



Comprehension of concrete and abstract words in semantic variant primary progressive aphasia and Alzheimer's disease: A behavioral and neuroimaging study



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ABSTRACT

The aim of this study was to investigate the comprehension of concrete, abstract and abstract emotional words in semantic variant primary progressive aphasia (svPPA), Alzheimer's disease (AD), and healthy elderly adults (HE). Three groups of participants (9 svPPA, 12 AD, 11 HE) underwent a general neuropsychological assessment, a similarity judgment task, and structural brain MRI. The three types of words were processed similarly in the group of AD participants. In contrast, patients in the svPPA group were significantly more impaired at processing concrete words than abstract words, while comprehension of abstract emotional words was in between. VBM analyses showed that comprehension of concrete words relative to abstract words was significantly correlated with atrophy in the left anterior temporal lobe. These results support the view that concrete words are disproportionately impaired in svPPA, and that concrete and abstract words may rely upon partly dissociable brain regions.

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1. Introduction

Semantic variant primary progressive aphasia (svPPA) is a neurodegenerative disease characterized by progressive breakdown of semantic knowledge (Hodges & Patterson, 2007; Hodges, Patterson, Oxbury, & Funnell, 1992). The most recent clinical diagnosis criteria include impaired naming, impaired word comprehension, impaired object knowledge, and surface dyslexia/dysgraphia, while repetition and speech production are spared (Gorno-Tempini et al., 2011). This syndrome is associated with bilateral atrophy of the anterior temporal lobes (ATL), typically predominating in the left hemisphere (Hodges et al., 1992).

The nature of semantic memory breakdown in svPPA has been the focus of much research in recent years, but there is still debate

concerning some of the specific deficits that characterize the semantic impairment in svPPA. One of those debates concerns the comprehension of abstract and concrete concepts. Concrete concepts are tangible entities that can be experienced via our senses and are typically highly imageable (e.g. objects). They are highly dependent upon the visual modality but also on other sensory modalities. Conversely, abstract concepts can be expressed only via language and are usually poorly imageable. A robust phenomenon known as the concreteness effect reflects an advantage in processing for concrete words (e.g. *tomato*, *computer*, *shoe*) over abstract words (e.g. *liberty*, *belief*, *trust*), both in terms of accuracy and reaction times in neurologically-intact participants (Paivio, 1991; Xiao, Zhao, Zhang, & Guo, 2012). The disadvantage in processing abstract words has also been found to be enhanced in patients suffering from neurological conditions such as acquired deep dyslexia and dysgraphia and Alzheimer's disease (AD) (Franklin, Howard, & Patterson, 1994, 1995; Peters, Majerus, De Baerdemaeker, Salmon, & Collette, 2009). According to the classical

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dual-coding hypothesis (Paivio, 1986, 1991), concrete words are better processed because they benefit from both visual and verbal coding, while abstract words benefit only from verbal coding (but see Kousta, Vigliocco, Vinson, Andrews, & Del Campo, 2011; Paivio, 2013, for a more recent debate). Thus, even though both concrete and abstract concepts can be expressed via language, concrete words have the additional advantage of being highly imageable and having richer semantic representations (Paivio, 1986, 1991). Alternatively, it has been proposed that abstract and concrete conceptual knowledge relies on qualitatively different representations, as abstract concepts, but not concrete concepts, are represented in an associative neural network (Crutch & Warrington, 2005, 2010). Lastly, the *Context Availability Theory* attributes concreteness effects to a less detailed representation in memory for abstract than concrete concepts (Schwanenflugel, Harnishfeger, & Stowe, 1988; Schwanenflugel & Shoben, 1983).

A number of studies have documented the reverse pattern in concrete and abstract word processing in svPPA patients. A number of single case studies and brief series have shown that svPPA patients were more impaired at processing concrete words than abstract words (Bonner, Ash, & Grossman, 2010; Breedin, Saffran, & Coslett, 1994; Catricala, Della Rosa, Plebani, Vigliocco, & Cappa, 2014; Macoir, 2009; Papagno, Fogliata, Catricala, & Miniussi, 2009; A. Reilly, Cross, Troiani, & Grossman, 2007; Warrington, 1975; Yi, Moore, & Grossman, 2007), an effect sometimes called reversal of the concreteness effect (RCE). This effect has been interpreted by some authors as resulting from atrophy to the inferior temporal cortex affecting visual association cortex and leading to the deterioration of visuoperceptual knowledge about objects (Yi et al., 2007). According to this view, RCE would result from a greater impairment in processing concrete words due to their imageability and crucial reliance on visual sensory knowledge (Bright, Moss, Longe, Stamatakis, & Tyler, 2007) while abstract words rely more on verbal associations.

Other studies, however, did not find this reversal of concreteness in svPPA (Hoffman, Jones, & Lambon Ralph, 2013; Hoffman & Lambon Ralph, 2011; Jefferies, Patterson, Jones, & Lambon Ralph, 2009). Authors who have not found RCE in svPPA suggested that when studying abstract and concrete word processing, studies should strictly control for factors such as word frequency and imageability of stimuli used in the semantic tasks. Indeed, they suggested that the use of higher frequency words to investigate abstract knowledge and the lack of strict control of imageability may benefit abstract words and may have resulted in RCE. A synonym judgment task combining a large manipulation of concreteness (i.e. imageability) and good control of word frequency should reliably lead to better processing of concrete words over abstract words (Hoffman & Lambon Ralph, 2011). These authors also suggested that premorbid level of functioning, such as occupation and education, may also account at least in part for RCE in the svPPA cases reported. In fact, several (but not all) of the previously reported cases of svPPA patients who showed RCE were professionals who presumably had a greater level of education and had developed more substantial abstract vocabulary, which may have helped these patients to better preserve their comprehension of abstract words (Hoffman & Lambon Ralph, 2011; Macoir, 2009). Severity of the disease was also pointed out as a potential factor modulating the presence of RCE in svPPA patients. For instance, Macoir (2009) reported the longitudinal single-case study of patient SC who initially presented RCE and greater deficits for perceptual/structural knowledge, but with disease progression RCE vanished as well the distinction between visual perceptual and non-perceptual knowledge. It is thus possible that RCE may be present earlier in the disease process, and that studies that did not find this advantage for abstract words recruited patients who were at more advanced stages.

Another factor which has not been investigated in detail in previous studies is the impact of other components that might ground concepts. Particularly, abstract concepts have been showed to be more emotionally valenced than concrete concepts (Kousta et al., 2011). Nonetheless, no study seems to have tested whether emotional words, especially abstract words, are processed similarly to non-emotional words in svPPA. Studies in normal healthy participants have found that emotional valence was accessed earlier than semantic aspects such as concreteness of verbs (Palazova, Sommer, & Schacht, 2013). Furthermore, one study showed that in AD, abstract words deteriorated more quickly than concrete words when there was no emotional valence to the words, but this difference between abstract and concrete words was not observed when emotional words were used (Giffard, Laisney, Desgranges, & Eustache, 2015). This suggests that words may be less prone to deterioration in some neurodegenerative diseases when they are emotionally anchored. It remains to be explored whether this is the case in svPPA patients.

Little is known about the neuroanatomical bases of abstract and concrete word processing in neurodegenerative diseases. Neuroimaging was reported in some case reports but only showed the pattern of atrophy, without allowing to correlate the behavioral data with RCE (Macoir, 2009; Papagno, Capasso, & Miceli, 2009; Reilly et al., 2007). Some studies found RCE in svPPA and suggested that RCE may result from underlying damage to the inferior temporal cortex causing a breakdown of structural and perceptual knowledge about concrete concepts (Macoir, 2009; Yi et al., 2007). This is supported by a study that measured cortical thickness in a subgroup of 5 svPPA patients, who showed an advantage in processing abstract verbs relative to concrete verbs, and which revealed significant cortical thinning in visual association areas within the anterior, lateral and ventral portions of the temporal lobes, while greater difficulty for concrete verbs relative to abstract words was related to thinning of the right anterior temporal cortex (Bonner et al., 2009). To our knowledge, only one recent study investigated the neural correlates of concrete and abstract word processing in a group of svPPA (Cousins, York, Bauer, & Grossman, 2016). This study, which also found RCE in svPPA, showed that the effect was associated with atrophy in the left ATL in svPPA, while a typical CE in the behavioral variant of frontotemporal dementia (bv-FTD) was associated with bilateral atrophy in the inferior frontal cortex. According to the initial “hub-and-spoke” theory of semantic memory, conceptual representations emerge from the interaction of modality-specific association cortices with a transmodal hub located in the ATL bilaterally (Patterson, Nestor, & Rogers, 2007). In a recent version of this model (Ralph, Jefferies, Patterson, & Rogers, 2017), the notion of a “graded ATL semantic hub” emerged, based on a decade of original work in this field. According to this model, a cross-modal hub is centered on the ventrolateral ATL, while semantic function varies in a graded manner across specific ATL subregions within the broader ATL. Notably, the medial ATL responds more to visual or concrete concepts due to greater connectivity to visual systems (relative to auditory or linguistic systems), whereas the anterior STS-STG responds more to abstract concepts because of its greater connectivity to language systems (Ralph et al., 2017).

Neuroimaging studies have also contributed to our understanding of concrete and abstract word processing. In a meta-analysis of the neuroimaging literature on semantic memory, Binder, Desai, Graves, and Conant (2009) reported that abstract concepts were found to activate the left inferior frontal gyrus (IFG), superior portions of the left ATL, and the superior temporal sulcus (STS). In contrast, concrete concepts were associated with more distributed activation across the two hemispheres, more specifically in bilateral angular gyrus (AG), bilateral dorsomedial prefrontal cortex, left posterior cingulate and left fusiform cortex. In another

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