Neuropsychologia ■ (■■■■) ■■■–■■■

Contents lists available at ScienceDirect

Neuropsychologia

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

For richer or poorer? Imageability effects in semantic dementia patients' reading aloud

Anna M. Woollams

Neuroscience and Aphasia Research Unit, School of Psychological Sciences, Zochonis Building, University of Manchester, Brunswick Street, Manchester M13 9PL, England

ARTICLE INFO

Article history:
Received 7 October 2014
Received in revised form
17 March 2015
Accepted 20 March 2015

Keywords:
Imageability
Semantic dementia
Reading
Spelling–sound consistency
Task differences

ABSTRACT

The degree to which a word's meaning evokes a mental image exerts an influence on performance across a variety of conceptual and linguistic tasks. In normal healthy participants, this effect takes the form of an advantage for high over low imageability words. Consideration of the influence of imageability on performance of patients with semantic dementia can provide information concerning its cognitive and neural bases. Semantic dementia patients show deficits in conceptual processing tasks, and an associated enhancement of the advantage for high over low imageability words. Semantic dementia patients also show deficits in linguistic processing tasks, including reading aloud words with inconsistent spelling–sound correspondences. This study provides the first systematic exploration of the influence of imageability on semantic dementia patients' reading aloud performance. Over 10 cases, the imageability effect seen for inconsistent words was actually reversed in reaction times, with faster performance for low than high imageability items. The same reversal was observed for inconsistent words when the frequency of legitimate alternative reading of components errors was considered, and this reversed effect grew larger with increasing semantic impairment. This result is interpreted in terms of the development of stronger connections along the direct pathway between spelling and sound for low than high imageability items that are then revealed under diminished semantic activation. This interpretation emphasises the interaction between form and meaning that occurs throughout learning in connectionist models.

1. Introduction

Semantic dementia is characterised by a progressive and selective deterioration of conceptual knowledge across multiple modalities as a consequence of atrophy to the anterior temporal lobes (Hodges et al., 1992; Neary et al., 1998). Consideration of patients suffering from this disorder offers a unique opportunity to understand both the structure of semantic memory itself and also the role of semantic knowledge in supporting other cognitive functions (Rogers et al., 2004a; Patterson et al., 2006). One dimension that has long been thought to be reflected in conceptual organisation is that of imageability (Paivio, 1971). Imageability is defined as the extent to which the meaning of a word evokes a mental image. In healthy participants, a processing advantage is observed for words with high relative to low imageability meanings in a variety of tasks, including conceptual tasks like concreteness or synonym judgments (Pobric et al., 2009; Yap et al., 2012) and also in linguistic tasks like lexical decision and reading aloud (Balota et al., 2004; Strain et al., 1995). Explorations of the impact of imageability upon semantic dementia patients' performance in conceptual processing tasks have shed light on both the representational and neural bases for this effect (Hoffman et al., 2013; Hoffman and Lambon Ralph, 2011; Jefferies et al., 2009). The goal of this paper was to provide the first systematic investigation of the influence of imageability upon semantic dementia patients' reading aloud performance.

There is general agreement that our knowledge of meaning is supported by activation of a distributed network of areas that overlap with the regions that process modality specific properties such as shape, colour, motion, sound, name and action (see Fig. 1). According to distributed accounts (e.g., Martin, 2007), the co-activation of these modality specific areas is all that is required for conceptual representation. The alternative hub-and-spoke view holds that anterior temporal regions (shown in red in Fig. 1) mediate between the modality specific components of meaning and provide amodal semantic representations for all known concepts (Patterson et al., 2007). This model has been developed on the basis of data from patients with semantic dementia, where anterior temporal damage results in a multi-modal semantic deficit that not only involves language problems but also difficulties in recognition of objects, colours, sounds, tastes, and smells

E-mail address: anna.woollams@manchester.ac.uk

http://dx.doi.org/10.1016/j.neuropsychologia.2015.03.023
0028-3932/

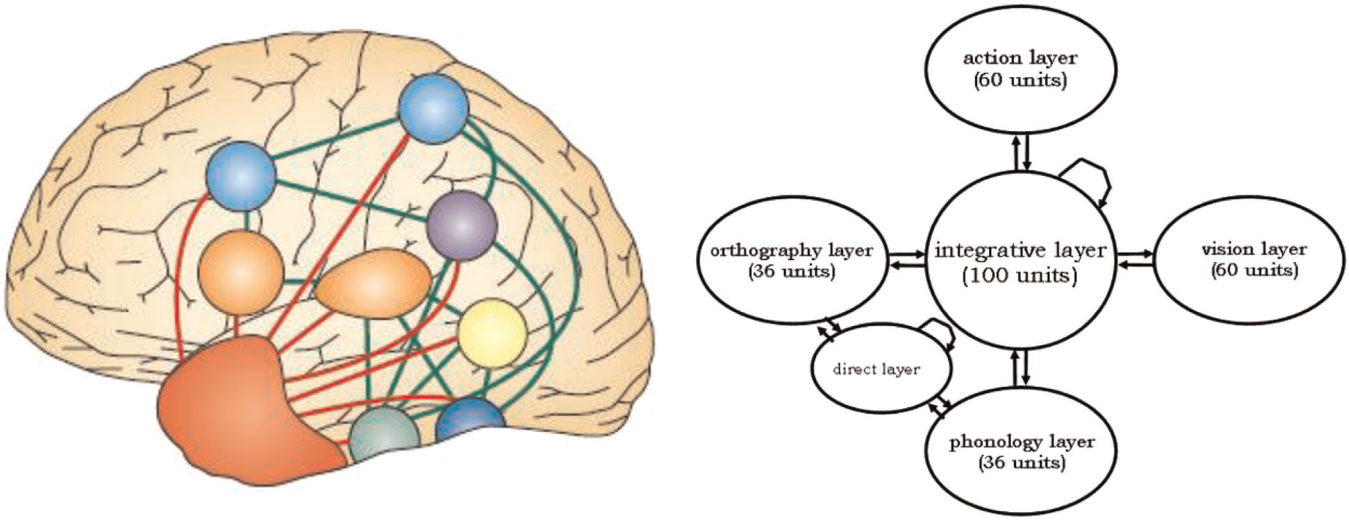

Fig. 1. The left panel depicts the neural aspects of the hub-and-spoke model of semantic representation (from Patterson et al., 2007), with colour coding reflecting the different knowledge types associated with each region: action=light blue, word forms=orange, sound=purple, motion=yellow, shape=green, colour=dark blue and amodal semantics=red. The right panel provides an example of a computational implementation of this account (from Dilkina et al., 2008) where the integrative layer contains amodal semantic representations. This model also includes the direct mappings between spelling (orthography) and sound (phonology).

(Adlam et al., 2006; Bozeat et al., 2000, 2002; Patterson et al., 2006; Piwnica-Worms et al., 2010; Rogers et al., 2004b, 2007). Although atrophy in semantic dementia does spread beyond anterior temporal regions with disease progression (Rohrer et al., 2009), it does not reliably encompass all the modality specific regions shown in Fig. 1. Indeed, voxel based morphometry studies have localised deficits in performance on both verbal and non-verbal semantic tests to the anterior temporal regions (e.g., Adlam et al., 2006; Mion et al., 2010). Further, both neuroimaging (e.g., Binney et al., 2010; Visser et al., 2010) and neurostimulation (e.g., Pobric et al., 2007; Woollams, 2012) implicate the anterior temporal lobe in semantic processing.

Computationally, the hub-and-spoke view has been implemented within highly interactive connectionist models (Dilkina et al., 2008, 2010; Rogers et al., 2004a). As shown in Fig. 1, in such models, a central integrative layer mediates between multiple sets of modality specific units. Over the course of learning, the integrative layer develops amodal semantic representations. This does not rule out direct connections between modality specific units, as shown in Fig. 1 between orthographic and phonological representation. The dimension of imageability has not been explicitly simulated in this hub-and-spoke framework, but within connectionist models more focussed on reading, the semantic representations of high imageability words have been assigned more semantic features (Plaut and Shallice, 1993) and have also been shown to contain more highly intercorrelated features (Harm and Seidenberg, 2004). Alternatively, it may be that the abstract semantic representations of high and low imageability words housed in anterior temporal lobe regions are similar in strength, but those for high imageability items are bolstered by activation of associated visual features in occipito-temporal cortex (Bonner et al., 2009). By either account, to the extent that high imageability concepts are presumed to have richer representations, then we might expect less severe deficits for high relative to low imageability words in semantic dementia (i.e., an exaggeration of the standard effect seen in healthy participants).

Surprisingly, however, a number of cases of semantic dementia have been reported to show a reversal of the imagebility effect in conceptual processing tasks, such as providing a definition to a spoken word (DRN (Cipolotti and Warrington, 1995); AB (Warrington, 1975)). In a number of other cases, this reversal of the concreteness effect in definitions has also been seen in word-to-picture matching tasks and synonymy/similarity judgements (SC (Macoir, 2009); DM (Breedin et al., 1994); MC (Papagno et al., 2009)). Such findings have also been replicated in case-series studies for verb stimuli in name selection to definition and similarity judgements (12 cases (Yi et al., 2007); 11 cases (Bonner et al., 2009)). These findings have been interpreted as reflecting that in semantic dementia, damage to visual association cortex in the ventral temporal lobes undermines performance for concrete words, but performance for abstract words then worsens as the disease progresses, as the reversed concreteness effects appear to be diminished in more severe cases (Bonner et al., 2009; Macoir, 2009). This account, however, does seem out of line with what is known in terms of the progression of atrophy in SD with increasing severity (Rohrer et al., 2009), as this spreads from the anterior temporal pole posteriorly to encompass ventral occipito-temporal regions. Indeed, Hoffman et al. (2012) have shown that sensitivity to visual features of objects in picture naming is compromised in those patients with more severe semantic impairments.

Other case-series studies have, however, shown the enhancement of the imageability effect expected according to the hub-and-spoke account across a variety of tasks. Jefferies et al. (2009) reported that in a synonym judgement task, there was an increase of the standard imageability effect seen in accuracy in semantic dementia patients relative to controls, with the effect reaching significance for 9 of the 11 cases. The same enhancement of the imageability effect is seen when repetitive transcranial magnetic stimulation is used to disrupt anterior temporal lobe function (Pobric et al., 2009). Hoffman and Lambon Ralph (2011) considered performance of 7 semantic dementia cases across a range of tasks previously used in the literature, and found a clear enhancement of the imageability effect in the synonym judgement task and a less pronounced increase picture–word association tests, but null imageability effects for the name selection to definition and similarity judgements that have previously shown reversed effects. An analysis of the stimuli used in these tasks demonstrated that an enhancement of the imageability effect is only observed when (a) there is a good separation in terms of imageability between the concrete and abstract items and (b) the frequency of abstract words was matched to that of the concrete words. Using just such stimuli, Hoffman et al. (2013) confirmed an enhancement of the imageability effect in six semantic dementia cases over synonymy judgements for nouns and verbs and also in tests of both semantic similiarity and associative relationships. It seems then that when

Please cite this article as: Woollams, A.M., For richer or poorer? Imageability effects in semantic dementia patients' reading aloud. Neuropsychologia (2015), http://dx.doi.org/10.1016/j.neuropsychologia.2015.03.023