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Attentional resource and processing speed limitations during sentence processing in Parkinson's disease☆

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Abstract

Several studies have suggested that patients with Parkinson's disease (PD) have sentence comprehension difficulty in part because of their limited executive resources. However, these assessments confound the executive resources contributing to sentence comprehension with the resources needed for task performance. In the present study, we used a word detection technique that minimizes task demands in order to evaluate attentional and processing speed resources during the comprehension of simple sentences without subordinate clauses and sentences containing subject-relative and object-relative center-embedded subordinate clauses. We found that PD patients have poor sensitivity to phonetic errors embedded in unbound grammatical morphemes, regardless of the clausal structure of the sentence, suggesting difficulty attending to grammatical morphemes. We also found that PD patients are significantly slowed in their sensitivity to phonetic errors in content words embedded in object-relative center-embedded sentences. Slowed sensitivity to content words in object-relative sentences was correlated with timed executive measures of planning. On a traditional measure of comprehension, these PD patients were impaired for sentences containing object-relative center-embedded clauses compared to sentences with subject-relative center-embedded clauses, and comprehension of object-relative sentences was correlated with executive measures. Our findings are consistent with the claim that limited executive resources for strategic attention and processing speed contribute to the sentence comprehension difficulties of PD patients.

1. Introduction

Parkinson's disease (PD) is an akinetic-rigid disorder with clinical features of tremor, rigidity, gait instability, and bradykinesia. This is due to the depletion of monoaminergic neurotransmitters—in particular, reduced dopamine projections to the basal ganglia and a frontal-striatal-thalamic loop. About 20% of PD patients have a dementia, but another 60% demonstrate cognitive impairments without a dementia. This includes difficulty with executive functions such as planning, selective attention, working memory, inhibitory control, and information processing speed (Brown & Marsden, 1988; Brown & Marsden, 1991; Maddox, Filoteo, Delis, & Salmon, 1996; Sharpe, 1992; Taylor, Saint-Cyr, & Lang, 1986). Many of these patients also exhibit sentence comprehension difficulty. The basis for this deficit, however, is unclear. Some investigators have attributed PD patients' impaired sentence comprehension to a grammatical processing deficit (Cohen, Bouchard, Scherzer, & Whitaker, 1994; Lieberman et al., 1992; Natsopoulos et al., 1991; Ullman et al., 1997). Others have argued that a limitation in executive resources contributes importantly to the sentence comprehension deficit in PD (Geyer & Grossman, 1994; Grossman, Carvell, Stern, Gollomp, & Hurtig, 1992; Grossman, Lee, Morris, Stern, & Hurtig, in press; Waters & Caplan, 1997). The results of these studies have been difficult to interpret because the resource demands thought to contribute to sentence comprehension have been confounded by the demands associated with task performance. In the present study, we used a technique with limited resource demands to investigate the role of

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attention and processing speed in non-demented PD patients' sentence comprehension difficulty.

Sentences containing complex clauses with a non-canonical word order—such as a sentence with an object-relative center-embedded subordinate clause like "The boy that the girl hugged is friendly"—are more difficult to understand than sentences containing a subject-relative center-embedded clause like "The boy that hugged the girl is friendly" (Ferreira, Henderson, Anes, Weeks, & McFarlane, 1996; Ford, 1983; Frazier & Rayner, 1982).[1] Direct probes of sentence comprehension in PD have demonstrated an exaggeration of this effect, namely, that PD patients have disproportionately greater difficulty understanding sentences with a grammatically complex clausal structure than sentences with a simpler clausal structure (Grossman et al., 1991; Lieberman, Friedman, & Feldman, 1990; Natsopoulos et al., 1991). Evidence of this sort has been interpreted to support the claim that PD patients have difficulty processing grammatical aspects of sentences. For example, one study correlated sentence–picture matching difficulty with the impaired categorical production of speech sounds in PD (Lieberman et al., 1992). This kind of speech deficit has been observed in Broca's aphasics who are thought to have a grammatical processing impairment (Blumstein, 1995), supporting the investigators' inference that the comprehension deficit in PD is also due to a grammatical impairment. Indeed, difficulty with the rules underlying syntactically licensed long-distance dependencies in sentences may be a specific instance of a broader deficit in procedural learning and rule-based processing associated with disorders of the basal ganglia (Ullman et al., 1997). Support for this hypothesis has come from the observation that PD patients have selective difficulty producing regular past tense forms of verbs despite preserved production of irregular past tense forms, and this difficulty was correlated with the severity of the patients' motor disorder.

An alternative approach has related the deficit understanding sentences in PD to the executive resource demands associated with comprehension processes such as gap-filling (Swinney & Fodor, 1989). Syntactic operations such as gap-filling allow the listener to determine that "the boy" in "The boy that the girl hugged is friendly" is the object of "hugged" even though it is encountered non-canonically at the beginning of the sentence rather than following the verb (Chomsky, 1981). Several executive resources appear to contribute to this gap-filling process. One obvious resource is concerned with working memory, or the ability to retain the moved constituent mentally until it must be retrieved at the gap (Gibson, 1998; Zurif, Swinney, Prather, Wingfield, & Brownell, 1995). Another crucial resource during the comprehension of center-embedded clauses is concerned with information processing speed. The absence of a phonetic marker at the gap leaves the gap-filling process vulnerable to degradation unless lexical retrieval at the gap proceeds instantaneously. Comprehension impairment in agrammatic patients has been associated with slowed lexical retrieval at the gap (Swinney, Zurif, Prather, & Love, 1996; Zurif, Swinney, Prather, Solomon, & Bushell, 1993). A third resource mediates shifting attention to grammatical morphemes during the course of comprehension since they are relatively difficult to detect. Grammatical morphemes like "that" are unstressed in oral presentation, yet these words explicitly mark the clausal structure of a sentence containing a center-embedded clause. Without "that," a sentence may become ambiguous and difficult to parse (as in the center-embedded garden-path sentence "The horse raced past the barn fell") (Bever, 1970). Finally, planning may be implicated in non-canonical sentences to co-ordinate the multiple mental activities necessary for their comprehension.

The role of these executive resources has been investigated during sentence comprehension in PD. For example, one study has associated slowed lexical retrieval in PD with difficulty understanding sentences containing object-relative center-embedded clauses (Grossman et al., 2002). PD patients were studied with a lexical priming procedure using a list presentation technique where the interstimulus interval between continuously presented words was 500, 1100, or 1500 ms. We found that the subgroup of PD patients with impaired comprehension of sentences containing object-relative center-embedded clauses differs from healthy control subjects and non-impaired PD patients since the impaired subgroup primed only at the prolonged 1500 ms interstimulus interval. This resembled the slowed lexical retrieval during gap-filling seen in stroke patients with Broca's aphasia who have more obvious grammatical comprehension difficulty (Swinney et al., 1996; Zurif et al., 1993). Another study demonstrated degradation of sentence comprehension during concurrent performance of a secondary task in PD (Grossman, Kalmanson, Bernhardt, Stern, & Hurtig, 2000). We have also reported that PD patients are impaired in their ability to detect the presence and nature of phonetic errors in the grammatical morphemes of center-embedded sentences (Grossman et al., 1992). In this study, moreover,

[1] From this perspective, non-canonical sentence structures involve constituent movement, and movement of this sort leaves a "trace"—an abstract, phoneticly unrealized placeholder—in the vacated position or "gap." Traces are held to be crucial for the assignment of thematic roles in a sentence, such roles being assigned to hierarchically structured sentence positions regardless of the identity of the assignee. If a thematic position contains a trace, then the trace is assigned the appropriate thematic role and the moved constituent gets its role only indirectly, by being coindexed to the trace (indicated by the subscript "i"). In the example above, "the boy" becomes the "huggee" by being linked to a trace after the verb, as in " $[\text{The boy}]_i$ that the girl hugged t_i is friendly".