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Grammatical encoding and learning in agrammatic aphasia: Evidence from structural priming

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ABSTRACT

The present study addressed open questions about the nature of sentence production deficits in agrammatic aphasia. In two structural priming experiments, 13 aphasic and 13 age-matched control speakers repeated visually- and auditorily-presented prime sentences, and then used visually-presented word arrays to produce dative sentences. Experiment 1 examined whether agrammatic speakers form structural and thematic representations during sentence production, whereas Experiment 2 tested the lasting effects of structural priming in lags of two and four sentences. Results of Experiment 1 showed that, like unimpaired speakers, the aphasic speakers evinced intact structural priming effects, suggesting that they are able to generate such representations. Unimpaired speakers also showed reliable thematic priming effects in all conditions; agrammatic speakers did so as well in most experimental conditions, suggesting that access to thematic representations may be intact. Results of Experiment 2 showed structural priming effects of comparable magnitude for aphasic and unimpaired speakers. In addition, both groups showed lasting structural priming effects in both lag conditions, consistent with implicit learning accounts. In both experiments, aphasic speakers with more severe language impairments exhibited larger priming effects, consistent with the "inverse preference" prediction of implicit learning accounts. The findings indicate that agrammatic speakers are sensitive to structural priming across levels of representation and that such effects are lasting, suggesting that structural priming may be beneficial for the treatment of sentence production deficits in agrammatism.

Introduction

Structural priming has played a central role in the development of models of normal sentence production (Pickering & Ferreira, 2008). For example, priming of syntactic structures without overlap of lexical items implies that mental representations of abstract syntax are independent of lexical items (Bock, 1986, 1989; Bock & Loebell, 1990). Further, the results of structural priming studies have contributed substantially to the understanding of how conceptual information (e.g., animacy, thematic roles) is mapped onto syntactic structure during sentence production (Bock, Loebell, & Morey, 1992; Branigan, Pickering, & Tanaka, 2008; Cai, Pickering, & Branigan, 2012; Köhne, Pickering, & Branigan, 2014; Pappert & Pechmann, 2014). In recent years, structural priming has also been argued to play a critical role in implicit language learning throughout the lifespan (Chang, Dell, & Bock,

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2006; Dell & Chang, 2014). However, structural priming has been relatively little-used to investigate the nature of sentence deficits in aphasia (though see Cho & Thompson, 2010; Hartsuiker & Kolk, 1998; Marin & Schwartz, 1998; Saffran & Martin, 1997). Structural priming studies with aphasic speakers have the potential to elucidate the nature of sentence production impairments and also inform models of normal sentence production. The present study used structural priming to address three questions about sentence production in aphasia and its implications for normal processing. First, we tested whether agrammatic speakers, like unimpaired speakers, form representations of the mapping between thematic and syntactic structure during sentence production. Second, we investigated whether aphasic speakers show lasting priming effects, consistent with intact implicit language learning ability. Third, we tested the hypothesis that more severe language impairments would be associated with larger priming effects, consistent with error-based learning accounts of structural priming (Chang et al., 2006; Dell & Chang, 2014).

Approximately 25% of stroke survivors with aphasia exhibit *agrammatism* (Pedersen, Vinter, & Olsen, 2004), which is characterized by nonfluent language production with syntactically simple utterances and frequent grammatical errors (Bastiaanse & Thompson, 2012). Grammatical impairments in agrammatic aphasia affect several aspects of language production. Individuals with agrammatic aphasia have greater difficulty producing sentences with complex verb-argument structures (e.g., dative sentences) compared to those with simpler structures (e.g., intransitive and transitive sentences) (Cho-Reyes & Thompson, 2012; Thompson, Lange, Schneider, & Shapiro, 1997). They also have difficulty producing syntactically complex sentences such as passives and embedded clauses (Caplan & Hanna, 1998; Cho-Reyes & Thompson, 2012; Faroqi-Shah & Thompson, 2003). On some theories, agrammatic sentence production deficits stem from an underspecification of linguistic representations (Friedmann & Grodzinsky, 1997), precluding the ability to generate fully-specified grammatical sentences, whereas other accounts link these deficits to impaired grammatical encoding, i.e., inability to implement grammatical representations in real-time (Cho & Thompson, 2010; Lee, Yoshida, & Thompson, 2015; Linebarger, Schwartz, Romania, Kohn, & Stephens, 2000).

One goal of research on language production in aphasia is to situate these deficits within psycholinguistic models of language production, which include stages such as message formation, lexical selection, grammatical function assignment, and morphosyntactic encoding (Bock & Ferreira, 2014; Bock & Levelt, 1994) and, in turn, to use aphasic deficit (and learning) patterns to inform these models. Agrammatic speakers frequently produce role reversal errors in semantically-reversible sentences (e.g., *The boy was chased by the girl* for *The girl was chased by the boy*) (Cho & Thompson, 2010; Saffran, Schwartz, & Marin, 1980; Thompson & Lee, 2009), suggesting deficits in the mapping from thematic roles (e.g., Agent, Theme) to syntactic structures (grammatical functions such as subject and object, or syntactic positions defined configurationally) (Bastiaanse & van Zonneveld, 2005; Cho & Thompson, 2010; Saffran et al., 1980; Schwartz, Linebarger, Saffran, & Pate, 1987; Schwartz, Saffran, Fink, Myers, & Martin, 1994; Thompson & Lee, 2009). In contrast, agrammatic speakers tend to exhibit relatively spared use of animacy information during sentence production, producing few role-reversal errors in semantically-irreversible sentences in which the subject and object have different animacy features (e.g., *The boy painted the picture*) (Saffran et al., 1980). Models of normal sentence production differ with respect to how conceptual-semantic information (thematic roles, animacy) is mapped onto syntactic structure (Bock et al., 1992; Branigan et al., 2008; Cai et al., 2012; Köhne et al., 2014; Pappert & Pechmann, 2014), and the abovementioned findings from aphasia suggest distinct mapping processes for thematic roles and animacy. Other errors produced by agrammatic speakers, such as omission and substitution of function words and grammatical morphology, point to deficits in morphosyntactic encoding (Caplan & Hanna, 1998; Faroqi-Shah & Thompson, 2003). Many individuals with agrammatic aphasia exhibit impairments in both thematic mapping and morphosyntactic encoding (Thompson et al., 2013); however, these substages of sentence production can be selectively impaired (Nespoulous et al., 1988), consistent with the distinct representation of these substages in models of normal sentence production.

Structural priming studies have provided some insight into the nature of agrammatic sentence production deficits. These studies have generally found intact structural priming effects in aphasic speakers, indicating a preserved ability to access and generate syntactic representations during sentence production in the face of otherwise impaired ability to generate grammatical sentences. Saffran and Martin (1997) examined structural priming in five participants with varying aphasia types. Participants described pictures after repeating transitive (active, passive) or dative prime structures. Priming was found for transitive structures, that is, more passive sentences were produced following passive vs. active primes and vice versa. No priming was found for dative structures; however, dative sentence production significantly increased in a sentence elicitation task administered before and after the experiment. In another study, Hartsuiker and Kolk (1998) assessed priming of transitive and dative structures in 12 Dutch-speaking agrammatic aphasic and 12 age-matched control participants. The authors manipulated experimental instructions across three sessions: participants were told to repeat sentences and (1) describe pictures to aid memory, (2) describe pictures without a memory task, and (3) reuse the prime structures to describe pictures. Control participants exhibited significant priming effects only with explicit instructions to reuse the previous structure, whereas aphasic speakers exhibited priming effects of similar magnitude across structures and test sessions. In a third study, Marin and Schwartz (1998) examined priming of closed-class words and grammatical morphology in six individuals with mild agrammatic aphasia and nine unimpaired adults. Both participant groups evinced priming for prepositions in locative phrases (e.g., *The man was **in** the car vs. The man*