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Aligning sentence structures in dialogue: evidence from aphasia

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Abstract

Syntactic alignment in dialogue is pervasive and enduring in unimpaired speakers, facilitating language processing and learning. Recent work suggests that syntactic alignment extends to the level of event-semantic properties (*syntactic entrainment*). Two experiments examined whether syntactic entrainment can ameliorate impaired message-structure mapping in persons with aphasia (PWA). In Experiment 1, participants first heard twelve picture descriptions, each using one of two suitable syntactic structures, prior to describing the same twelve pictures themselves. In Experiment 2, participants also repeated the heard picture descriptions, thereby increasing the depth of encoding for prime sentences. PWA showed a robust tendency to re-use previously encountered syntactic structures in their own production only in Experiment 2. They produced fewer 'mapping' errors (e.g., thematic role reversals) in Experiment 2 than in Experiment 1. Syntactic entrainment remains resilient in aphasia, strengthening their event-semantic-to-syntax mappings, at least when active encoding of prior message-syntax associations is ensured.

Keywords

syntactic alignment; aphasia; syntactic priming; grammatical encoding; mapping deficit; sentence production

Introduction

Speakers align with their conversational partners at various levels of linguistic representation, forming a tacit agreement about how meaning is to be mapped onto a linguistic form (Branigan, Pickering, & Cleland, 2000; Branigan, Pickering, McLean, & Cleland, 2007; Brennan & Clark, 1996; Pickering & Garrod, 2004; Warker, Dell, Whalen, & Gereg, 2008). For example, interlocutors in a dialogue converge on particular referring expressions such as 'brown loafer' rather than using alternatives such as 'shoe' (i.e., *lexical entrainment*; Brennan & Clark, 1996; Garrod & Anderson, 1987; Garrod & Clark, 1993; Garrod & Doherty, 1994; Wilkes-Gibbs & Clark, 1992). The tendency to align syntactic structures is even more pervasive (see Pickering & Ferreira, 2008 for review). In studies of syntactic priming, it has been well-established that simply hearing a double-object (DO, e.g., *the boy is giving a singer a guitar*) structure produced by a conversational partner increases

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the probability of encoding a similar message with a DO structure rather than the alternative, prepositional-object structure (PO; *e.g., the boy is giving a guitar to a singer*; Branigan et al., 2000; 2007). Syntactic alignment occurs minimally at the level of surface structural configuration (phrasal nodes), but can extend to the levels of lexical items (Hartsuiker, Bernolet, Schoonbaert, Speybroek, Vanderelst, 2008; Pickering & Branigan, 1998; Scheepers et al., 2017) and event-semantic properties (Gruberg, Ostrand, Momma, & Ferreira, under review). It is well-established that syntactic alignment reflects cognitive adaptation processes supporting efficient information transfer as well as language learning in unimpaired speakers, above and beyond mere repetition (Chang, Dell, & Bock, 2006; Chang, Janciauskas, & Fitz, 2012; Ferreira, Kleinman, Kraljic, & Siu, 2012; Fine & Jaeger, 2013; Jaeger & Snider, 2013; Pickering & Garrod, 2004; Reitter, Kelly, & Moore, 2011). A significant question yet to be explored is if and to what extent effects related to syntactic alignment continue to operate in speakers with impaired grammatical encoding. This study addresses this gap by investigating whether individuals with aphasia demonstrate a specific form of syntactic alignment called *syntactic entrainment*.

The term *syntactic entrainment* was recently coined by Gruberg and colleagues (under review) based on the discovery that interlocutors develop associations between event-semantic content and syntactic structures, independently of conventional syntactic priming. Gruberg et al. used a series of collaborative picture matching tasks in combination with a blocked priming design to test if young adults would use the same syntactic structures as their interlocutors to refer to specific events. In their task, the participants first heard the experimenter describe a set of 12 action pictures, and matched them in the described order. Then they switched roles and the participant described the same 12 pictures for the experimenter (purportedly) to also match the picture order. This blocking created a lag of (on average) 12 intervening utterances between the prime and the target, ruling out a mere repetition effect. The participants showed a robust entrainment effect (mean 12.6% difference), whereby they re-used previously heard syntactic structures to describe the *same picture card* in the production block as they heard used to describe that card in the matching (prime) block (see also Gruberg, Wardlow, & Ferreira, 2014 for a larger entrainment effect found in children). This effect is not partner-specific, as young adults demonstrated approximately equal effects when describing pictures to a different partner from the one who originally had described those same pictures, and it is not due to visual depiction of the pictures, as the effect is approximately equal when describing a different visual depiction of an event as they saw in the prime block. However, importantly, hearing a set of primes involving the same type of semantic events (e.g., dative sentences that all involve transfer of possession as described by a verb such as *give*) significantly reduced the syntactic entrainment effect, indicating interference from the same event-semantic category, compared to when the participants heard primes consisting of heterogeneous event-semantic categories (e.g., a mix of events including giving, throwing, telling, and showing). Collectively, these findings suggest that syntactic entrainment involves an association between representations that include rather abstract event-semantic categories and those that determine surface syntactic structures in the sentence.

There is not yet a consensus that a single mechanism leads to syntactic priming or alignment. Earlier accounts attributed syntactic priming to transient accessibility of recently processed linguistic representations (e.g., Pickering & Branigan, 1998). However, more recent accounts propose that syntactic alignment reflects some sort of communicative goal-driven adaption processes or language learning that creates enduring changes in the language processing system (Bock & Griffin, 2000; Chang et al., 2006; 2012; Jaeger & Snider, 2013; Pickering & Garrod, 2004; Reitter, Kelly, & Moore, 2011 among others). The Interactive Alignment Model (Pickering & Garrod, 2004) holds that priming occurs to facilitate alignment in dialogue. Interlocutors align their linguistic representations at many levels, including lexical and syntactic, to create shared 'routines' or situational models in dialogue, which in turn simplify information processing. Due to its functional goal, syntactic priming is expected to be greater in an interactive, goal-driven communicative task such as a dialogue rather than in a monologue or spontaneous speech (Reitter & Moore, 2014; Branigan et al., 2000). Similarly, Jaeger and Snider (2013) propose that syntactic priming supports efficient information transfer. They propose that syntactic priming is caused by a speaker's expectation-error based adaptation to the statistical properties in the linguistic environment. As a speaker listens to their interlocutor, they make predictions about what structures their interlocutor will use to ease information processing. When their expectation-based prediction is wrong, the speaker adjusts their preferences for future production, thereby minimizing joint expectation errors.

Others view syntactic priming as a reflection of mechanisms of language learning. The dual-path connectionist model instantiated by Chang and colleagues (2006) posits that priming is a consequence of implicit learning (see also Bock & Griffin, 2000). Language is processed via two distinct systems: a meaning system, which encodes lexical-semantic representations of words and events, and a sequencing system, which determines word order. The sequencing system, implemented as a simple recurrent network (Elman, 1990), is trained to learn syntax via error-based weight adjustments. The model predicts the next word during incremental comprehension of the prime sentence. When a different word order is encountered, this discrepancy (error) creates connection weight changes in the sequencing system via backpropagation, thereby increasing the probability of predicting or generating the actually observed word order in the future. Importantly, this implicit learning mechanism is assumed to operate throughout the life span, independent of developmental changes in explicit memory systems, accounting for both language acquisition and syntactic priming in adulthood (Chang et al., 2012). In addition, because error-driven learning occurs during incremental comprehension of language input, this model predicts that comprehension-based primes are sufficient to bias one's syntactic production. Different from Chang's implicit learning model, Reitter et al. (2011) attribute syntactic priming to memory-retrieval based learning within the ACT-R model (Anderson, Bothell, Byrune, et al., 2004). This model stipulates that priming occurs via a combination of longer-lasting base-level and short-lived spreading activation in declarative memory. When a linguistic representation is retrieved from memory, there is spreading activation to related representations. Although the activation decays as a power-law, retrieving a structure from memory changes its base level activation, resulting in increased retrieval probability for the syntactic structure, which in turn leads to lasting priming effect (learning).

Although specific cognitive mechanisms and functional goals of syntactic alignment differ, common across these models is that humans' tendency to use previously encountered sentence structures is remarkably pervasive and enduring. The alignment process spans across various levels of linguistic representations and occurs from early in life (3–4 years-olds) into adulthood (Branigan & McLean, 2016; Peter et al., 2015; Pickering & Garrod, 2004; Rowland, Chang, Ambridge, Pine, & Leiven, 2012). A question that has received little attention is if and to what extent the mechanism of syntactic alignment remains resilient in impaired grammatical encoding systems. If syntactic alignment reflects choices that language users make for efficient language processing and/or language learning, can impaired speakers adjust their 'mapping' preferences in response to prior linguistic experiences such that they can circumvent difficulties that may arise during grammatical encoding? The present study addresses this question by examining if persons with stroke-induced aphasia (PWA) demonstrate syntactic entrainment in a dialogue-like task.

Studying PWA makes an ideal case to test this question because sentence processing in aphasia is often conceived as a disorder in message-syntax mapping (Saffran, Schwartz, Martin, 1980; Schwartz, Saffran, Fink, Meyers, & Martin, 1994 Thompson, Faroqi-Shah, & Lee, 2015 for review). A focal brain lesion in the perisylvian language areas results in impaired sentence production and comprehension in PWA that is marked by a lack of linguistic structures that accurately represent relational meanings in the message. For example, a semantically reversible sentence such as 'the boy chased the dog' is difficult to many PWA, as opposed to a semantically irreversible sentence such as 'the boy chased the ball', because PWA have to employ grammatical mapping, rather than relying on heuristic strategies, to accurately process the reversible sentences (Caramazza & Zurif, 1976; Saffran et al., 1980; Schwartz, Saffran, & Marin, 1980). Sentences with non-canonical word order (e.g., passives) and increased number and complexity of event roles (e.g., datives compared to intransitives; unaccusatives than unergative intransitives) are also vulnerable in aphasia, due to their increased demands for grammatical encoding. As a result, PWA often produce 'mapping' errors such as role-reversal errors (e.g., *The woman is saving the man* for *The man is saving the woman; The man is saved by the woman* for *The woman was saved by the man*) (Caramazza & Zurif, 1976; Cho & Thompson, 2010; Saffran et al., 1980).

A group of researchers have proposed that these mapping deficits are manifestation of fundamentally impaired syntactic representations. Brain injuries result in a loss of certain syntactic representations or an underspecified syntactic tree, yielding inability to build syntactic structures or to map semantics (e.g., thematic roles) onto syntax (Caramazza & Zurif, 1976; Friedmann, 2000; Friedmann & Grodzinsky, 1997; 1997; Grodzinsky, 1989; Hagiwara, 1995; Saffran et al., 1980; Schwartz et al, 1980). On this representational account of mapping deficits, PWA would fail to develop associations in message-structure mappings in response to prior linguistic input such as their conversational partner's sentences, because the target syntactic representations are likely impaired in the system.

Against this representational account, others have attributed mapping deficits to inefficient processing or use of linguistic representations rather than a loss of syntax as such (Cho & Thompson, 2010; Haarman & Kolk, 1991; Kolk, 1995; Kolk & Heeschen, 1992; Lee & Thompson, 2011a; 2011b; Lee, Yoshida, & Thompson, 2015; Linebarger, Schwartz, Romania, Kohn, & Stephens, 2000; Linebarger, Schwartz, & Saffran, 1983; Thompson et al., 2015 for review). For example, PWA can successfully detect grammatical violations in sentences despite their inability to correctly produce and comprehend those sentences, indicating that linguistic representations remain relatively intact (Kim & Thompson, 2000; Linebarger et al., 1983). However, a pathological change in the system may cause reductions in cognitive resources or some sort of linguistic buffer that is needed for efficient activation and integration of multiple linguistic materials, resulting in inability to implement grammatical encoding in real-time (e.g., Kolk, 1995; Kolk & Heeschen, 1992; Lee & Thompson, 2011a; 2011b; Lee et al., 2015; Linebarger et al., 2000). This processing account of mapping deficits postulates that linguistic representations are preserved but weakly accessible for PWA. Thus, it is expected that PWA would be able to develop message-syntax associations when provided support, such as prime sentences, because prior processing of a target message-syntax mapping would facilitate future grammatical encoding of a similar or same message, ameliorating computational overload that PWA would otherwise experience.

Indeed, albeit very few studies are available, there is evidence that syntactic priming facilitates use of structures that are typically difficult for PWA (Hartsuiker & Kolk, 1998; Rossi, 2015; Saffran & Martin, 1997; Verreyt, Bogaerts, Cop, Bernolet, De Letter, Hemelsoet, Santens, & Duyck, 2013). For example, in Harstuiker and Kolk (1998), PWA showed increased production of transitive and dative structures immediately after repeating prime sentences, although the priming effect was not reliable in healthy controls. Priming effects in aphasia could persist over four intervening utterances (Cho-Reyes, Mack, Thompson, 2016) and up to a month after repeated structural priming sessions (Lee & Man, 2017; cf. Schuchard, Nerantzini, Thompson, 2017). However, importantly, the existing studies have not yet demonstrated if syntactic entrainment is operative and enduring in PWA, strengthening the mapping between a deeper level of event-semantic content and sentence structure. Previous evidence was largely limited to priming at the level of phrasal nodes, without strong evidence that priming indeed extends to the level of a deeper event semantics. For example, in Cho and Thompson (2010), although their PWA were able to better produce passive morphology (*V+ed by*) after reading passive prime sentences, their ‘passive’ sentences were still marked with predominant role-reversal errors. This suggests that priming was not effective enough to mediate deficits in event semantics-to-surface structure mapping. More recent studies have demonstrated preserved lexical (verb) boost on priming effects (Yan et al., 2018) and some priming of thematic role order in PWA (Cho-Reyes et al., 2016), hinting that mechanisms of syntactic alignment may extend to the levels beyond surface constituent nodes in aphasia. However, these studies elicited target sentences immediately after the prime, failing to examine if the effects are powerful enough to yield persisting effects in aphasia. Without having a robust and enduring priming effect between the levels of event semantics and syntactic structural representations demonstrated in PWA, it would be difficult to clearly tell whether pervasive mapping deficits in aphasia are truly due to a processing or representational disorder. It would also be difficult to tell if phenomena like syntactic priming could indeed be used as an intervention strategy for grammatical encoding deficits beyond the level of surface sentence structures in aphasia.

The purpose of the present study was, therefore, to examine whether PWA develop enduring associations between event semantic content and surface syntactic structures, i.e., syntactic entrainment, based on prior linguistic experiences in a dialogue-like task. Adapting the collaborative picture matching task used in Gruberg et al. (under review), we examined this question in two experiments allowing different depths of processing prime sentences. In Experiment 1, a comprehension-to-production task was used, where participants heard descriptions of 12 pictures produced by a confederate in the priming block. Then, they described the same set of pictures back to the confederate. In Experiment 2, participants also repeated the confederate's descriptions during the prime block, thereby ensuring encoding of message-syntax mapping to be greater than in Experiment 1.

Experiment 1

Methods

Participants.—Data for Experiment 1 are from 20 young adults (YA; 6 men, 14 women), 20 healthy older adults (OA; 10 men, 10 women), and 13 participants with stroke-induced aphasia (PWA; 8 men, 5 women). We included young adults to replicate the syntactic entrainment effect found in Gruberg et al. (under review), as we have slightly modified the stimuli (see *Materials* below) to use with PWA. All healthy participants had to score within normal limits on the Cognitive-Linguistic Quick Test (CLQT, Helm-Estabrooks, 2001). The CLQT measures one's performance in the domains of language, attention, memory, executive functions, and visuospatial skills. Then the domain scores are computed into a Clinical Severity Rating (CSR) to determine whether the person's performance is below normal limits or not. All young adults performed within normal limits (CSR mean: 4.0/4.0; normal range: 3.5–4.0). One OA was excluded because of his below normal-limits scores on the CLQT (CSR: 3.4; normal range: 3.5–4.0). The remaining OA scored within normal limits (CSR range: 3.8–4.0). Participants' demographic information is provided in Table 1. All participants had at least 12 years of education. The OA had more years of education than young adults (OA vs. YA: $t(37) = 3.40$, $p < .05$). They scored higher on Shipley's vocabulary test (Shipley, 1940) compared to the YA ($t(37) = 2.50$, $p < .05$), consistent with literature showing increased vocabulary in older adults (Burke & Shafto, 2008; Guendouzi, Lonchke, & Williams, 2011; Kemper & Summer, 2001). The OA were matched in years of education with PWA ($t(30) = .60$, $p = .56$), although they were older than the PWA ($t(30) = 2.39$, $p = .02$). All participants had normal or corrected-to-normal vision, were monolingual speakers of American English, and had no reported history of neurological (prior to stroke) or psychological disorders. All participants passed a hearing screening at 500, 1000, and 2000 Hz at 40dB in at least one ear. All participants provided informed consent prior to participation.

The PWA suffered an ischemic or hemorrhagic cerebrovascular accident (12 left hemisphere, 1 right hemisphere). The Western Aphasia Battery-Revised (WAB-R; Kertesz, 2006) and the Northwestern Assessment of Verbs and Sentences (NAVS; Thompson, 2011) were administered with all PWA (see Table 2). They presented with mild-to-moderate language impairment with various types of fluent or nonfluent aphasia (WAB-R AQ: 65.3 – 89.8). All PWA showed relatively intact auditory comprehension of single words and simple sentences (WAB-R AC: 7.4–10/10). In terms of verbal expression, PWA were able to produce at least some simple sentences (e.g., *the man is catching fish*) in spontaneous speech (Fluency scores 4–9/10 on the Picnic picture description task), with relatively intact naming of single words (Naming scores 7.5–10/10). Variable performance was observed in repetition of words, phrases, and sentences (Repetition scores 4.3–10/10). None exhibited more than mild apraxia of speech via informal screening. On the NAVS (Thompson, 2011), PWA showed relatively good comprehension of single verbs (VCT), while they showed mild-to-moderate difficulty in the production of single verbs (VNT). On the Argument Structure Production Test (ASPT), in which they produced sentences with increasing numbers of arguments (intransitive, transitive, and dative) when provided with written words and an action-depicting picture, all PWA showed relatively intact ability to formulate sentences except for A4, who scored 46% correct. On the Sentence Production Priming Test (SPPT) and Sentence Comprehension Test (SCT) of the NAVS, the participants overall showed greater difficulty with sentences involving non-canonical word order (passives, object wh-questions, and object relative clauses) compared to those with canonical word order (actives, subject wh-questions, and subject relative clauses).

Both verbal and nonverbal working memory tests were administered for all participants, as shown in Table 1. For verbal working memory, the picture-pointing span test (DeDe, Ricca, Knilans, & Trubl, 2014) was used, in which participants heard a series of words and were asked to point to the corresponding pictures in the same (forward) or reverse (backward) order starting from 2 to 6 (for PWA) or 8 (for YA and OA). For each span, a set of five trials was included. Participants' span score was determined based on the highest span for which the participant pointed to all the items correctly in three out of five trials. An additional 0.5 points was awarded if the participant correctly pointed to all items in two out of five trials on a higher span level. Non-verbal working memory was assessed using the Corsi block-tapping test (Kessels, van Zandvoort, Postma, Kappelle, & de Haan, 2000), where participants were shown a highlighted sequence of blocks on a screen and then were asked to click on the blocks in the same or reverse order starting with 2 blocks. Each span included 2 trials. The test was discontinued when the participant failed two trials within the same span length. The OA performed significantly worse than the YA on both Corsi forward and backward span tests (t (37)'s < −3.840, p's > .01) but not on the Picture Pointing span measures (t(37)'s < −1.757, p's > .05). The PWA performed worse than the OA on the Picture Pointing span measures (t(30)'s < −7.525, p's < .001), but not on the Corsi span measures (t(30)'s < −1.295, p's > .05), indicating that their verbal, but not non-verbal memory is compromised.

Materials.—A total of 48 event-depicting picture cards were adopted from Gruberg et al. (under review), consisting of 16 transitive, 16 dative, and 16 locative actions. Inclusion of different types of verb classes strengthens the generalizability of the effect across different sentence types in the language (note that Gruberg et al., under review, found similar magnitudes of syntactic entrainment across these verb classes). The cards depicted an action event on 3–1/6 in by 4–1/8 in sized paper. Transitive actions could be described with an active (*the whale is swallowing the man*) or passive structure (e.g., *The man is being swallowed by the whale*) structure. Datives could be described using a PO (e.g., *The stewardess is serving coffee to the man*) or DO (e.g., *The stewardess is serving the man coffee*) structure. Locatives could be described using an *on*-variant (e.g., *The elephant is spraying water on the clown*) or *with*-variant (e.g., *The elephant is spraying the clown with water*) structure. Different from Gruberg et al.'s stimuli, on each picture card the target verb and nouns were printed to minimize word retrieval difficulties for PWA. The 48 experimental cards were split further into 4 decks of 12 cards including 4 transitive, 4 dative, and 4 locative events each. All 4 decks of the cards were used with all participants with the order of the decks counterbalanced.

A set of 96 prime sentences (32 per action type) were prepared and split into two lists (48 primes per list); each prime list contained one of two possible syntactic structures per target picture (e.g., a passive prime in List 1: *The barn is being destroyed by the tornado*, and an active prime in List 2: *The tornado is destroying the barn*). Within each participant group, half received List 1 and the other received List 2 in a counterbalanced order. The structures in each list were ordered as transitive-locative-dative so that pictures depicting the same structure type could not appear twice in a row.

Procedure.—A collaborative picture-matching card game was used between the participant and two experimenters: the main experimenter and a confederate. The main experimenter gave instructions and the confederate experimenter played the game with the participant. At the beginning of the task, the participant chose their starting roles by selecting a slip of paper that designated them as ‘director’ or ‘matcher’ (both slips had ‘matcher’ written on them to ensure that the confederate would always be the director first to deliver the prime sentences). The director’s role was to describe their cards using a single sentence, and the matcher’s role was to place their cards in the same order that the director described, as shown in Figure 1. For each round, the participant was given a copy of the same deck of cards as the confederate, and the cards were arranged on the table with two rows of 6 cards each. A barrier board was placed between the two players so that they could not see each other’s workspaces.

Each of the four rounds of the main task included two blocks, a priming block and a target production block. During the priming block, the confederate director described his or her pictures, using scripted prime sentences, while the participant placed (‘matched’) the cards in the order described. Then, during the target production block, the participant played the director role, describing the pictures in sentences for the confederate to match them in the correct order. The confederate and participant switched their roles after each set of 12 pictures. Prior to the target production block, the main experimenter shuffled the participant’s 2–3 picture cards, while ensuring that pictures depicting the same action event were never adjacent and there were still approximately 10–12 intervening pictures between the prime and the target response. The effect of syntactic entrainment was defined as the participant’s tendency to re-use the same sentence structure as the confederate experimenter to refer to the *same picture card* during the production block. This process was repeated for all 4 decks of 12 cards. Afterwards, the entire task was repeated, resulting in a total of 96 trials per participant.

A set of practice items (1 transitive, 1 dative, 1 locative) preceded the experimental task. For PWA, at the beginning of the game, familiarization of the target nouns and verbs was conducted by asking them to read each word on all cards in a random order. This was done to minimize word production difficulties in PWA. During familiarization, feedback was provided for incorrect oral reading of words. However, no feedback as to the accuracy of the participant's picture description was provided during the experimental task.

Data coding and analysis.—The experimental session was audio recorded and the participants' responses were transcribed verbatim. The primary measure of interest were counts of the syntactic structures used by the participants during the production block. For each response, we first scored them as 'correct' or 'incorrect'. The response was scored as 'correct' if one of the alternating target structures was produced (e.g., either active or passive for a transitive action). Substitutions of synonyms (e.g., *girl* for *woman*, *offer* for *hand*) and legitimate prepositions (i.e., *for the boy* instead of *to the boy*) were accepted. Disfluencies, including fillers and self-corrections were accepted as the focus of the study was production of syntactic structures not the fluency of responses. When responses were self-corrected, the last response was used for analysis. In addition, for the responses from PWA, omission of articles and phonemic paraphasias that were at least 50% intelligible were accepted. All other responses were considered 'incorrect' and excluded from the analysis of syntactic entrainment (but see error analyses below). Independent samples t-tests were used to compare group differences in production of 'correct' responses.

To test syntactic entrainment effects on participants' production of sentence structures, we used logit mixed effects models (Baayan, Davidson, & Bates, 2008; Jaeger, 2008). Only 'correct' responses were included for this analysis. To be able to enter trials from all three verb classes into a single statistical model, the alternations within each verb class needed to be collapsed into a common category. Thus, we further idiosyncratically classified as a binary variable whether a prime or target structure was preferred (1) versus non-preferred (0) structure. Active, PO, and *on*-variant locative structures were classified as *preferred* structures, whereas passive, DO, and *with*-variant locative sentences were *non-preferred*, based on general preferences for the former structures in the language when using materials like those in the experiment. We conducted the binary syntactic structure coding across the action types, because whether these action types elicit different entrainment effect was not of our theoretical interests and Gruberg et al. (under review) did not observe any statistical differences across these action types. The significant syntactic entrainment was defined by increased likelihood that the participants produced the preferred target structure for a picture in the production block, after they heard that picture described with a preferred structure compared to when they heard that picture described with a non-preferred structure in the matching block.

All models were calculated using the *glmer* function from the lme4 package (Bates, Maechler, Bolker, & Walker, 2014). The dependent variable was the production of preferred structures (preferred = 1, non-preferred = 0). Prime type (preferred vs. non-preferred) and Group (YA, OA, PWA), and their interaction were entered as fixed factors in the models. The random effects structure included by-participant and by-item effects. We first fit the maximal random effects structure. If the fully maximal model showed a convergence warning, we simplified random slope structure by removing the slope with a smallest variance (Barr, Levy, Scheepers, & Tily, 2013). Model comparisons were then performed using the ANOVA test in R, with a threshold of $p < .05$, to determine whether the interaction or each of the fixed main effects contributed to model fit. If they did, they were kept in the model.

For incorrect responses, we tallied error types. Role reversal errors included when thematic roles were reversed in the target structure (e.g., *The dog is pulling the clown* for *The clown is pulling the dog*). Non-target structure errors included semantically equivalent responses with a non-target sentence structure (e.g., *The leash is being thrown to the dog* instead of *The girl is throwing a leash to the dog/The girl is throwing the dog a leash*). Argument structure errors included incorrect or omitted production of thematic roles (e.g., *The man is splattering a canvas* for *The man is splattering a canvas with paint; The woman rubs baby lotion* for *The woman rubs the baby with lotion*). Non-sentence errors included strings of words that did not include a verb (e.g., *The man he he the man… the beer the cooler*). Verb and noun substitutions were sentences with a semantically or syntactically off-target verb (e.g., *feeding* for *handing*) or off-target noun (e.g., *woman* for *(male) worker*). Finally, 'other' errors included responses with multiple error types, unintelligible, or abandoned responses.

Results and discussion

Young and older adults produced 'correct' responses in 98% (1871/1900) and 96% (1756/1824) of the total responses respectively ($t(37) = .817$, p =. 419, equal variances assumed). PWA produced 'correct' sentences in 76% (955/1248) of the trials, which was significantly lower than the accuracy of OA (96%; $t\,(30) = 3.502$, $p = .004$, equal variances not assumed).

The results of syntactic entrainment effects are presented in Figure 2 by the proportions of preferred responses under different prime conditions. The breakdown for each action type is presented in Table 3. The maximal model to converge included random by-participant and by-item intercepts as well as by-participant slopes for prime and group and by-item slopes for prime, group, and their interaction. The prime factor significantly improved the model fit ($\chi^2\,(1) = 25.84$, $p < .001$), indicating that the participants were more likely to use a preferred structure for a picture in the target block when the confederate used a preferred structure for the same picture in the prime block. However, the group factor did not improve the model fit ($\chi^2\,(1) = 2.32$, $p = .127$). Importantly, the interaction between prime and group improved the model fit, thus, it was kept in the model ($\chi^2\,(1) = 4.83$, $p = .02$). YA were more likely to produce a preferred structure when primed with a preferred structure (M (SD) = 75% (11)) compared to when primed with a non-preferred structure (62% (15); $t(19) = 5.939$, $p <$. 001). The strength of the YA group's syntactic entrainment resulted in a large effect size (Cohen's $d = .94$). However, no entrainment effects were found for OA or PWA (OA: 73% (14) preferred prime versus 69% (13) non-preferred prime; $t(19) = 1.820$, $p = .085$; PWA: 78% (15) preferred prime versus 76% (16) non-preferred prime; $t(12) = -.3000$, $p = .769$).

The results of error analyses for PWA are provided in Table 4. Error analyses were not conducted for YA and OA, because they produced few errors. PWA produced various types of errors. Due to a limited number of samples per error type, no statistical analyses were performed. The most common errors were role-reversal errors, responses with non-target structures, and incorrect argument structure errors.

To summarize, the results from Experiment 1 indicate that YA demonstrate syntactic entrainment in a comprehension-based collaborative picture matching task, replicating Gruberg et al. (under review): when they hear an event described using a particular syntactic structure, they are more likely to use that structure subsequently when describing the same event. However, neither OA nor PWA showed reliable syntactic entrainment effects when they simply heard their confederate partner's sentences, indicating their ability to re-use previously heard syntactic structures was reduced compared to healthy young adults.

Experiment 2

In Experiment 2, we tested if PWA and OA demonstrate syntactic entrainment effects when the task involved oral repetition of the primes, thereby increasing the depth of encoding the prime's syntactic structures. The task from Experiment 1 was modified so that the participants repeated their partner's sentences during card matching (prime) block, obligating prior production of the prime sentence structures. The remainder of the experiment was the same as in Experiment 1.

Methods

Participants.—Experiment 2 included 12 healthy OA (6 men, 6 women), and 8 PWA secondary to a left ischemic or hemorrhagic cerebrovascular accident (4 men, 4 women). Nine OA and 4 PWA also had participated in Experiment 1 at least 9 months prior. An additional 1 PWA had participated in Experiment 1 six months before Experiment 2. The participants played the game with a different confederate partner from Experiment 1. Participant information is presented in Table 5. The OA and PWA were matched for age and years of education (t's(18) < .933, p's > .362). All participants had normal or corrected-to-normal vision, were monolingual speakers of American English, and had no reported history of neurological (prior to stroke) or psychological disorders. All participants passed a hearing screening at 500, 1000, and 2000 Hz at 40dB in at least one ear. In addition, all OA scored 4.0/4.0 on the Clinical Severity Rating of the CLQT (Helm-Estabrooks, 2001), ruling out the presence of age-related cognitive decline in the participants. PWA performed significantly worse than OA on the Picture Pointing span measures ($t(18)$'s > 5.18, p's < .01) and the Corsi forward span ($t(17) = 2.39$, $p < .05$) but not on the Corsi backward span ($t(17) = 1.87$, $p > .05$).

On the WAB-R (Kertesz, 2006) and the NAVS (Thompson, 2011), the PWA showed generally similar patterns as in Experiment 1. They demonstrated relatively intact auditory comprehension of single words and sentences, as measured by the Auditory Comprehension (AC) section of the WAB-R, and the Verb Comprehension Test (VCT) and Sentence Comprehension Test (SCT) of the NAVS. While greater variability was noted in verbal expression, the PWA demonstrated ability to produce single nouns and verbs as well as different types of sentences at least 50% of the time, as measured by the Naming section of the WAB-R, and the Verb Naming Test (VNT) and sentence production subtests (ASPT and SPPT) of the NAVS. Importantly, we included PWA whose Repetition score was higher than 8/10 to ensure that the PWA were able to repeat the confederate's sentences in the experimental task. None exhibited more than mild apraxia of speech via an informal screening.

Materials.—The same stimulus materials and design as Experiment 1 were used in Experiment 2.

Procedure, coding and analyses.—The same picture matching game was used as in Experiment 1, with one modification: during the priming block of 12 pictures, after the confederate described each picture card as the director, participants were asked to repeat the confederate's sentence before they found and placed the matching card in order. One repetition of the prime sentence by the confederate was permitted upon request. As in Experiment 1, after the participant matched all 12 cards, the participants switched roles to be the director. Then in the production block, the participant described the same 12 pictures for the confederate to match. The response of primary interest were the sentence structures that the participant produced in the production block. As in Experiment 1, there were approximately 10–12 intervening trials between the prime (confederate's sentence that participant had to repeat during the matching block) and the target (the participant's self-generated sentence during the production block). This procedure was repeated for a total of 4 decks of pictures (12 pictures/deck). Then, the whole game was repeated, resulting in a total of 96 trials per participant.

To ensure that the analysis of syntactic entrainment effects included only the target sentences that the participant produced following correct repetition of the prime, thus ensuring that they fully encoded the syntactic structure of the prime, we excluded trials where the participant failed to repeat the confederate's sentence correctly in the matching block. Repetitions that did not include all the nouns and verb in the correct word order were considered as 'inaccurate' repetitions. In the same fashion as Experiment 1, the participants' responses produced during the production block were determined to be correct (target responses) vs. incorrect (errors). The correct responses were then coded as preferred or non-preferred structures. The same error analysis was conducted for incorrect responses. For statistical analyses, we followed the same procedures as in Experiment 1.

Results and discussion

OA and PWA correctly repeated prime sentences 99% (1151/1152) and 95% (733/768) of the time respectively. Of the trials in which the participants correctly repeated the confederate's prime sentences, OA and PWA showed 98% (1132/1151) and 82% (608/733) accurate target (either preferred or non-preferred target structure) sentences in the production block. The group difference was significant, indicating that message-to-structure mapping is impaired in PWA ($t(18) = 2.678$, $p = .031$, equal variances not assumed).

The syntactic entrainment effects from Experiment 2 are presented in Table 3 and Figure 3. The maximal model to converge included random by-participant and by-item intercepts as well as the by-participant and by-item slopes for prime, group, and their interaction. The prime factor significantly improved the model fit ($\chi^2(1) = 31.35$, $p < .001$). The group factor was not reliable ($\chi^2(1) = 2.25$, $p = .133$). Importantly, the prime by group interaction term ($\chi^2(1) = .041$, $p = .839$) did not improve the model fit, indicating that both older adults and PWA showed significant entrainment effects. The OA produced on average 18% more preferred structures after the confederate's production of preferred (M (SD) = 82% (16)) than non-preferred structures (64% (12); $t(11) = 6.319$, $p < .001$). The syntactic entrainment effect size in OA was large ($d = 1.25$, Cohen, 1992). In parallel, the PWA were 24% more likely to produce preferred structures in the preferred vs. non-preferred primes, with the effect size of $d = .69$ (M (SD) = 77% (11) vs. 53% (18); $t(7) = 2.967$, $p = .021$)[1].

Figure 4 shows the magnitudes of syntactic entrainment effects for individual PWA. Although there was individual variability in the magnitudes of syntactic entrainment, all but one PWA showed positive syntactic entrainment in Experiment 2.

Table 4 also summarized the frequency of different error types produced in Experiment 2. Although PWA still produced various types of errors, qualitative comparisons revealed that PWA produced notably smaller proportions of role-reversal errors and sentences with non-target structures in Experiment 2 compared to in Experiment 1.

To summarize, both our OA and PWA showed significant syntactic entrainment effects when they not only heard but also repeated the confederate's sentences during the matching block, although the effect size was somewhat reduced for PWA. In addition, seven out of eight PWA showed syntactic entrainment effects. These results contrast with the results from the comprehension-to-production picture matching task (Experiment 1), where OA and PWA failed to show syntactic entrainment. We now turn to the implications of the current results.

General Discussion

The present study investigated the newly discovered phenomenon of *syntactic entrainment* (Gruberg et al., under review) as a means to better understand the mechanisms of syntactic alignment in individuals with stroke-induced aphasia and their healthy older adult counterparts. Current theories of syntactic alignment posit that interlocutors' tendency to converge on syntactic structures is a pervasive and persistent phenomenon in human dialogue, reflecting choices that language users make to ease information transfer or the processes of language learning (Bock & Griffin, 2000; Chang et al., 2006; 2012; Jaeger & Snider, 2013; Pickering & Garrod, 2004; Reitter et al., 2011). However, little is known about if and to what extent the mechanisms of syntactic alignment remain resilient in speakers with impaired grammatical encoding, with a potential to ameliorate their message-syntax mapping deficits. We examined whether persons with stroke-induced aphasia demonstrate syntactic entrainment in a set of collaborative picture matching tasks. In Experiment 1, the participant simply listened to the confederate's sentences ('primes') during the picture matching, while in Experiment 2, the participant orally repeated the primes during picture matching, thereby encouraging greater depth of processing for the prime sentences prior to target production.

[1]Because some of our participants also participated in Experiment 1 (6–14 months prior), we ran an additional model to confirm that prior participation in Experiment 1 did not influence the magnitude of syntactic entrainment effect in Experiment 2. We included Completion of Experiment 1 (completed or not) and Prime type and their interaction as fixed factors and by-participant and by-item intercepts as random effects. The entrainment effect did not vary as an effect of participants' having completed Experiment 1 ($\chi^2(1) = 0.002$, $p = .968$).

Our findings demonstrated that there are robust and enduring syntactic entrainment effects in both persons with aphasia and healthy older adults at least in Experiment 2. In Experiment 1, when the primes were processed via comprehension only during the matching game, young adults showed a robust tendency to re-use the syntactic structure previously produced by the confederate conversational partner to describe the same event content in the production block. The average entrainment effect of 13% found in our young adults closely replicates the 12.6% effect in Gruberg et al. (under review), indicating that our stimuli were effective in eliciting a syntactic entrainment effect. However, syntactic entrainment effects were not statistically significant in healthy older adults and participants with aphasia. Healthy older adults demonstrated only a numerically greater tendency (mean 4% difference) to re-use preferred structures following preferred vs. non-preferred primes. For participants with aphasia, although they were successfully able to complete picture matching and produce the target sentences in 76% of the total trials, they did not converge on the syntactic structures that their partner used to describe particular pictures.

However, in Experiment 2, both healthy older adults and participants with aphasia clearly demonstrated ability to align message-structure associations with their partner. Healthy older adults were 18% more likely to re-use the confederate's syntactic structures to describe the picture cards in the target production block, which occurred about 10–12 trials after, with the effect size being large ($d = 1.25$; Cohen, 1992; Dunlap, Cortina, Vaslow, & Burke, 1996). More importantly, participants with aphasia also demonstrated a clearly significant syntactic entrainment effect (mean 24% difference, $d = .69$), although their effect size was smaller than that of the healthy older group. The reduced effect size suggests that there is greater individual variability in the aphasic group, compared to the healthy older counterparts, mostly likely due to brain lesions in addition to aging. However, when individual variability was taken into account in the mixed effects models, the group difference in syntactic entrainment was not statistically significant, suggesting that participants with aphasia overall showed a comparable entrainment effect as healthy older adults.

The finding that participants with aphasia showed a comparable magnitude of syntactic entrainment effect as older adults is interesting given their demonstrated evidence of mapping deficits on other measures. Recall that they produced significantly fewer correct sentences compared to older adults in both experiments. In addition, they showed various levels of impairments on a set of clinical tests assessing sentence production (ASPT, SPPT_C, and SPPT_NC of the NAVS in Table 6, for example). These data suggest that they indeed are impaired in message-to-structure production, though the severity may vary across participants. Despite these impairments, our participants with aphasia showed a persistent syntactic entrainment effect in Experiment 2 at both group and individual levels. Additionally, qualitative comparisons of error types between the experiments revealed that our participants with aphasia produced notably fewer role-reversal errors and sentences with non-target structures in Experiment 2, indicating that their message-structure associations became strengthened, when they were successfully 'entrained' by the primes. Taken together, these findings suggest that syntactic entrainment is mostly likely preserved and persistent in persons with aphasia, robust to their mapping deficits.

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The series of converging data from Experiment 2 shed light on the nature of grammatical encoding in aphasia. This is the first evidence demonstrating that persons with aphasia have preserved ability to develop associations between event semantics and surface syntactic structure in alignment with their conversational partner in a dialogue setting. This indicates that the mechanisms of syntactic alignment extend to a deeper semantic level, beyond the levels of surface phrasal nodes as shown in most previous syntactic priming studies with aphasia, and suggests that syntactic alignment in the aphasic system could occur as extensively as in normal system, spreading across different levels of representations (Pickering & Ferreira, 2008; Pickering & Garrod, 2004). This evidence in turn is inconsistent with accounts of aphasia that posit capacity to build syntactic representations is lost or syntactic knowledge as such are underspecified in the aphasic system (e.g., Caramazza & Zurif, 1976; Friedmann, 2000; Friedmann & Grodzinsky, 1997; Grodzinsky, 2000; Saffran et al., 1980; Schwarz et al., 1980). Instead, the current work provides support for the processing accounts of mapping deficits in aphasia (e.g., Kolk, 1995; Kolk & Heeschen, 1992; Lee et al., 2015; Linebarger et al., 2000; Thompson et al., 2015). Significant syntactic entrainment found in Experiment 2 suggests that both event-semantic and syntactic phrasal representations are present in their grammatical encoding system and they become more easily accessible when provided adequate support -- in this case, prior encoding of the target semantics-syntax mapping via the conversational partner's sentences or primes. Furthermore, the results of Experiment 2, especially given how large and persisting the effect was in our participants with aphasia, suggest that syntactic entrainment is a possibly powerful way to implement as a therapeutic technique to strengthen grammatical encoding processes in persons with aphasia.

It is worth considering why our healthy older and aphasic participants failed to show significant syntactic entrainment effects in Experiment 1, in contrast to the clear entrainment effects seen in Experiment 2. Recall that in Experiment 1, we used a task that did not obligate encoding of primes' syntactic structures: participants simply heard the confederates' sentences (primes) during the matching task, whereas they also repeated the primes in Experiment 2. Therefore, the lack of significant entrainment effects in Experiment 1 could be due to this difference in the depth of encoding for prime sentences. It is possible that our participants simply relied on lexical items (e.g., a noun) to identify corresponding pictures during the matching block, instead of fully attending to the syntax of the prime sentence. It is also possible that the activated syntactic structure might have decayed too fast when they simply comprehended the primes, failing to bias their future production of syntactic structures, especially in the current task where the target sentence was produced after 10–12 intervening utterances. This is a feasible possibility especially given that both aging and aphasia are associated with reduced memory for syntax (Kemper, Greiner, Marquis, Prenovost, & Mitzner, 2001; Kemper & Sumner, 2001; Kemper, Thompson, & Marquis, 2001 for healthy aging; Caplan & Waters, 1999; Caplan, Waters, DeDe, Michaud, Reddy, 2007 for evidence in both aging and aphasia).

Within the scope of current results and considering the absence of prior studies examining syntactic entrainment in aging and aphasia, it is difficult to delineate whether and what different cognitive processes or strategies underlie the null results between our healthy older adults and participants with aphasia. For example, there is only one published study by

Hardy, Messenger and Maylor (2017) examining syntactic priming in older adults using a dialogue-like task. Their older adults showed a large syntactic priming effect (25.2% difference) on production of transitive sentences, different from the non-significant 5% entrainment effect found in our older adults for transitives in Experiment 1 (Table 3). However, their study examined only immediate, not lasting, priming effects and priming across different, not same, event contents. Therefore, it is difficult to make direct comparisons with the current study. Future work is needed to systematically investigate the influence of different time intervals and individuals' loci of cognitive-linguistic deficits on the magnitudes of syntactic entrainment/priming in older adults as well as in persons in aphasia.

The current findings also provide implications for models of normal syntactic alignment. The biggest take-home message from the current study is that humans' tendency to re-use previously experienced message-structure mappings to facilitate future grammatical encoding is by and large operative and enduring in aging and impaired grammatical encoding systems, provided that task conditions encourage sufficient depth of processing of the syntactic structures. In line with the Interactive Alignment Model (Pickering & Garrod, 2004) and adaptation model (Jaeger & Snider, 2013), the present findings show that both healthy older and aphasic speakers do converge on syntactic structures to refer to specific events with their interlocutors. This convergence process may serve to ease overall language processing and information transfer for healthy older adults and persons with aphasia in a goal-driven communication task.

The robust syntactic entrainment found in our participants with aphasia expand learning-based models of syntactic priming by showing that a phenomenon like syntactic priming in fact may also reflect the mechanisms of syntactic re-learning in impaired speakers, not just normal language acquisition or learning. This perspective would be in line with the error-based implicit learning model (Chang et al., 2006; 2012), as the model holds that implicit syntactic learning is a life-long process. However, comprehension only-based prior linguistic experience did not transfer to the participants' production system in Experiment 1, at least with the number of utterances used in the current design. This somewhat deviates from the implicit learning model whereby comprehension-based errors are predicted to be sufficient to modify future syntactic production because weight-changing errors are created during incremental comprehension of language input and the sequencing system is shared between the modalities. The Reitter et al. (2011)'s hybrid learning model may be better able to explain our dissociated findings between Experiments 1 and 2 in terms of memory-based activation. In Experiment 1, shallower processing of prime sentences might have resulted in too little increase in base-level activation of the target syntactic structures over competing alternatives in our participants. However, a more active encoding and retrieval of the target syntactic structures via repetition of primes in Experiment 2 might have caused significant changes in the base-level activation of the target structure even after some decay, biasing future syntactic production in our participants.

To conclude, the current study investigated a newly discovered phenomenon of syntactic entrainment in persons with aphasia in order to better understand the nature of impaired grammatical encoding in aphasia. Specifically, it was investigated whether persons with aphasia and healthy older adults have preserved ability to develop event content-syntax associations in response to their conversational partner's sentences using a set of dialogue-like collaborative picture matching tasks. Both persons with aphasia and healthy older adults demonstrated a large and enduring syntactic entrainment effect when encoding of the primes' message-syntax associations was ensured. The effect was comparable between the groups. These findings suggest that the associations between event semantics and syntactic structures can be strengthened via syntactic entrainment in line with processing accounts of mapping deficits in aphasia. The findings also inform current models of syntactic alignment by demonstrating that the mechanisms of syntactic entrainment remain by and large resilient in aging and impaired systems.

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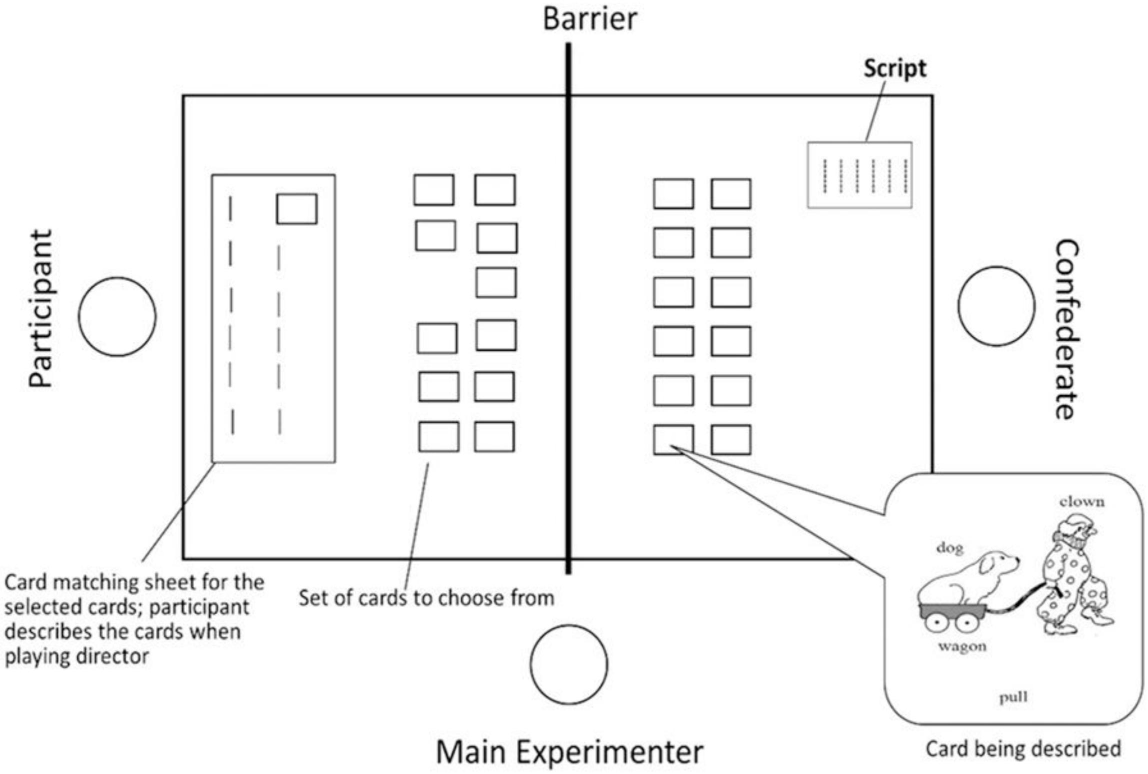

Figure 1.
Set-up of the syntactic entrainment experimental task.

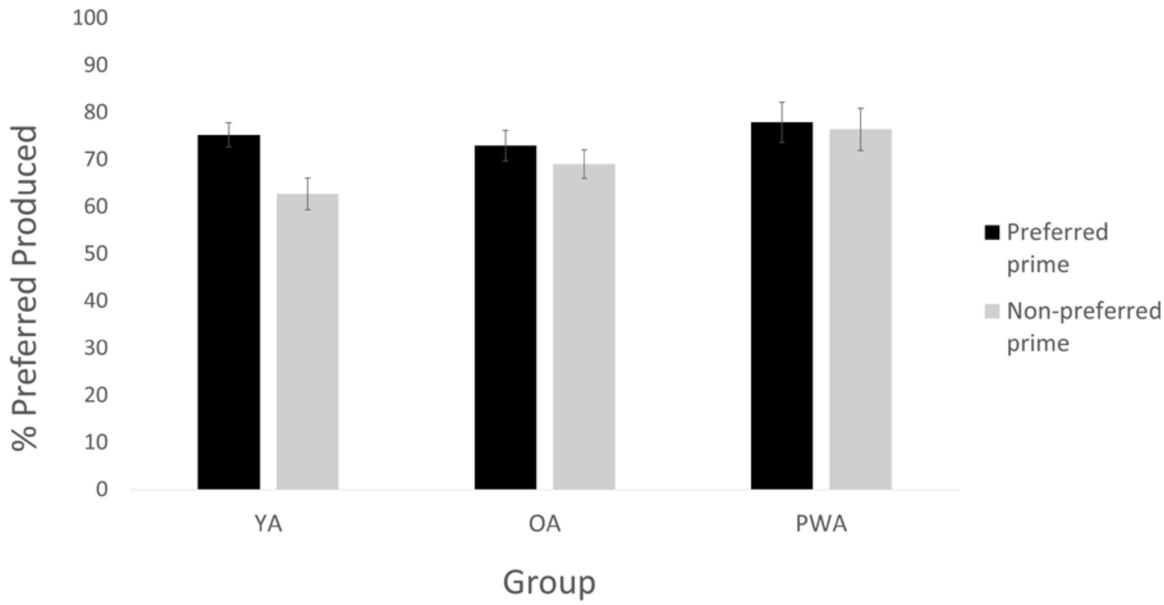

Figure 2.
Percent of preferred structures produced under preferred versus non-preferred primes (with standard errors) for young adults, older adults, and participants with aphasia for Experiment 1.

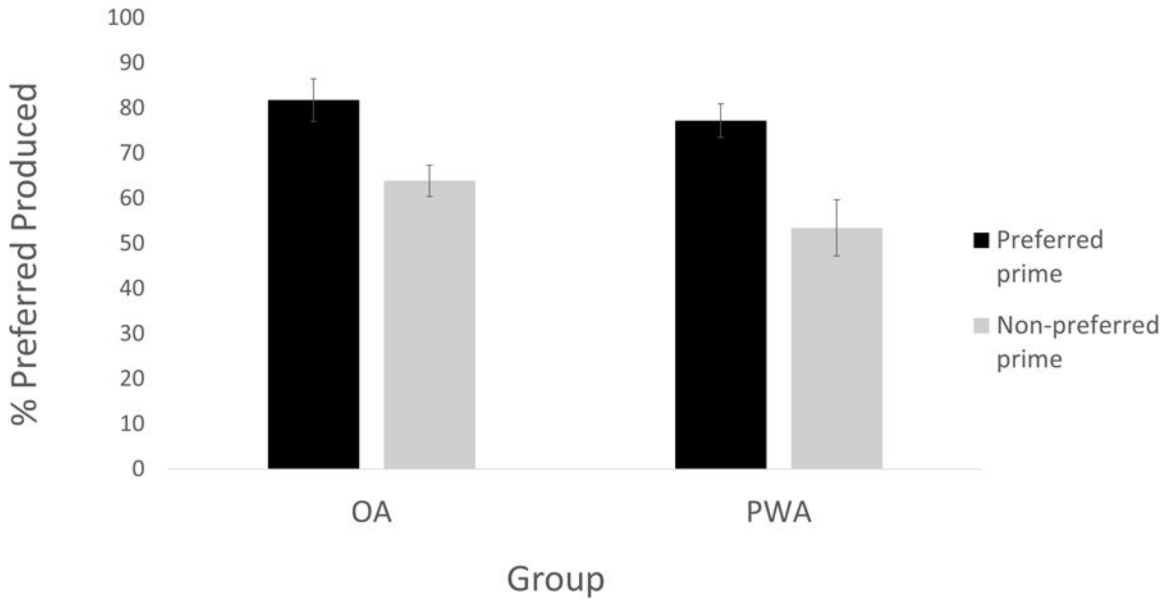

Figure 3.

Percent of preferred structures produced under preferred versus non-preferred primes (with standard errors) for older adults and participants with aphasia in Experiment 2.

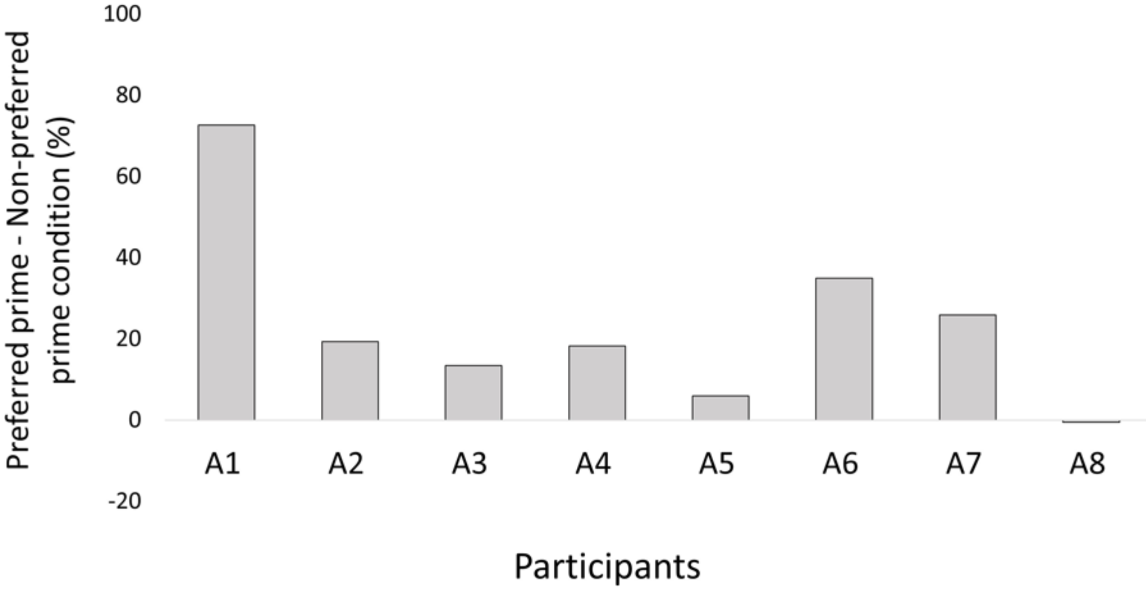

Figure 4.
The magnitude of syntactic entrainment effect (% difference in production of preferred sentences) for individual participants with aphasia, Experiment 2

Table 1.

Participants' demographic information and test scores (group means and standard deviations), Experiment 1

Group	Age	Education (yrs)	Shipley's Vocabulary	Picture Pointing Span		Corsi Block Span	
				Forward	Backward	Forward	Backward
YA	20.6 (2.2)	14.1 (1.6)	31.8 (2.8)	5.6 (1.0)	4.9 (1.2)	5.7 (.6)	5.9 (.9)
OA	69.0 (7.6)	16.7 (3.0)	34.4 (3.8)	5.1 (.7)	4.4 (.8)	4.9 (.8)	5.0 (.7)
PWA	61.8 (9.2)	17.3 (2.8)	N/A	2.9 (.5)	2.1 (.9)	4.6 (.9)	4.7 (1.1)

Table 2.

Language testing scores for participants with aphasia, Experiment 1

	WAB-R					NAVS						
Participant	**AQ (100)**	**Fluency (10)**	**AC (10)**	**Naming (10)**	**Rep (10)**	**VNT (100)**	**VCT (100)**	**ASPT (100)**	**SPPT_C (100)**	**SPPT_NC (100)**	**SPC_C (100)**	**SCT_NC (100)**
A1	73.9	5	7.4	8.7	6.8	72.7	100	78.1	86.7	66.7	93.3	73.3
A2	83	5	9.6	9.1	9.8	90.9	100	100	100	87	100	100
A3	87	6	9	9.5	10	90.9	100	100	100	93.3	100	100
A4	78.5	5	7.5	8.7	9	81.8	95.5	46.9	26.7	20	60	73.3
A5	86.4	6	9.8	8.6	9.8	90.9	100	93.8	93.3	80	100	86.7
A6	79.6	5	10	9	6.8	95	100	100	87	33	100	73
A7	89.8	8	10	9.1	8.8	86	100	100	100	93	87	60
A8	75.5	5	9.5	8.1	7.2	95.5	100	100	100	66.7	100	80
A9	67.4	5	7.9	7.5	4.3	77	100	97	27	0	93	7
A10	65.3	4	8.1	5.2	8.4	50	100	100	47	53	53	53
A11	81.5	5	8.2	9.2	9.4	86	100	94	93	73	80	73
A12	85.4	9	9.2	7.9	8.6	68	86.4	96.8	100	87	100	87
A13	83	5	10	10	9.2	97	100	100	100	93	100	100
Mean	79.7	5.6	8.9	8.5	8.3	83.2	98.6	92.8	81.6	65.1	89.7	74.3
SD	7.5	1.4	1.0	1.2	1.6	13.3	3.9	15.1	28.2	30.3	16.1	25.0

Note. AQ = Aphasia Quotient, AC = Auditory Comprehension, Rep = Repetition, VNT = Verb Naming Test, VCT = Verb Comprehension Test, ASPT = Argument Structure Production Test, SPPT = Sentence Production Priming Test, SCT = Sentence Comprehension Test. All reported NAVS values = total % correct.

Table 3.

Proportions of preferred responses (actives, PO, on-locative variant) under preferred (Pref) vs. non-preferred (Non-pref) prime conditions for Experiment 1 and 2.

Group	Transitive		Dative		Locative		Overall	
	Pref	Non-pref	Pref	Non-pref	Pref	Non-pref	Pref	Non-pref
Experiment 1								
YA	0.81	0.67	0.66	0.56	0.79	0.65	0.75	0.62
OA	0.74	0.69	0.71	0.68	0.76	0.71	0.73	0.69
PWA	0.73	0.79	0.82	0.74	0.81	0.75	0.78	0.76
Experiment 2								
OA	0.86	0.6	0.77	0.63	0.81	0.69	0.82	0.64
PWA	0.92	0.62	0.63	0.55	0.72	0.34	0.77	0.53

Table 4.

Error types produced by PWA for Experiments 1 and 2

	Experiment 1		Experiment 2	
Error types	**Number**	**Percent**	**Number**	**Percent**
Role reversal errors	70	24%	18	14%
Non-target structure	44	15%	6	5%
Incorrect argument structure	58	20%	32	25%
Non-sentence	11	4%	19	14%
Verb substitution	17	6%	0	0%
Noun substitution	8	3%	4	3%
Other	82	28%	50	39%
Total	290	100%	129	100%

Note. Values reported as count of errors (percentage out of total errors).

Table 5.

Participants' demographic information and test scores (group means with standard deviations), Experiment 2

Group	Age	Education (yrs)	Picture Pointing Span		Corsi Block Span	
			Forward	Backward	Forward	Backward
OA	69.3 (7.5)	15.4 (3.0)	5.2 (.7)	4.4 (.9)	5.0 (.5)	4.9 (.7)
PWA	65.6 (9.9)	16.0 (3.2)	2.8 (1.3)	2.1(1.0)	3.9 (1.1)	4.1 (1.0)

Table 6.

Language testing scores for participants with aphasia, Experiment 2

	WAB-R					NAVS						
Participant	**AQ (100)**	**Fluency (10)**	**AC (10)**	**Naming (10)**	**Rep (10)**	**VNT (100)**	**VCT (100)**	**ASPT (100)**	**SPPT_C (100)**	**SPPT_NC (100)**	**SCT_C (100)**	**SCT_NC (100)**
A1	65.3	4	8.1	5.2	8.4	50	100	100	47	53	53	53
A2	81.5	5	8.2	9.2	9.4	86	100	94	93	73	80	73
A3	85.4	9	9.2	7.9	8.6	68	86.4	96.8	100	87	100	87
A4	83	5	10	10	9.2	97	100	100	100	93	100	100
A5	77.5	5	9.1	8.7	8.1	86.4	100	90.6	86.7	46.7	100	100
A6	92.9	9	9.4	9.5	8.6	91	100	97	100	100	100	100
A7	97.4	9	10	9.7	10	95.4	100	100	100	100	100	100
A8	74.3	4	8.4	7.4	8.4	90.1	81.8	53	60	40	60	60
Mean	82.2	6.3	9.0	8.5	8.8	83.1	96.0	91.4	85.8	74.1	86.6	84.1
SD	10.2	2.3	0.8	1.6	0.6	16.1	7.5	15.9	20.8	24.6	19.9	19.6

Note. AQ = Aphasia Quotient, AC = Auditory Comprehension, Rep = Repetition, VNT = Verb Naming Test, VCT = Verb Comprehension Test, ASPT = Argument Structure Production Test, SPPT = Sentence Production Priming Test, SCT = Sentence Comprehension Test. All reported NAVS values = total % correct.