Brain & Language 165 (2017) 45–54

Contents lists available at ScienceDirect

Brain & Language

journal homepage: www.elsevier.com/locate/b&l

Dissociable substrates underlie the production of abstract and concrete nouns ☆

Katheryn A.Q. Cousins *, Sharon Ash, David J. Irwin, Murray Grossman *

Department of Neurology and Penn Frontotemporal Degeneration Center, University of Pennsylvania, United States

ARTICLE INFO

Article history:
Received 29 June 2016
Revised 14 September 2016
Accepted 14 November 2016
Available online 29 November 2016

Keywords:
Semantic memory
Production
Abstract
Concrete
svPPA
bvFTD

1. Introduction

A central question in neurolinguistics is how semantic concepts - the generalizable knowledge of entities, people and events - are represented in the brain. Imaging studies in healthy subjects have identified broad networks involved in lexical and semantic processing, including the angular gyrus, the lateral and ventral temporal gyri, and the left inferior frontal gyrus (Binder, Desai, Graves, & Conant, 2009; Binney, Embleton, Jefferies, Parker, & Ralph, 2010; Davis & Gaskell, 2009; Price, 2010). Evidence suggests that semantic concepts are represented in a distributed manner, with modality-specific sensory-motor cortices, heteromodal association areas, and frontal regions being recruited partially based on modality-specific knowledge associated with the corresponding concept (Binder & Desai, 2011; Martin & Chao, 2001; Saffran, 2000). Thus, many studies have shown that different semantic and lexical categories - such as living *vs.* manufactured, or nouns *vs*. verbs - are supported, in part, by different combinations of these brain regions (Binder et al., 2009; Chao, Haxby, & Martin, 1999; Grossman et al., 2013; Luzzatti et al., 2002). One such important categorical distinction is the representation of abstract and concrete nouns. Concrete nouns typically refer to entities that are tangible and exist in the real world, and thus have perceptible features, such as appearance, feel, or sound. These sensory features are thought to be crucial for concrete noun representations, and grounded cognition and dual coding theories propose that sensory feature knowledge - predominantly of visual features - support concrete concept processing (Paivio, 1991). Thus, activation of associated sensory knowledge during concrete word comprehension recruits corresponding visual and other sensory association cortices (Barsalou, 2008; Binder & Desai, 2011; Martin, 2007). Indeed, the importance of visual feature knowledge distinguishes concrete from abstract nouns, and the dual coding theory proposes that concrete concepts have both linguistic- and sensory-based representations, while abstract concepts have only linguistically-based representations. In support of the view that concrete nouns are supported by visual features, imaging studies in controls have shown that the visual association cortex, including the left inferior temporal lobe and the left parahippocampal gyrus, are implicated in the processing of concrete compared to abstract nouns (Bonner, Price, Peelle, & Grossman, 2015; Sabsevitz, Medler, Seidenberg, & Binder, 2005; Wang, Conder, Blitzer, & Shinkareva, 2010).

In contrast, abstract nouns have minimal physical or tangible qualities, and they primarily refer to entities that exist within language and thought. Whereas sensory information is thought to be more important for processing concrete concepts, the contextual

☆ This work was supported in part by NIH (AG017586, AG038490, AG053488) and the Wyncote Foundation.

* Corresponding authors at: Department of Neurology - 3 West Gates, Hospital of the University of Pennsylvania, 3400 Spruce Street, Philadelphia, PA 19104-4283, United States.

E-mail addresses: kcous@mail.med.upenn.edu (K.A.Q. Cousins), mgrossma@mail.med.upenn.edu (M. Grossman).

http://dx.doi.org/10.1016/j.bandl.2016.11.003

and linguistic information that surrounds a word is thought to be essential for acquiring and processing abstract words (Della Rosa, Catricalà, Vigliocco, & Cappa, 2010). Because they do not have tangible referents, the meanings associated with abstract nouns are more varied and less literal (Johnson & Lakoff, 1980; Lakoff & Johnson, 1999), and abstract nouns have been shown to appear in a more diverse set of contexts (Hoffman, Ralph, & Rogers, 2013). Thus, the contextual availability hypothesis proposes that abstract concepts have increased contextual ambiguity compared to concrete concepts (Schwanenflugel, Harnishfeger, & Stowe, 1988; Schwanenflugel & Shoben, 1983; van Hell & De Groot, 1998). Abstract noun processing may thus require executive functioning systems for semantic selection and contextual integration, supported in part by portions of the frontal lobe (Hoffman, Jefferies, & Ralph, 2010). For example, when hearing the statement, "I didn't mean to offend, that's just my way", the polysemous quality of a noun like "way" requires semantic selection; to best understand this statement, the interpretation of "way" as "manner or characteristic" should be selected, and competing alternatives, such as "path or direction", should be inhibited. A likely anatomical candidate for this role of semantic control and selection in abstract noun comprehension is the left inferior frontal gyrus (Moss et al., 2005; Thompson-Schill, D'Esposito, Aguirre, & Farah, 1997), and functional imaging studies have shown that abstract word processing activates the inferior frontal gyrus more so than concrete word processing (Hoffman, Binney, & Ralph, 2015; Wang et al., 2010).

In a previous study, we examined the role of temporal and frontal regions in concrete and abstract noun comprehension using a two-alternative, forced-choice similarity task (Cousins, York, Bauer, & Grossman, 2016). Comprehension was tested in patients with semantic variant Primary Progressive Aphasia (svPPA) and behavioral variant Frontotemporal Degeneration (bvFTD), syndromes which correspond to focal regions of cortical atrophy hypothesized to be important in concrete and abstract noun processing: the ventral temporal lobes and the inferior frontal gyrus, respectively. Our findings supported a combination of grounded cognition and contextual availability theories, and demonstrated that partially dissociable substrates support the comprehension of concrete and abstract nouns, discussed below.

1.1. Impairment of concrete noun comprehension in svPPA

Also known as Semantic Dementia, svPPA is characterized by the progressive loss of verbal and non-verbal semantic memory (i.e. single word and object comprehension). Patients with svPPA present with impaired confrontation naming and lexical retrieval (Amici et al., 2007; Hodges & Patterson, 2007; Mesulam, Grossman, Hillis, Kertesz, & Weintraub, 2003), and some can also present with mild behavioral changes (Hodges & Patterson, 2007). Degeneration in svPPA tends to be most severe in the left anterior and ventral temporal lobes (Acosta-Cabronero et al., 2011; Mion et al., 2010; Rogalski et al., 2011). In our previous study, patients with svPPA had differentially worse knowledge for concrete nouns compared to abstract. This selective impairment in svPPA has been previously observed by several groups: while not seen by all (Hoffman, Jones, & Ralph, 2013; Jefferies, Patterson, Jones, & Lambon Ralph, 2009), many studies have reported differentially worse comprehension for concrete words in svPPA (Breedin, Saffran, & Coslett, 1994; Macoir, 2009), and have implicated the anterior and ventral temporal lobes in concrete word processing (Bonner et al., 2009; Bonner et al., 2015). Similarly, we found that poor concrete noun comprehension in svPPA related to atrophy of the left anterior temporal lobe, including the left inferior temporal gyrus. The inferior temporal gyrus is part of the visual processing stream and has been shown to be involved in visual object processing (Chao et al., 1999; Martin, Haxby, Lalonde, Wiggs, & Ungerleider, 1995; Miyashita, 1993). These findings are in agreement with the dual coding and grounded cognition perspectives that the representations of concrete nouns are supported by visual features, and that degradation of the visual association cortex in svPPA impairs concrete noun knowledge.

1.2. Impairment of abstract noun comprehension in bvFTD

Patients with bvFTD present with progressive behavioral or personality changes such as disinhibition, poor judgment, increased apathy, and loss of empathy (Piguet, Hornberger, Mioshi, & Hodges, 2011; Rascovsky et al., 2011; Wittenberg et al., 2008). The disease is associated with profound frontal lobe atrophy, including the orbitobasal and dorsolateral cortices and the anterior cingulate, as well as some modest atrophy to the anterior temporal lobe, which is commonly more prominent on the right than the left. In our previous study, we found that bvFTD patients are differentially worse at comprehending abstract compared to concrete nouns. This was a novel finding, since bvFTD is not typically associated with semantic deficits. This may be because traditional evaluations of semantic knowledge often have a highly concrete picture stimulus set (*e.g.* Boston Naming Test, Kaplan, Goodglass, & Weintraub, 2001; Pyramids and Palm trees, Howard & Patterson, 1992) and are thus not sensitive to the deficit for abstract concepts that we observed in bvFTD. In addition, we found that poor abstract noun knowledge related to atrophy in the inferior frontal gyrus, a region shown to be important in semantic control and selection (Moss et al., 2005; Thompson-Schill et al., 1997). These results support the assertion by the contextual availability hypothesis that executive functioning and semantic selection processes in the frontal lobe are important to abstract noun processing.

These findings in svPPA and bvFTD suggest that the grounded cognition, dual coding, and context availability perspectives, while incomplete on their own, together offer some understanding of how temporal and frontal regions can differentially support the comprehension of concrete and abstract nouns. In the present study we investigate whether atrophy to these temporal and frontal regions in svPPA and bvFTD also impairs the ability to produce concrete and abstract nouns, respectively.

1.3. Noun comprehension vs. production

While we and others (Hoffman et al., 2015; Sabsevitz et al., 2005) have found that partially dissociable regions underlie abstract and concrete noun comprehension, we do not necessarily assume that these same regions also support connected speech production for abstract and concrete nouns. The classic Broca-Wernicke-Lichtheim-Geschwind model of language processing proposes separate pathways for language comprehension and production, with Broca's area being the anatomic center of language production and Wernicke's area being essential to comprehension (Geschwind, 1970; Poeppel, Emmorey, Hickok, & Pylkkänen, 2012). Updated models suggest that, while comprehension and production operations are distinct, there may be portions of these lexical processing networks that are common to both comprehension and production (Indefrey, 2011; Price, 2010, 2012; Shalom & Poeppel, 2007). Thus, structures involved in the comprehension of concrete and abstract nouns might also be recruited to support retrieval during production.

This study aims to expand our previous work and examine the underlying structures and processes that support retrieval of abstract and concrete nouns during connected speech. To elicit semi-structured speech samples, svPPA and bvFTD patients participated in the Cookie Theft picture description task (Goodglass & Kaplan, 1983). By using the Cookie Theft picture, we were able to