Time course of grammatical encoding in agrammatism

Abstract

Two on-line sentence production experiments explored the time course of grammatical encoding in normal and agrammatic speakers. Incremental models suggest grammatical encoding proceeds in a word-by-word manner, without advanced planning. Structural models suggest a hierarchical predicate structure (e.g., verb argument structure, VAS) is encoded prior to speech onset. Results showed that when agrammatic speakers produced sentences in a pre-defined order, they produced sentences incrementally, similar to controls. However, in a free sentence production task, both controls and agrammatic speakers encoded VAS prior to speech onset. Further, agrammatic speakers' syntactic deficits resulted in a greater use of VAS than controls.

Introduction

Producing a sentence involves encoding a nonlinguistic message into a grammatical structure, by retrieving lexical items and integrating them into a sentence structure (Bock & Levelt, 1994; Levelt, 1995). It has been suggested that individuals with agramamtism are impaired in grammatical encoding (Bastiaanse & van Zonneveld, 2004, 2005; Lee & Thompson, 2004 and others). However, whether and how their grammatical encoding processes differ from those of normal speakers has not been investigated. This study examined the time course of grammatical encoding in agrammatism.

Predictions come from two competing views of sentence production. In the incremental model of production, the unit of grammatical encoding is each lexical item. Thus, speakers begin their utterance upon planning the minimal unit of the utterance (i.e., one word) and coordinate planning and speaking during speech (Griffin, 2001; Kempen & Heonkemp, 1983; Shriefers, Teruel, & Meinshausen, 1998). While this simultaneous planning and speaking allows an efficient use of processing resources, a failure in timely coordination results in disfluent and erred production. In contrast, the structural model suggests that speakers encode a hierarchical structure of the sentence predicate (e.g., verb argument structure, VAS) prior to speech onset, lessoning conflicts between concurrent planning and execution of speech (Lindsley, 1975; Ferreira, 2000; Meyer, 1996). Most evidence from normal speakers suggests that language production is highly incremental. However, few studies have focused on the use of VAS and little attention has been given to how grammatical encoding unfolds in impaired systems. In this study, two experiments examined real-time planning of two different sentence types in normal and agrammatic speakers.

Experiment 1

Experiment 1 examined production of a sentence with a fixed order, using eyetracking. Fifteen young controls and 12 agrammatic speakers participated. Participants described a set of three object pictures, using the sentence 'the A (*sofa*) and the B (*kite*) are above the C (*pen*)'. For each word position, codability (name agreement) was manipulated, resulting in the A-low, B-low, and C-low codable conditions. Each of the three conditions was compared to the baseline condition in which all three pictures were highly codable nouns. Previous studies have shown that pictures with low codability (low name agreement, e.g., *oven/stove*) result in greater difficulty retrieving the lemma compared to highly codable nouns (high name agreement, e.g., *bed*), reflected by increased speech latencies and gaze durations in young and older healthy speakers (Griffin, 2001; Snodgrass & Vanderwart, 1980). Participants' speech onset latencies and gaze durations to each picture were measured. Gaze durations of each picture were aligned with speech onset latencies of the first word (A) to examine whether or not the picture's lemma was prepared before or after speech onset of the sentence. It was predicted that if speakers prepare only the 1st word before speaking (the incremental model), speakers will show longer speech onset time and gaze duration to low-codable A vs. high-codable A *prior to speech onset*, but the codability effects for B and C will appear *during speech*. Conversely, if speakers prepare more than the 1st word (the structural model), the codability effects for B were also predicted to be seen *prior to speech onset*.

<u>*Results*</u>

Control speakers prepared to name only the first word (A), before they began speaking. They spent longer time to begin speaking when A had low codability (1,062ms) than the baseline condition (923ms) ($p < .001$, t-test). However, speech onset latencies from the B-low (933ms) and C-low codable (929ms) conditions were not different from that of the baseline condition (p's $> .05$, t-tests). Gaze duration measures further supported this finding (Figure 1). Controls gazed at A longer when it had low codability compared to when it had high codability *prior to speech onset* ($p < .05$, t-test). However, they gazed at low codable B and C longer than high codable B and C, respectively, *during speech* (p's $< .05$, t-tests), suggesting the B and C were prepared after speech onset of A.

Agrammatic speakers showed the same pattern as controls. Their speech onset latencies were longer in the A-low codability condition (2,503ms) than in the baseline condition (1,933ms) ($p < .01$, t-test). However, their speech onset latencies from the B-low (2,047 ms) and C-low codability (2,037ms) conditions were not different from that of the baseline condition (1,933 ms) (p's $>.05$, t-tests). For gaze durations (Figure 1), they gazed at A longer when it had low codability compared to when it had high codability *prior to speech onset* ($p < .01$, t-test), suggesting that they prepared only A prior to speech onset. However, they showed longer gaze durations to low codable B and C than high codable B and C, respectively, *during speech* (p's $< .01$, t-tests).

Experiment 2

Experiment 2 examined whether VAS is encoded prior to speech onset, using a lexical prime paradigm. Twenty-five young controls, 20 age-matched controls, and 15 agrammatic speakers were tested. Participants described pictures with an alternating transitive action after they orally read a verb prime. Half of the pictures elicited a transitive sentence (*the man is rolling a tire*) and the other half elicited an unaccusative sentence (*the tire is rolling*). Verb primes consisted of nonalternating transitive (*kick*) and unaccusative verbs (*rise*). Each target sentence was elicited twice, following a prime verb whose argument structure was consistent with that of the target sentence (1a, 2a in Table 1) vs. one whose argument structure was inconsistent with that of the target sentence (1b, 2b). It was hypothesized that if VAS is encoded prior to speech onset, speech onset latencies (RTs) will be faster when a prime verb's argument structure is consistent with that of the target sentence, compared to when it is not.

Results

Table 2 shows the results with *p*-values. Young and age-matched controls showed significantly faster RTs (speech onset latencies) in the transitive-transitive condition compared to the unaccusative-transitive condition; however, statistically reliable differences between the unaccusative-unaccusative and transitive-unaccusative conditions were not found. Agrammatic speakers showed significantly faster RTs in the transitive-transitive compared to the unaccusative-transitive condition. In addition, for the unaccusative targets, they showed significantly faster RTs in the unaccusative-unaccusative than in the transitive-unaccusative condition.

Discussion

Results from Experiment 1 showed that when speakers produced a sentence in a pre-defined order, both controls and agrammatic speakers plan only the first lemma prior to speech onset and plan the rest during speech, consistent with the incremental model of sentence production and previous findings in normal speakers (Griffin, 2001; Shriefers et al., 1999). However, importantly, Experiment 2 revealed that when speakers are not asked to use a particular sentence structure, they encoded VAS information as part of the initial sentence planning. Both controls and agramamtic speakers showed facilitation in speech onset times followed by a consistent VAS prime for transitive targets. Further, agrammatic speakers showed significant priming effects in the unaccusative condition, which are known to be impaired in this population. Taken together, these findings suggest that hierarchical syntactic information is utilized actively from the earliest stage of sentence production in agrammatism, consistent with structural models of sentence production (Ferreira, 2000; Lindsley, 1975; Lee & Thomspon, 2010, in press). Further theoretical and clinical implications will be discussed.

Figure 1. Mean time gazing at each picture (with SE) before and after speech onset of A for young controls (top) and agrammatic speakers (bottom figure), Experiment 1

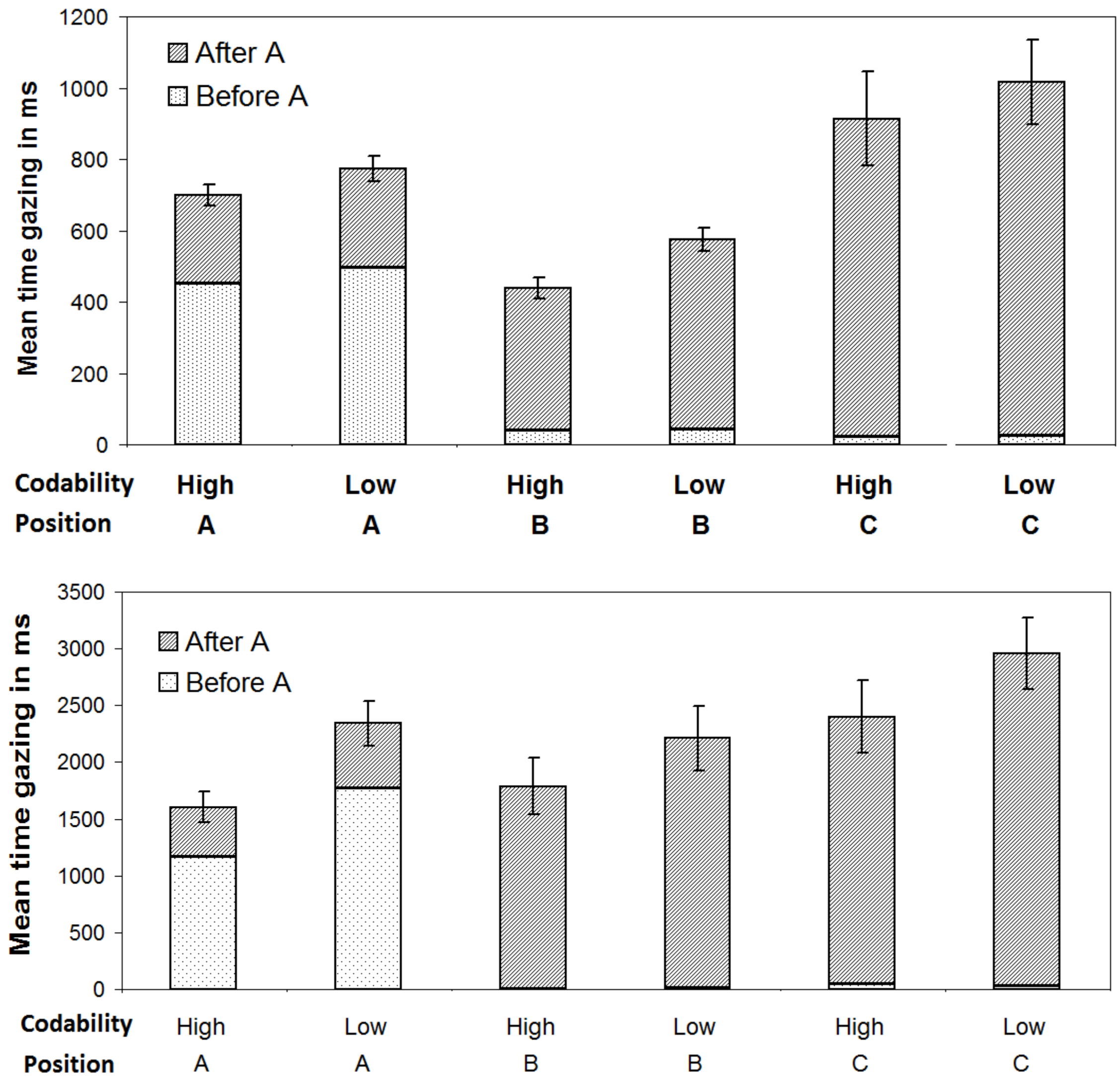

Table 1. Experimental conditions and sample stimuli, Experiment 2

Prime-target pairs	Prime verb	Target Sentence
1a. Transitive-Transitive	kick [NP_{agent}[V NP_{theme}]]	The man is rolling a tire. [NP_{agent}[V NP_{theme}]]
1b. Unaccusative - Transitive	rise [NP_{theme} [V]]	The man is rolling a tire. [NP_{agent}[V NP_{theme}]]
2a. Unaccusative - Unaccusative	rise [NP_{theme} [V]]	The wheel is rolling. [NP_{theme} [V]]
2b. Transitive - Unaccusative	kick [NP_{agent}[V NP_{theme}]]	The wheel is rolling. [NP_{theme} [V]]

Table 2. Experiment 2 results: accuracy (% correct) and RT (speech onset times in msec) data for correct trials only.

Target	Transitive			Unaccusative		
Prime	Trans	Unacc	*p*-value	Unacc	Trans	*p*-value
Young controls						
Accuracy	81	89	<.001	81	83	n.s.
RT	1,110	1,169	< .001	1,044	1,062	n.s.
Age-matched controls						
Accuracy	90	91	n.s.	81	80	n.s.
RT	1,244	1,318	< .001	1,220	1,242	n.s.
Agrammatic speakers						
Accuracy	57	61	n.s.	41	51	< .05
RT	3,099	3,334	< .001	3,300	3,756	< .001

Note: Trans = Transitive, Unacc = Unaccusative, *p*-values: paired t-tests, 2-tailed.