Neuropsychologia 48 (2010) 248–261

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

"Pre-semantic" cognition revisited: Critical differences between semantic aphasia and semantic dementia

Elizabeth Jefferies [a,*], Timothy T. Rogers [b], Samantha Hopper [c], Matthew A. Lambon Ralph [c]

[a] Department of Psychology, University of York, York YO10 5DD, UK
[b] University of Wisconsin-Madison, Madison, USA
[c] University of Manchester, UK

ARTICLE INFO

Article history:
Received 5 January 2009
Received in revised form 8 September 2009
Accepted 13 September 2009
Available online 18 September 2009

Keywords:
Semantic cognition
Semantic dementia
Aphasia
Pre-semantic
Reading
Verb inflection
Spelling
Lexical decision
Object decision
Colour decision
Picture copying

ABSTRACT

Patients with semantic dementia show a specific pattern of impairment on both verbal and non-verbal "pre-semantic" tasks, e.g., reading aloud, past tense generation, spelling to dictation, lexical decision, object decision, colour decision and delayed picture copying. All seven tasks are characterised by poorer performance for items that are atypical of the domain and "regularisation errors" (irregular/atypical items are produced as if they were domain-typical). The emergence of this pattern across diverse tasks in the same patients indicates that semantic memory plays a key role in all of these types of "pre-semantic" processing. However, this claim remains controversial because semantically impaired patients sometimes fail to show an influence of regularity. This study demonstrates that (a) the location of brain damage and (b) the underlying nature of the semantic deficit affect the likelihood of observing the expected relationship between poor comprehension and regularity effects. We compared the effect of multimodal semantic impairment in the context of semantic dementia and stroke aphasia on the seven "pre-semantic" tasks listed above. In all of these tasks, the semantic aphasia patients were less sensitive to typicality than the semantic dementia patients, even though the two groups obtained comparable scores on semantic tests. The semantic aphasia group also made fewer regularisation errors and many more unrelated and perseverative responses. We propose that these group differences reflect the different locus for the semantic impairment in the two conditions: patients with semantic dementia have degraded semantic representations, whereas semantic aphasia patients show deregulated semantic cognition with concomitant executive deficits. These findings suggest a reinterpretation of single-case studies of comprehension-impaired aphasic patients who fail to show the expected effect of regularity on "pre-semantic" tasks. Consequently, such cases do not demonstrate the independence of these tasks from semantic memory.

1. Introduction

Patients with semantic dementia (SD) have a highly selective and progressive impairment of semantic memory associated with bilateral atrophy of the anterior temporal lobes (ATL; Hodges, Patterson, Oxbury, & Funnell, 1992; Mummery et al., 2000; Snowden, Goulding, & Neary, 1989). Other cognitive functions, including phonology, syntax, executive skills and episodic memory, remain relatively intact in this condition. Nevertheless, SD patients show a highly predictable pattern of breakdown on a number of tasks typically thought to be "pre-semantic", including reading single words aloud (Funnell, 1996; Patterson & Hodges, 1992; Woollams, Lambon Ralph, Plaut, & Patterson, 2007); spelling to dictation (Graham, Patterson, & Hodges, 2000; Parkin, 1993); producing the past tense form of verbs from the present tense (Cortese, Balota, Sergent-Marshall, Buckner, & Gold, 2006; Patterson, Lambon Ralph, Hodges, & McClelland, 2001); lexical decision (Moss, Tyler, Hodges, & Patterson, 1995; Rogers, Lambon Ralph, Hodges, & Patterson, 2004); immediate serial recall of short lists of words (Jefferies, Jones, Bateman, & Lambon Ralph, 2004; Jefferies, Jones, Bateman, & Lambon Ralph, 2005; Knott, Patterson, & Hodges, 1997; Knott, Patterson, & Hodges, 2000); object decision, i.e., deciding if line drawings represent real objects (Breedin, Saffran, & Coslett, 1994; Hovius, Kellenbach, Graham, Hodges, & Patterson, 2003; Rogers, Hodges, Ralph, & Patterson, 2003; Rogers, Lambon Ralph, Hodges, et al., 2004) and copying drawings of objects after a brief delay (Bozeat et al., 2003; Lambon Ralph & Howard, 2000).

In all of these tasks, the input tends to specify the required output and thus might conceivably drive a response without any support from the semantic system. For example, in reading aloud, the strong connection between orthography and phonol-

* Corresponding author. Tel.: +44 01904 434368; fax: +44 01904 433181.
E-mail address: ej514@york.ac.uk (E. Jefferies).

0028-3932/$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.neuropsychologia.2009.09.011

ogy might be able to generate the correct output independently of the meaning of the word. Studies of patients with SD suggest this is not the case for all words. These patients are poor at reading items with atypical spellings that they no longer fully understand and often pronounce them as if they were more typical (i.e., show surface dyslexia with regularisation errors such as PINT rhymes with mint'; Woollams et al., 2007). This pattern suggests that semantic memory plays a critical role in deriving phonology from orthography, especially for words with unsystematic (or "irregular") orthography-to-phonology mappings (Plaut, McClelland, Seidenberg, & Patterson, 1996). A similar pattern has been observed for the other "pre-semantic" tasks listed above: SD patients show poorer comprehension of lower frequency items (Bozeat et al., 2000; Funnell, 1995) and in every task in which regularity/typicality and frequency have been orthogonally varied, studies have shown an interaction between these variables, with greater impairments observed for lower frequency items that are atypical of the domain being investigated (references above).

A recent study obtained strong evidence to suggest that the semantic memory impairment in SD is causally linked to deficits on all of these "pre-semantic" tasks, despite their disparate nature (Patterson et al., 2006). Fourteen SD patients were tested on six tasks: reading aloud, spelling to dictation, past tense generation, lexical decision, object decision and delayed picture copying. In all six tasks, every patient showed the predicted pattern of significant impairment on lower frequency irregular/atypical items; and across patients, all tasks showed a significant interaction between frequency/familiarity and typicality/regularity (the sole exception being delayed-copy drawing where familiarity was not manipulated). In addition, errors for the atypical items were largely regularisations or LARC errors (legitimate alternative rendering of components). Regularisation errors occurred when the most frequent transformation was over-applied and so these errors were more typical of the domain than the correct response (e.g., in past tense generation, creep → "creeped"). The LARC errors were similar, but this time an alternative plausible transformation was over-applied (e.g., peep → "pept" as in "crept"). Finally, in all six "pre-semantic" tests, accuracy on the irregular items was strongly predicted by the level of semantic impairment, suggesting that deficits on individual tasks are a consequence of a central semantic impairment rather than parallel damage to unrelated domain-specific mechanisms.

In a series of papers, Patterson and colleagues have put forward an explanation of the impact of semantic memory impairment on these "pre-semantic" tasks (Patterson et al., 2006; Plaut et al., 1996; Rogers, Lambon Ralph, Garrard, et al., 2004; Woollams et al., 2007). Regular items that are typical of their domain are supported sufficiently by domain-specific representations alone, without the need for the additional support which comes automatically from semantic memory (all real words and objects have an associated meaning). For example, the correspondences between orthography and phonology are sufficient for reading regular words. Domain-specific representations are less able to specify the correct transformation for atypical items, however, and as a consequence, the automatic input from semantic memory plays an important role in constraining correct production. Regularisation/LARC errors occur when domain-specific representations reflecting transformations that are typical of the domain come to dominate attempts to produce irregular targets in the absence of support from semantic memory. This theory has been implemented in computational models of reading aloud (Plaut et al., 1996), past tense generation (Joanisse & Seidenberg, 1999) and delayed picture copying (Rogers, Lambon Ralph, Garrard, et al., 2004).

Despite the strength of the empirical and theoretical work reviewed above, the view that semantic memory plays a key role in "pre-semantic" processing remains controversial. This is because semantically impaired cases sometimes fail to show the expected influence of regularity in particular tasks. For example, there are case reports of patients with profound semantic impairment who can successfully read words with irregular pronunciations (Blazely, Coltheart, & Casey, 2005; Cipolotti & Warrington, 1995; Gerhand, 2001; Lambon Ralph, Ellis, & Franklin, 1995). These dissociations, although rare, are traditionally thought of as critical within cognitive neuropsychology because they imply that semantic impairment and surface dyslexia are separable. By this view, SD patients who are surface dyslexic have two independent deficits affecting semantic memory and reading respectively.[1]

In this context, it is important to note that while the association between semantic impairment and surface dyslexia is extremely strong, especially in SD (Woollams et al., 2007), there can be notable deviations away from the expected pattern. First, there are important and stable individual differences in domain-specific efficiency that modulate the exact degree of semantic reliance in reading aloud (e.g., some individuals rely on semantic processes more or less than the group average; Dilkina, McClelland, & Plaut, 2008; Woollams et al., 2007). This results in varying degrees of surface dyslexia in patients with SD. Secondly, there might be crucial differences between patients with different aetiologies of brain damage. Although the relationship between semantic impairment and surface dyslexia is clear in SD, it may be weaker or even non-existent in other patient groups. We say "may" because there are very few studies investigating this link in other semantic syndromes. A few studies have shown that patients who have semantic impairment resulting from Alzheimer's disease (AD) have difficulty reading and spelling irregular words (Cortese, Balota, Sergent-Marshall, & Buckner, 2003; Strain, Patterson, Graham, & Hodges, 1998) and generating irregular past tense forms (Cortese et al., 2006; Ullman et al., 1997; although see Lambon Ralph et al., 1995, for an exception to this pattern); and it is known that surface dyslexia can also follow traumatic brain injury (Behrmann & Bub, 1992; Coltheart, Byng, Masterson, Prior, & Riddoch, 1983; Marshall & Newcombe, 1973). The relationship between poor comprehension and "pre-semantic" abilities in stroke aphasia has received even less attention, despite the fact that many stroke aphasic patients have comprehension problems. Furthermore, the few studies that do exist have yielded somewhat contradictory results. At least some of the hallmarks of surface dyslexia – e.g., regularisation errors – have been observed in some comprehension-impaired stroke aphasic patients (e.g., Peach, 2002), but other single-case studies demonstrate that comprehension impairment in stroke aphasia does not always give rise to such a pattern (Gerhand, 2001). At any rate, these patients often have additional phonological deficits that make it difficult to interpret patterns of performance in tasks requiring a spoken response (Peach, 2002). The effect of semantic impairment on other pre-semantic tasks – for example, past tense generation, spelling, word- or picture-recognition, and delayed picture copying – has scarcely received *any* attention in stroke aphasia, even though a comparison of tasks that utilise different input and output modalities would aid the interpretation of deficits in patients with additional phonological problems.

[1] Following the same logic, the results of Patterson et al. (2006) would result from damage to multiple independent subsystems supporting visual word recognition, visual object recognition, visual working memory, spelling, and verb inflection. Although independent deficits to semantics and domain-specific processes could readily account for problems in one task, this account is less viable when all of these domains are considered together: many different domain-specific representations, spanning a very wide range of verbal and non-verbal tasks, would have to be impaired *in parallel* following circumscribed damage to the anterior temporal cortices. Patterson et al. (2006) further note that this notion of 'associated but unrelated deficits' does not explain why SD patients show regularity effects in all of these tasks.