Brain & Language 123 (2012) 183–190

Contents lists available at SciVerse ScienceDirect

Brain & Language

journal homepage: www.elsevier.com/locate/b&l

# Elicitation of specific syntactic structures in primary progressive aphasia

Jessica DeLeon [a], Benno Gesierich [a], Max Besbris [a], Jennifer Ogar [a], Maya L. Henry [a], Bruce L. Miller [a], Maria Luisa Gorno-Tempini [a], Stephen M. Wilson [a,b,c,*]

[a] Memory and Aging Center, Department of Neurology, University of California, San Francisco, United States
[b] Department of Speech, Language and Hearing Sciences, University of Arizona, United States
[c] Department of Neurology, University of Arizona, United States

ARTICLE INFO

*Article history:*
Accepted 9 September 2012
Available online 6 October 2012

*Keywords:*
Syntax
Production
Primary progressive aphasia
Voxel-based morphometry

ABSTRACT

Many patients with primary progressive aphasia (PPA) are impaired in syntactic production. Because most previous studies of expressive syntax in PPA have relied on quantitative analysis of connected speech samples, which is a relatively unconstrained task, it is not well understood which specific syntactic structures are most challenging for these patients. We used an elicited syntactic production task to identify which syntactic structures pose difficulties for 31 patients with three variants of PPA: non-fluent/agrammatic, semantic and logopenic. Neurodegenerative and healthy age-matched participants were included as controls. As expected, non-fluent/agrammatic patients made the most syntactic errors. The structures that resulted in the most errors were constructions involving third person singular present agreement, and constructions involving embedded clauses. Deficits on this elicited production task were associated with atrophy of the left posterior inferior frontal gyrus.

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## 1. Introduction

Primary progressive aphasia (PPA) is a neurodegenerative syndrome in which focal degeneration of language areas leads to progressive language deficits, with other cognitive domains relatively spared (Gorno-Tempini et al., 2011; Mesulam, 1982, 2001). There are three widely recognized variants of PPA. Non-fluent/agrammatic PPA is characterized by agrammatism and/or apraxia of speech (Grossman et al., 1996; Hodges & Patterson, 1996); semantic PPA (also known as semantic dementia) involves deficits in lexical and semantic knowledge (Hodges, Patterson, Oxbury, & Funnell, 1992; Snowden, Goulding, & Neary, 1989; Warrington, 1975); and logopenic PPA is associated with phonological and word-finding deficits (Gorno-Tempini et al., 2004, 2008). The three variants differ in terms of distribution of atrophy (Gorno-Tempini et al., 2004) and underlying pathologies (Grossman, 2010; Snowden et al., 2011).

Syntactic production and comprehension are impaired in non-fluent/agrammatic PPA and to some extent in logopenic PPA, but are relatively spared in semantic PPA (Gorno-Tempini et al., 2004; Grossman et al., 1996; Hodges & Patterson, 1996; Thompson, Ballard, Tait, Weintraub, & Mesulam, 1997; Wilson, Dronkers, et al., 2010; Wilson, Henry, et al., 2010; Wilson et al., 2011; for review see Wilson, Galantucci, Tartaglia, & Gorno-Tempini, 2012). Assessment of syntactic production is not always straightforward. Most studies that have investigated syntactic production in PPA have done so by quantitative analysis of samples of connected speech (Ash et al., 2006, 2009; Bird, Lambon Ralph, Patterson, & Hodges, 2000; Graham, Patterson, & Hodges, 2004; Gunawardena et al., 2010; Knibb, Woollams, Hodges, & Patterson, 2009; Meteyard & Patterson, 2009; Orange, Kertesz, & Peacock, 1998; Patterson, Graham, Lambon Ralph, & Hodges, 2006; Patterson & MacDonald, 2006; Rogers & Alarcon, 1998; Thompson et al., 1997; Thompson, Cho, et al., 2012; Wilson, Henry, et al., 2010). While this approach provides rich and comprehensive data, the unconstrained nature of elicited narratives or picture descriptions poses several challenges. Individuals differ in terms of which syntactic structures they will select to tell a narrative or describe a scene. Therefore, it is difficult to determine which particular syntactic structures are difficult for patients, because some patients may attempt challenging structures, resulting in errors, whereas others may produce simplified structures in order to avoid errors (Wilson, Henry, et al., 2010). Furthermore, sometimes when patients make errors, it is not possible to determine the intended structure with certainty.

An alternative approach, which has been employed in just a few studies, is to use elicited production tasks (Thompson, Meltzer-Asscher, et al., 2012; Weintraub et al., 2009). Weintraub et al. (2009) proposed the Northwestern Anagram Test (NAT), which requires that patients assemble words on printed cards to produce sentences describing pictures. The words that are provided (the first few of which are placed for the patient) constrain the sentence that can be produced. Using the NAT, the authors showed that PPA patients perform more poorly on non-canonical syntactic structures—passives, object wh-questions, and object relatives—than

* Corresponding author Address: Department of Speech, Language and Hearing Sciences, University of Arizona, P.O. Box 210071, Tucson, AZ 85721, United States.
*E-mail address:* smwilson@u.arizona.edu (S.M. Wilson).

0093-934X/$ - see front matter Published by Elsevier Inc.
http://dx.doi.org/10.1016/j.bandl.2012.09.004

they do on canonical structures. However PPA patients were not divided according to variants in that study. In a subsequent study, impairments on the NAT were linked to reduced cortical thickness in the left inferior frontal gyrus, ventral sensorimotor cortex, and supramarginal gyrus (Rogalski et al., 2011).

In another study from the same group, Thompson, Meltzer-Asscher, et al. (2012) investigated syntactic production in non-fluent/agrammatic and logopenic patients using two elicitation procedures. In one, the Sentence Production Priming Test (SPPT), the experimenter would describe a picture using a particular sentence structure, and the patient was required to describe another picture using the same structure. In the other, a sentence completion task was used to elicit verbs in various finite or non-finite forms. The authors showed that non-fluent/agrammatic patients have specific difficulties with non-canonical structures such as passives, object wh-questions, and object relatives, and with production of finite verb forms. Their performance was better when they produced canonical structures and non-finite verb forms. In contrast, logopenic patients made comparatively few errors, and did not show the same decrement in performance on non-canonical structures and non-finite verb forms (Thompson, Meltzer-Asscher, et al., 2012).

These elicited production studies have provided valuable data about production of syntactic structures in PPA. However, only a limited range of structures have been investigated so far. Furthermore, the NAT and the SPPT likely make significant demands on executive processes and verbal working memory, which may complicate interpretation. Finally, while Thompson, Meltzer-Asscher, et al. (2012) compared non-fluent/agrammatic and logopenic patients, no study has examined syntactic production using an elicited production procedure in all three PPA variants.

In this study, we investigated syntactic production in the three variants of PPA, using an elicited production task (Goodglass, Gleason, Bernholtz, & Hyde, 1972) to probe production of eleven specific syntactic structures varying in complexity. This simple story completion task is easily understood by patients and appears to make limited demands on other processes. The primary aim of the study was to determine which structures are difficult for patients with PPA. A secondary aim was to identify brain regions where atrophy was predictive of syntactic production deficits as quantified by this elicited production task.

## 2. Methods

### 2.1. Participants

Six groups of participants were recruited through the UCSF Memory and Aging Center: three variants of PPA; patients with behavioral variant fronto-temporal dementia (bvFTD); patients with other neurodegenerative diseases (“mixed neurodegenerative”); and healthy age-matched controls. The bvFTD and mixed neurodegenerative groups were included as neurodegenerative control groups. All participants gave written informed consent, and the study was approved by institutional review boards at UCSF and the University of Arizona.

Participants received a comprehensive evaluation including a neurological history and examination, neuropsychological testing, and neuroimaging. Patients were diagnosed with PPA based on recently published criteria (Gorno-Tempini et al., 2011), with bvFTD according to established criteria (Neary et al., 1998), or with other neurodegenerative diseases (see below). The mixed neurodegenerative group were patients whose language was evaluated because they had some language symptoms, but for whom language was not the primary complaint. Additionally, participants were required to be fluent in English, and to have sufficiently preserved language abilities to be able to complete the task.

A total of 58 individuals took part in the study. There were 16 patients with non-fluent/agrammatic PPA, 7 with semantic PPA, 8 with logopenic PPA, 6 with bvFTD, 9 with other neurodegenerative diseases, and 12 healthy age-matched controls. The mixed neurodegenerative group comprised patients who were diagnosed with Alzheimer’s disease ($N = 4$), corticobasal syndrome with suspected Alzheimer’s pathology ($N = 3$), mixed bvFTD and Alzheimer’s disease ($N = 1$), and mixed bvFTD with motor neuron disease ($N = 1$).

Demographic information and neuropsychological data for each group is presented in Table 1. The three PPA variant groups did not differ from one another in terms of age, sex, handedness, education, MMSE, CDR, age of disease onset, or years from first symptom. Because patients who could not complete the task at all were not included, our samples were composed of mild to moderate patients, as reflected in the MMSE and CDR scores.

### 2.2. Elicited production task

We used an elicited production task described by Goodglass et al. (1972) to determine which common syntactic constructions are spared or impaired in the three variants of PPA. The examiner began the task by informing the patient ‘I will begin a story and ask you to finish it in the most logical and most simple way possible’. A prompt was then read, such as the first item: ‘My friend comes in. I want him to sit down. So I say to him... what?’ The patient then typically responded ‘Sit down’ or similar. This item targets an intransitive imperative. The examiner repeated the prompt once if requested by the patient, but no other directions or prompts were given.

There were 14 targeted structures, each with two items, for a total of 28 items. However the last three structures (the last six items) rarely yielded the intended response, so we did not include those in our analysis. The complete list of prompts for the 11 structures analyzed, along with the intended responses and targeted structures are shown in Table 2.

Participants’ responses were recorded on a Sony camcorder and digitized with VirtualDub, except for one of the patients with non-fluent/agrammatic PPA who was mute and completed the task by writing. Responses were transcribed and coded by two raters (JDL and MB), both of whom were blind to patient diagnosis.

The raters coded: (1) whether the targeted syntactic construction was attempted; (2) if attempted, whether the targeted syntactic structure was produced correctly; (3) presence of any syntactic errors, e.g. missing determiners or inflections (in the target structure or in other parts of the response, regardless of whether the target structure was attempted); (4) presence of any semantic errors, defined as use of words or phrases that were inappropriate for the intended meaning or context (in the target structure or in other parts of the response, regardless of whether the target structure was attempted).

We scored a response as an attempt at the target syntactic structure if it contained all of the required elements for the particular item. For example, for item 10a to be scored as attempted, the response had to be a declarative sentence including a passive in the past tense. If the target syntactic structure was attempted, we recorded it as a correct attempt if it was free of syntactic errors. The response could still be recorded as a correct attempt if it contained semantic errors, phonological paraphasias or distortions.

We also counted the number of words produced by each subject in total. We excluded non-narrative words such as coordinating conjunctions and comments that did not directly address the prompt. We excluded filled pauses, i.e. words such as ‘ah’ or ‘um’. We also excluded false starts, which included partial words that were either followed by production of the word in completed