 2/3-inch sheets of card stock paper.

Four lists were created for this experiment so that each sentence and verb type were used for prime sentences across participants (active-same verb, passive-same verb, active-different verb, passive-different verb). Each list included of 96 trials split into two blocks: datives and transitives. For example, list 1 consisted of all 48 transitive target-prime pairs appearing first, followed by all dative target-prime pairs, whereas list 3 consisted of all 48 dative target-prime pairs appearing first, followed by all 48 transitive target-prime pairs. Each target picture was presented only once within each list and was paired with one of the four types of primes across the four lists (e.g. same verb active, same verb passive, different verb active, different verb passive for transitive targets). For example, the target picture "The cat is chasing the witch" was paired with the same-verb active prime "the dog is chasing the boy" in list 1, but with a same-verb passive prime "the boy is being chased by the dog" in list 2 and so on. The order of presentation for the experimental trials was pseudo-randomized so that no same sentence structures appeared in more than 3 consecutive trials (e.g. passive, passive, active), and no same verb type appeared in more than 3 consecutive trials (e.g. same, same, different).

Procedure. Prior to the experimental task, all participants were familiarized with the target and filler nouns and verbs as single words using a stimulus book. This was done to minimize the word-retrieval difficulties of PWA during sentence production. For nouns, each word was also paired with its corresponding black-and white line picture. Verbs were presented as single words on a page with no corresponding picture. The participants were asked to label the noun pictures and read the verbs. Feedback was provided for errors.

For the experimental task, both the participant and the experimenter had a stack of face-down cards in front of them on the table. The experimenter's stack consisted of primes and fillers, while the participants stack consisted of targets and fillers. The participants were told that they would be playing a picture matching game with the experimenter. The experimenter first flipped over the card on the top of their stack and described it with a single sentence using all of the words on the card, then the participant did the same with their stack. The participant and the experimenter took turns flipping over the top card and then describing it. Participants were told that the goal of the of the game is to match their card with the experimenter's card and then call out "Bingo" when that occurred. The experimenter always flipped and described their card first

and produced a prime sentence based on a colored dot at the bottom of their card (green=act, orange=passive, PO=pink, DO=blue). No colored dots were present on the participant's card. The game was proceeded by a practice round consisting of 4 trials. Participants' responses were recorded for analysis.

Data Coding. Participants' recorded responses were transcribed verbatim and coded as correct or incorrect. A correct response consisted of utterances with all words presented on the card produced in one of the 2 alternating structures (active or passive, DO or PO). If multiple attempts occurred, the final attempted was scored. Semantically similar substitutions ("boy" for "man"), intelligible phonological paraphasias, omission of articles, and self-corrections were accepted. Variances in tense form (e.g., is/was pushing, pushed, is/was pushed) were also accepted.

For transitive targets, a correct active response must have been produced in a NP (agent) V NP (theme) order to be scored. Correct passive responses must have had the theme occur before the verb and the agent must have occurred after the verb preceded by the preposition "by". All correct passive responses included use of a past-participle form of the target verb followed by an auxiliary (e.g, was lifted). In datives, PO structures must have contained "to" or a semantically legitimate substitution of another preposition that can be used with an animate noun (for, with); however, more general prepositions (on, in) were not scored as correct. For DO structures, the response produced in the order of NP (agent) V NP (goal) NP (theme) was scored as correct. All other responses were scored as incorrect.

Priming effects were only analyzed on correct responses. The priming effect was defined as the increase in production of an arbitrarily selected 'preferred' structure following the same vs. different prime structure. Therefore, the priming effect for transitives was measured as the increase of active sentences produced (out of all correct active + passive responses) following an active prime vs. passive prime. The priming effect for datives was measured as the increase of PO sentences (out of all correct PO + DO responses) produced following a PO prime vs. DO prime. A set of mixed Analysis of Variance (ANOVA) tests were used to test priming effects, entering prime type and verb type as within-subject factors and group as a between-subject factor. When there was a significant 2- or 3-way interaction involving group, follow-up ANOVAs were conducted within each group to further examine the nature of the interactions.

RESULTS

For HOA, eight responses were excluded from a total of 1,152 responses due to experimenter errors, resulting in 1,144 scorable responses. For PWA, 13 responses were excluded from a total of 1,152 responses due to experimenter errors, resulting in 1,139 scorable responses.

Priming Analysis. Figure 1 shows the priming effects for transitive and dative targets and their verb type. Individual data for PWA are reported in Table 2 and 3.

For *transitive targets*, a 2 (prime type) x 2 (verb type) x 2 (group) ANOVA revealed a main effect of prime (F (1, 22) = 40.80, p <.001), indicating overall increased production of active responses after active vs. passive primes. There was a main effect of verb, suggesting that participants overall produced more active (preferred) responses in the different vs. same verb prime condition (F (1, 22) = 11.40, p < .001). There was no significant group effect, indicating that the two groups did not differ in their production of the preferred structure (F (1, 22) = 1.535 p = .228). However, importantly, there were significant interactions between prime x verb (F (1, 22) = 31.21, p <. 001) and a prime x verb x group interaction (F (1, 22) = 4.34, p <.05)

A 2 (prime) x 2 (verb) ANOVA conducted within each group revealed that HOA showed significant structural priming (F (1,11) = 9.22, p < .01). There was a significant effect of verb, indicating greater production of actives in the different vs. same verb condition (F (1, 11) = 9.224, p = .011). Importantly, HOA showed a lexical boost effect, as indicated by a significant interaction between prime type and verb type (F (1,11) = 27.83, p < .001). HOA showed a greater priming effect when the verb was repeated between prime and target (66.2% difference) compared to when the verb was not repeated between the prime and the target (31.9% difference).

For PWA, a 2 x 2 ANOVA revealed that their overall priming effect did not reach significance, although they produced more actives following active vs. passive primes (F (1,11) = 3.879, p = .075), The main effect of verb was not reliable either (F (1, 11) = 2.300, p = .158). However, PWA showed a significant interaction between verb and prime type, i.e., lexical boost (F (1,11) = 6.508, p = .027). They showed a larger priming effect for the same-verb (23.0% difference) than the different-verb priming condition (7.3% difference).

For the *dative targets*, a 3-way ANOVA revealed that there was a significant priming effect, indicating overall increased production of PO structures following PO vs. DO primes (F (1,22) = 8.005, p = .010). There was a group effect (F (1, 22) = 6.510, p = .018) indicating that

PWA overall produced more PO structures than HOA regardless of prime conditions. In addition, there was a significant prime x group interaction (F (1, 22) = 6.133, p = .021). However, the rest of the main effect or 2- and 3-way interactions was not significant (F's < 1.307, p > .320).

A 2 (prime) x 2 (verb) ANOVA conducted within each group revealed that HOA showed significant priming (F (1,11) = 7.605, p = .019), indicating that participants were more likely to produce a PO target after hearing a PO vs. DO prime. However, there were no effect of verb type (F (1, 11) = 0.248, p = .628) or prime x verb interaction (F (1,11) = 1.064, p = .324). HOA showed only a numerically greater priming effect when the verb was repeated between prime and target (23%) compared to when the verb was not repeated between prime and target (17%).

Different from HOA, a 2 x 2 ANOVA conducted within PWA revealed no significant main effect of verb or prime or interaction between prime type and verb type (F's < .563, p's > .468). Overall, PWA produced only numerically more PO structures following PO vs. DO primes. In addition, although PWA showed a slightly larger priming effect in the same verb prime condition (7.8%) than in the different verb condition (4.3%), the difference did not reach statistical significance.

DISCUSSION.

Structural priming is a phenomenon that is crucial to language processing and learning in unimpaired speakers. There is a growing interest in utilizing structural priming as a way to support the rehabilitation of sentence production in PWA, however research on the underlying mechanisms of structural priming in PWA is limited. The purpose of this study was to better understand the factors that influence the presence and degree of structural priming in PWA. Specifically, the present study examined the effects of same vs. different-verb primes on the production of transitive and dative sentences in a group of PWA and HOA when transitive and dative structures were presented in blocks. We asked if our participants would show increased priming and a significant lexical boost, when priming is offered through a blocked design.

Our HOA showed robust abstract priming and lexical boost in transitive targets and significant abstract priming only in dative targets. This pattern is consistent as that found in HOA of Man et al. (2019), although the magnitudes of these priming effects are generally greater for our HOA. For transitives, our HOA showed evidence of structural priming in 33.1% of responses when a verb was not shared between the prime and target and 66.2% when a verb was shared between the prime and the target, while the HOA in Man et al (2019) showed 25% vs. 47% priming effects in the different and same verb conditions.

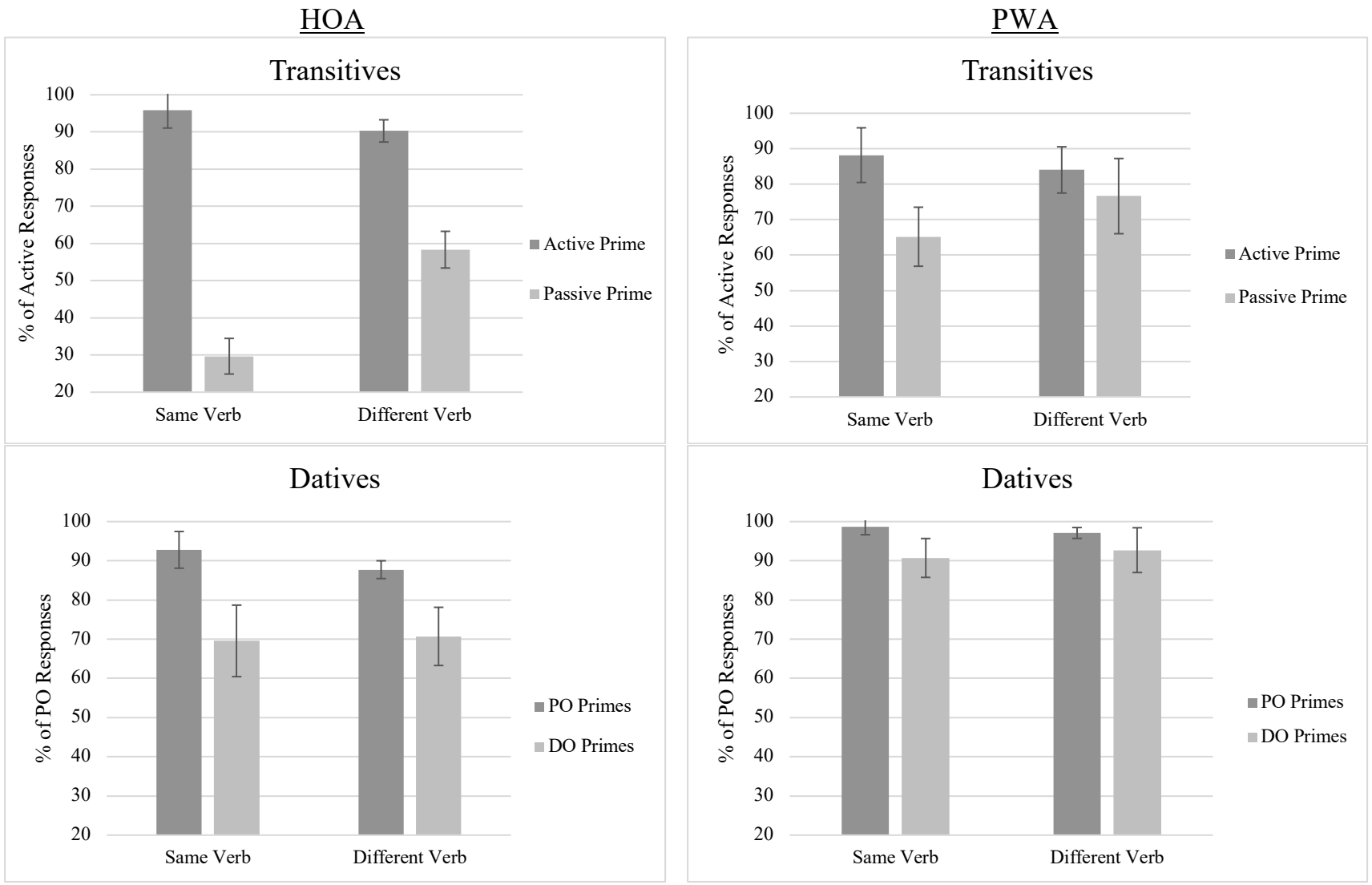

Figure 1. Priming results (with standard error bars) for transitive (top) and dative (bottom) targets for HOA (left) and PWA (right).

Table 2. Individual PWA's priming results for transitive targets, as indicated by proportion of active responses out of all correct (active + passive) responses.

	Same Verb		Different Verb	
PWA	Active Prime	Passive Prime	Active Prime	Passive Prime
A1	100%	100%	100%	100%
A2	66.7%	45.5%	50%	66.7%
A3	100%	100%	100%	100%
A4	100%	100%	100%	100%
A5	100%	100%	100%	100%
A6	33%	50%	50%	50%
A7	100%	66.7%	100%	90.9%
A8	100%	90.9%	100%	100%
A9	58.3%	25%	25%	25%
A10	100%	16.7%	100%	45.5%
A11	100%	0%	83.3%	41.7%
A12	100%	87.5%	100%	100%

Table 3. Individual PWA's priming results for dative targets, as indicated by proportion of PO responses out of all correct (PO + DO) responses.

	Same Verb		Different Verb	
PWA	PO Prime	DO Prime	PO Prime	DO Prime
A1	100%	100%	100%	100%
A2	100%	72.7%	100%	90.9%
A3	100%	100%	100%	100%
A4	100%	100%	100%	100%
A5	100%	100%	100%	100%
A6	100%	91.7%	100%	100%
A7	100%	100%	100%	100%
A8	100%	100%	100%	100%
A9	100%	100%	100%	100%
A10	83.3%	33.3%	81.8%	41.7%
A11	100%	100%	100%	80%
A12	100%	90.1%	83.3%	100%

For dative targets, HOA in both studies showed only abstract priming. Our HOA showed evidence of structural priming in 17% and 23% of responses, respectively, in the different and same verb conditions, while the HOA in Man et al (2019) showed 11% vs. 18% priming effects in the different vs. same verb conditions. This indicates that blocking stimuli during a priming task did not improve lexical boost effect in datives for HOA. The current findings from our HOA are also in line with the previous studies showing that structural priming occurs throughout the lifespan (Chang et al., 2006; Reitter et al., 2011; Bock & Griffin, 2000; Hardy et al., 2017 Man et al., 2019).

The data from PWA showed mixed evidence. Our PWA showed a significant lexical boost in transitive targets, different from Man et al. (2019), but they still failed to show significant priming effects in the dative targets. Our PWA showed evidence of structural priming in 7% of responses when a verb was not shared between the prime and target and 23% when a verb was shared between the prime and the target, indicating a significantly enhanced priming as a result of lexical (verb) overlap. This pattern contrasts with Man et al. (2019) where their PWA did not show lexical boost in priming (10% vs. 15%). For the dative block, our PWA showed only numerically greater PO responses in both same (7.9 %) and different (4.3%) verb conditions. These results, suggest that blocking stimuli has at least a temporary effect on production in PWA when lexical information overlaps. However, blocking stimuli did not significantly improve priming in dative sentences for PWA.

Collectively, the current findings suggest that some level of structural priming at the comprehension-to-production level is preserved in PWA. Further, our current findings suggest that the degree of structural priming in HOA and PWA is not largely depended on how specific sentence structures are presented, such as whether all transitive targets are presented before all dative targets. However, there are some limitations for this study. It cannot be completely ruled out that the lack of significant priming in datives for PWA are due to our small sample size. Thus, more participants need to be tested before a firm conclusion is made. Another issue is that, as noted in the introduction, Man et. al. did not find significant structural priming for datives in PWA when dative and transitive targets were interspersed across the experiment. We suggested that this may be due to the greater prediction error-based learning or pragmatic saliency that transitives have over datives when they are mixed amongst each other. However, in our current study still did not find significant structural priming for datives in PWA when stimuli were blocked by structures. It is still possible that greater prediction error-based learning mechanisms for transitives are to blame

for the lack of structural priming for datives in our study. Although the target structures were blocked (transitive vs. dative), the alterations of structures were interspersed across blocks (PO vs. DO). In terms of prediction error-based learning mechanisms, the error between what a participant heard compared to what they predicted across PO and DO datives may still be so small that structural priming did not occur when the structures occurred together. Additionally, the low level of pragmatic saliency between PO and DO may reduce the likelihood of structural priming occurring within dative structures. Further research is needed to determine if different ways of presenting stimuli would lead to more effective priming in PWA.

Theoretically, the current findings suggest that comprehension-based prior linguistic experiences could shape syntactic production in PWA, indicating that abstract linguistic representations remain intact, but accessing these representations is impaired in PWA. This is in line with the view that aphasia is a processing disorder, rather than a representational disorder (Bastiaanse & Van Zonneveld, 2004; Bock & Levelt, 1994; Lee & Thompson, 2004). Specifically, accessing both structural and lexical information can be facilitated in PWA when primed adequately. However, it is unclear based on the current study whether lexically independent and dependent priming are associated with two distinctive (implicit vs. explicit as proposed in Chang et al., 2006) or the same (declarative, Reitter et al., 2011) memory processes in PWA.

The results from the current study hold clinical significance when priming is used to ameliorate sentence production deficits in PWA. First, our findings indicate that when providing implicit intervention for syntactic deficits in PWA, the presentation of blocked stimuli likely does not improve sentence production compared to mixed stimuli in a comprehension-to-production dialogue task (as in Man et al., 2019). This may counter to the principles often employed in traditional therapy, where target structures are taught one at a time. However, our findings do suggest that utilizing stimuli with lexical overlap in sentence production priming could result in better outcomes for PWA, specifically when the intervention is targeting facilitating immediate production of transitive sentences. It is possible that overlapping lexical information (e.g., verb) acts as a cue to the memory of a prime and creates a bias for PWA to repeat a structure, thus leading to greater productions of target structures within a therapy session (Pickering & Branigan, 1998; Chang et al., 2012).

In conclusion, there is a growing interest in utilizing structural priming as a tool for sentence production rehabilitation for PWA, however the preserved linguistic mechanisms of

structural priming and how it facilitates sentence production in PWA remains relatively unknown. The present study was a systematic investigation on whether the order of stimulus presentation affects the presence and degree of structural priming in PWA. Specifically, this study aimed to determine whether presenting stimuli in a blocked pattern (i.e. presentation of all dative targets, followed by all transitive targets) would lead to structural priming for datives and lexical boost in PWA. HOA showed abstract structural priming for both transitive and dative targets and a significant lexical boost for transitive targets when stimuli were presented in a blocked pattern, similar to Man et al. (2019) where the stimuli were presented in a mixed pattern. PWA showed significant priming effects in the transitive block, with the presence of lexically-mediated boost in priming. However, they did not show a reliable priming or lexical boost in the dative block. These findings suggest that comprehension-based prior linguistic experiences could shape sentence production, indicating that linguistic representations remain intact, but accessing these representations is impaired in PWA. However, the presentation of these prior linguistic experiences does not influence the ability to more readily access these representations. Thus, it is feasible that structural priming could act as a tool to rehabilitate a PWA's access to complicated syntactical structure, but the presentation of target stimuli would likely not influence outcomes.

REFERENCES

Bastiaanse, R., & van Zonneveld, R. (2005). Sentence production with verbs of alternating transitivity in agrammatic Broca's aphasia. *Journal of Neurolinguistics, 18(1)*, 57-66.

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.

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.

Caramazza, A., & Berndt, R. S. (1985). A multicomponent deficit view of agrammatic Broca's aphasia. *In Agrammatism* (pp. 27-63).

Caramazza, A., & Miceli, G. (1991). Selective impairment of thematic role assignment in sentence processing. *Brain and Language, 41(3)*, 402-436.

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

Chang, F., Janciauskas, M., & Fitz, H. (2012). Language adaptation and learning: Getting explicit about implicit learning. *Language and Linguistics Compass, 6(5)*, 259-278.

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, 91*, 202-218.

Cho-Reyes, S., & Thompson, C. K. (2012). Verb and sentence production and comprehension in aphasia: Northwestern Assessment of Verbs and Sentences (NAVS). *Aphasiology, 26(10)*, 1250-1277.

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*(1), 155–159.

Ferreira, V. S., & Bock, K. (2006). The functions of structural priming. *Language and Cognitive Processes, 21(7-8)*, 1011-1029.

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

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*, 588-596.

Harris, L., Olson, A., & Humphreys, G. (2011). Rehabilitation of past tense verb production and non-canonical sentence production in left inferior frontal non-fluent aphasia. *Aphasiology, 26(2),* 143-161

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.

Hartsuiker, R. J., & Kolk, H. H. (1998). Syntactic persistence in Dutch. *Language and Speech, 41(2)*, 143-184.

Jaeger, T. F., & Snider, N. E. (2013). Alignment as a consequence of expectation adaptation: Syntactic priming is affected by the prime's prediction error given both prior and recent experience. *Cognition, 127(1)*, 57-83.

Kertesz, A. (2006). *Western Aphasia Battery–Revised* (*WAB-R*) Pro-Ed. Austin, TX.

Lee, J., Hosokawa, E., Meehan, S., Martin, N., & Branigan, H. (2019) Priming sentence comprehension in aphasia: effects of lexically independent and specific structural priming. *Aphasiology, 33(7)*, 780-802

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

Lee, J., Man, G., Ferreira, V., & Gruberg, N. (2019). Aligning sentence structures in dialogue: evidence from aphasia. *Language, Cognition, and Neuroscience*, *34(6)*, 720-735.

Lee, M., & Thompson, C. K. (2004). Agrammatic aphasic production and comprehension of unaccusative verbs in sentence contexts. *Journal of Neurolinguistics, 17(4)*, 315-330.

Lee, J., & Thompson, C. K. (2011a). Real-time production of arguments and adjuncts in normal and agrammatic speakers. *Language and Cognitive Processes, 26(8)*, 985-1021.

Lee, J., & Thompson, C. K. (2011b). Real-time production of unergative and unaccusative sentences in normal and agrammatic speakers: An eyetracking study. *Aphasiology, 25(6-7)*, 813-825.

Lee, J., Yoshida, M., & Thompson, C. K. (2015). Grammatical planning units during real-time sentence production in speakers with agrammatic aphasia and healthy speakers. *Journal of Speech, Language, and Hearing Research, 58(4)*, 1182-1194.

Maher, L. M., Catterjee, A., Rothi, L. J., & Heilman, K. M. (1995). Agrammatic Sentence Production: the use of a temporal—spatial strategy. *Brain and Language, 49*, 105-124.

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.

Man, G., Meehan, S., Martin, N., Branigan, H., & Lee, J. (2019). Effects of Verb Overlap on Structural Priming in Dialogue: Implications for Syntactic Learning in Aphasia. *Journal of Speech, Language, and Hearing Research*, *62(6)*, 1933-1950.

Martin, N., Kohen, F. P., & Kalinyak-Fliszar, M. (2010). A processing approach to the assessment of language and verbal short-term memory abilities in aphasia. *In Clinical Aphasiology Conference* (pp. 23-27).

Martin, N., Kohen, F., Kalinyak-Fliszar, M., Soveri, A., & Laine, M. (2012). Effects of working memory load on processing of sounds and meanings of words in aphasia. *Aphasiology, 26(3-4)*, 462-493.

Martin, N., Minkina, I., Kohen, F. P., & Kalinyak-Fliszar, M. (2018). Assessment of linguistic and verbal short-termmemory components of language abilities in aphasia. *Journal of Neurolinguistics, 48*, 199-225.

McAllister, T., Bachrach, A., Waters, G., Michaud, J., & Caplan, D. (2009). Production and comprehension of unaccusatives in aphasia. *Aphasiology, 23(7-8)*, 989-1004.

Miceli, G., Silveri, M. C., Romani, C., & Caramazza, A. (1989). Variation in the pattern of omissions and substitutions of grammatical morphemes in the spontaneous speech of so-called agrammatic patients. *Brain and Language, 36(3)*, 447-492.

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.

Reitter, D., Keller, F., & Moore, J. D. (2011). A computational cognitive model of syntactic priming. *Cognitive Science, 35(4)*, 587-637.

Rochon, E., Laird, L., Bose, A., & Scofield, J. (2005). Mapping therapy for sentence production impairments in nonfluent aphasia. *Neuropsychological Rehabilitation, 15(1)*, 1-36.

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

Saffran, E. M., Schwartz, M. F., & Marin, O. S. (1980a). Evidence from aphasia: Isolating the components of a production model. *Language Production, 1*, 221-241.

Saffran, E. M., Schwartz, M. F., & Marin, O. S. (1980b). The word order problem in agrammatism: II. Production. *Brain and language, 10(2)*, 263-280.

Schwartz, M. F., Saffran, E. M., Fink, R. B., Myers, J. L., & Martin, N. (1994). Mapping therapy: A treatment programme for agrammatism. *Aphasiology, 8(1)*, 19-54.

Thompson, C. K. (2012). Northwestern Assessment of Verbs and Sentences (NAVS).

Thompson, C. K. (2003). Unaccusative verb production in agrammatic aphasia: The argument structure complexity hypothesis. *Journal of Neurolinguistics, 16(2-3)*, 151-167.

Thompson, C.K., Faroqi-Shah, Y., & Lee, J. (2015). Models of sentence production. In A.E. Hills (Ed.), The Handbook of Adult Language Disorders (pp. 328 – 354). New York, NY: Psychology Press.

Thompson, C. K., Lange, K. L., Schneider, S. L., & Shapiro, L. P. (1997). Agrammatic and nonbrain-damaged subjects' verb and verb argument structure production. *Aphasiology, 11(4-5)*, 473-490.

Thompson, C. K., Shapiro, L. P., Kiran, S., & Sobecks, J. (2003). The role of syntactic complexity in treatment of sentence deficits in agrammatic aphasia: The complexity account of treatment efficacy (CATE). *Journal of Speech, Language, and Hearing Research, 46(3)*, 591-607.

Yan, H., Martin, R. C., & Slevc, L. R. (2018). Lexical overlap increases syntactic priming in aphasia independently of short-term memory abilities: Evidence against the explicit memory account of the lexical boost. *Journal of Neurolinguistics, 48*, 76-89.