RESEARCH REPORT

A TEMPORAL LOBE FACTOR IN VERB FLUENCY

Per Östberg*, Raffaella M. Crinelli*, Rimma Danielsson, Lars-Olof Wahlund, Nenad Bogdanovic and Sven-Erik Fernaeus

(Section for Clinical Geriatrics, Neurotec Department, Karolinska Institutet, Karolinska University Hospital, Huddinge, Stockholm, Sweden; *Equal contribution)

Abstract

Verb fluency requires self-sustained verb retrieval. The brain correlates of this task are virtually unknown. We investigated the relations between verb and noun (semantic) fluency and regional brain perfusion in subjects with varying degrees of cognitive decline, ranging from very mild subjective impairment to Alzheimer's disease (AD). Data consisted of single-photon emission computed tomography (SPECT) data and temporally resolved verb and noun fluency scores from 93 participants. Impaired verb fluency was predicted by a temporal lobe hypoperfusion factor and low education, whereas high age and low perfusion in the parietotemporal-occipital region predicted impaired noun fluency. Analysis of perfusion within the temporal region indicated primary involvement of the temporal pole and medial temporal lobe in AD. This might reflect pathology of the anterior parahippocampal region, which appears early in neurodegenerative disease. Although temporal lobe structures have not usually been implicated in verb processing, early temporal pathology thus appears to contribute to impaired verb fluency in cognitive decline.

Key words: dementia, language, mild cognitive impairment, nouns, verbs

Introduction

Verb and noun deficits figure prominently among neurocognitive dissociations. In fact, the double dissociation of impaired verb/noun production was already documented in the mid-18th century (Denes and Dalla Barba, 1998; Östberg, 2003). The linguistic basis for such observations goes back to antiquity, however, with the division of words into eight parts-of-speech by Dionysius Thrax (Robins, 1989). In Dionysius' classification, a verb or *rhēma* lacked case inflection but was inflected for tense, person, and number. Semantically, verbs were defined as signifying an activity or a process performed or undergone. A noun or *ónoma*, in contrast, was characterized by case inflection and by signifying a concrete or abstract entity.

Today, verbs and nouns are considered universally distinct lexical categories, although a few languages appear to lack the distinction between nouns and verbs (see Baker, 2003, for discussion). The brain correlates of verb and noun processing remain unclear. In particular, it remains obscure whether verbs and nouns as lexical categories depend on differential brain systems or regions. Verb deficits are generally held to be associated with frontal lobe lesions, whereas noun deficits are associated with posterior lesions, in particular of the left temporal lobe. This general conclusion, however, is weakened by the tacit assumption of a one-to-one relationship between lexical category and conceptual category. Experimental stimuli have typically been drawn from conceptual categories associated with each lexical category: things, or more specifically, physical objects for nouns; and (human) activities for verbs. Nouns certainly express all physical object concepts but can also express virtually any other conceptual category, including state or activity concepts normally associated with verbs. PET studies with conceptually matched noun and verb stimuli for lexical decision have yielded largely overlapping or identical brain activation patterns (Perani et al., 1999; Tyler et al., 2001). It would appear that the complex interrelationships between lexical category, conceptual structure, and phonological structure in lexical items preclude a straightforward neural localization of noun and verb processing (Black and Chiat, 2003). It has been proposed, however, that verb processing requires more executive resources than noun processing, implying that disproportionate problems with verbs are to be expected in various brain pathologies. Action naming was indeed more impaired than object naming in frontotemporal dementia, and correlated with executive dysfunction rather than linguistic dysfunction as in Alzheimer's disease (AD) (Silveri et al., 2003; see also Cappa et al., 1998).

Recent studies have employed the verb fluency task as a measure of verb processing (Piatt et al., 1999a, 1999b, 2004; Östberg et al., 2005). Verb fluency requires self-sustained enumeration of activity verbs during one minute. It may be construed as a "pure" measure of verb retrieval in contrast to action picture naming, which involves visual perception and access to semantics from the visual system, and in contrast to verb generation in

which verbs are produced in response to stimulus nouns. In contrast to lexical decision, verb fluency also engages the speech production system. It is disproportionately impaired, as compared to noun and letter-based word fluency, in Parkinson's disease (PD) with dementia (Piatt et al., 1999a). Piatt et al. (1999a) suggested that the task is sensitive to the striatal loop pathology associated with PD. A comparable verb fluency deficit was observed in persons with HIV-1 disease, which is also associated with striatal loop pathology (Woods et al., 2005). Verb fluency has been studied in healthy elderly subjects (Piatt et al., 1999b, 2004). It was found to be in modest to moderate relation to tests of executive function, but unrelated to episodic memory and picture (i.e. noun) naming. This suggests that verb fluency taps aspects of executive function not measured by standard tests. Further statistical evidence for distinctness of the verb fluency test comes from factor analyses of verb, letter-based, and noun (category) fluency, in which verb fluency loads on a separate factor (Östberg et al., 2005).

Verb fluency contrasts with letter-based (or phonemic) fluency, that requires the enumeration of words that begin with a given letter, and with noun fluency (or category fluency or semantic fluency), that requires subjects to enumerate nouns from a taxonomy such as animals or a semantic field such as supermarket items. Noun fluency is particularly impaired in AD (Monsch et al., 1997), semantic dementia (Hodges et al., 1992), schizophrenia (Kremen et al., 2003), depression (Fossati et al, 2003; c.f., Ravdin et al., 2003), and – as compared to letter-based fluency – PD (Henry and Crawford, 2004).

In contrast to verb fluency, noun fluency and letter-based fluency are widely used in the assessment of dementia and other cognitive disorders. Although both verb and noun fluency are semantically oriented fluency tasks, they differ in important regards. First, nouns are typically used for referring, whereas verbs are typically used to predicate. The task of enumerating single verbs may therefore be considered less "natural" for the speaker than enumerating single nouns from a well-defined category. Secondly, a nominal category such as animals represents a taxonomy. This means that a particular hierarchical sense relation, taxonymy (Cruse, 1986), holds between the target words. The targeted word set is therefore characterized by a relatively "tight" configuration. The word set targeted by verb fluency, in contrast, is less tightly defined ('human activities'), with limited taxonomical structure. Some taxonomical structure or troponymy does exist among verbs but is more shallow and "bushy" than taxonymy among nouns (Fellbaum, 1998). Verb taxonomies thus tend to have fewer hierarchical levels than noun taxonomies, with a relatively large number of subordinate verbs (troponyms) for each superordinate. Thirdly, the "lead-in" concepts for verb and noun fluency differ in clarity: compare "things that people do" with "animals".

PD and AD are neurodegenerative diseases that may have relatively long preclinical and oligosymptomatic phases. Patients do not meet clinical diagnostic criteria until the neuropathological process has spread into several brain regions and caused marked devastation in structures that are affected early (Braak and Braak, 1991; Braak et al., 2003). Up to now, however, the brain correlates of verb and noun fluency deficits have not been studied in subjects with milder grades of cognitive decline, i.e., with less severe brain involvement. The neuropathological lesions of Alzheimer's and Parkinson's diseases appear very early in the anterior parahippocampal region including the perirhinal and entorhinal cortex. Severe neuronal loss in this region can precede dementia with several years, and in PD parahippocampal atrophy also appears in the same stage of the disease process as the well-known nigrostriatal pathology (Braak et al., 2003). Since lesions in the parahippocampal region not only produce deficits in recognition memory but also in executive function (Davachi and Goldman-Rakic, 2001; Chavoix et al., 2002), it is possible that verb fluency is affected not only by striatal loop pathology but also by early temporal lobe neurodegenerative changes that isolate the higher centers of the limbic loop (Östberg et al., 2005).

The present study was aimed at investigating a possible relation between impaired performance in verb and noun fluency tasks and perfusion deficits in specific brain areas in subjects with different levels of cognitive impairment. In particular, we hypothesized that signs of temporal lobe pathology are associated with decreased verb fluency. Toward that end, we used regional hypoperfusion factors derived from single-photon emission computed tomography (SPECT) and temporally resolved verb and noun fluency scores from participants assessed at a memory disorders clinic, ranging from very mild subjective cognitive decline to mild (objective) cognitive impairment and AD. Mild cognitive impairment (MCI) is associated with a strongly increased risk for dementia of the Alzheimer's type; indeed up to 84% of MCI patients show Alzheimer-type changes on neuropathological examination (Morris et al., 2001).

Material and Method

Participants

The participants (n = 93) were examined at the memory clinic, Department of Geriatrics, Karolinska University Hospital, Huddinge, because of cognitive complaints. This is a secondary/tertiary referral center with referrals from e.g. occupational