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Dissociating the semantic function of two neighbouring subregions in the left lateral anterior temporal lobe

Ana Sanjuán [a,b,*], Thomas M.H. Hope [a], 'Ōiwi Parker Jones [a,c], Susan Prejawa [a], Marion Oberhuber [a], Julie Guerin [a], Mohamed L. Seghier [a], David W. Green [d], Cathy J. Price [a]

[a] Wellcome Trust Centre for Neuroimaging, University College London, London WC1N 3BG, United Kingdom
[b] Neuropsychology and Functional Imaging Group, Departamento de Psicología Básica, Clínica y Psicobiología, Universitat Jaume I, Castellón, Spain
[c] Wolfson College, University of Oxford, Oxford OX2 6UD, United Kingdom
[d] Experimental Psychology, University College London, London WC1E 6BT, United Kingdom

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ABSTRACT

We used fMRI in 35 healthy participants to investigate how two neighbouring subregions in the lateral anterior temporal lobe (LATL) contribute to semantic matching and object naming. Four different levels of processing were considered: (A) recognition of the object concepts; (B) search for semantic associations related to object stimuli; (C) retrieval of semantic concepts of interest; and (D) retrieval of stimulus specific concepts as required for naming. During semantic association matching on picture stimuli or heard object names, we found that activation in both subregions was higher when the objects were semantically related (mug–kettle) than unrelated (car–teapot). This is consistent with both LATL subregions playing a role in (C), the successful retrieval of amodal semantic concepts. In addition, one subregion was more activated for object naming than matching semantically related objects, consistent with (D), the retrieval of a specific concept for naming. We discuss the implications of these novel findings for cognitive models of semantic processing and left anterior temporal lobe function.

1. Introduction

The role of the anterior temporal lobe in semantic memory has been highlighted by studies of patients with semantic difficulties and functional imaging studies of healthy participants (for reviews, see Binder et al. (2009); Binder and Desai (2011); Lambon Ralph and Patterson (2008); Lambon Ralph (2013), Patterson et al. (2007); Price (2012); Wong and Gallate (2012)). Here, we focus on the functional responses in and around a left lateral anterior temporal lobe (LATL) region that was localised by Pobric et al. (2010) as a site where semantic matching performance was impaired during a temporary "virtual lesion" produced by repetitive transcranial magnetic stimulation (rTMS). The location of the TMS testing site was based on previous studies that reported the contribution of the same LATL region to synonym judgements and naming tasks on written words and pictures (Binney et al., 2010; Pobric et al., 2007; Lambon Ralph et al., 2009) using non-semantic control conditions such as number judgements. More recently, Visser et al. (2012) used the same semantic matching paradigm as Pobric et al. (2010) in an fMRI study and found activation in the same LATL region for the semantic compared to a perceptual matching task.

In both Pobric et al. (2010) and Visser et al. (2012), the semantic task of interest consisted of semantic association decisions on pictures of objects or their written names, using a paradigm akin to the Pyramids and Palm Trees test (Howard and Patterson, 1992). Participants were required to indicate which of the two choice stimuli that appeared at the bottom of the screen was more closely related to the target stimulus shown at the top of the screen. The control condition was a perceptual matching task on scrambled pictures or scrambled words with instructions to select which of the 2 stimuli below was a vertically flipped mirror-image of the target above. This perceptual matching baseline condition controlled for visual processing and task difficulty, but was not informative about how the LATL region of interest contributed to semantic decisions. This leaves open questions about what LATL is actually doing within the semantic system. The current study considers three possible roles for the LATL during semantic matching: (A) recognising object concepts (e.g. the concept 'grapes' from a word or picture of 'grapes'); (B) searching for associations related to each object concept (e.g. 'wine' from the presentation of 'grapes'); and (C) retrieving a semantic concept of interest (e.g. the concept 'fruit' that is common to presentations of

* Corresponding author at: Wellcome Trust Centre for Neuroimaging, University College London, 12 Queen Square, London WC1N3BG, United Kingdom.
E-mail address: anatsanjuan@gmail.com (A. Sanjuán).

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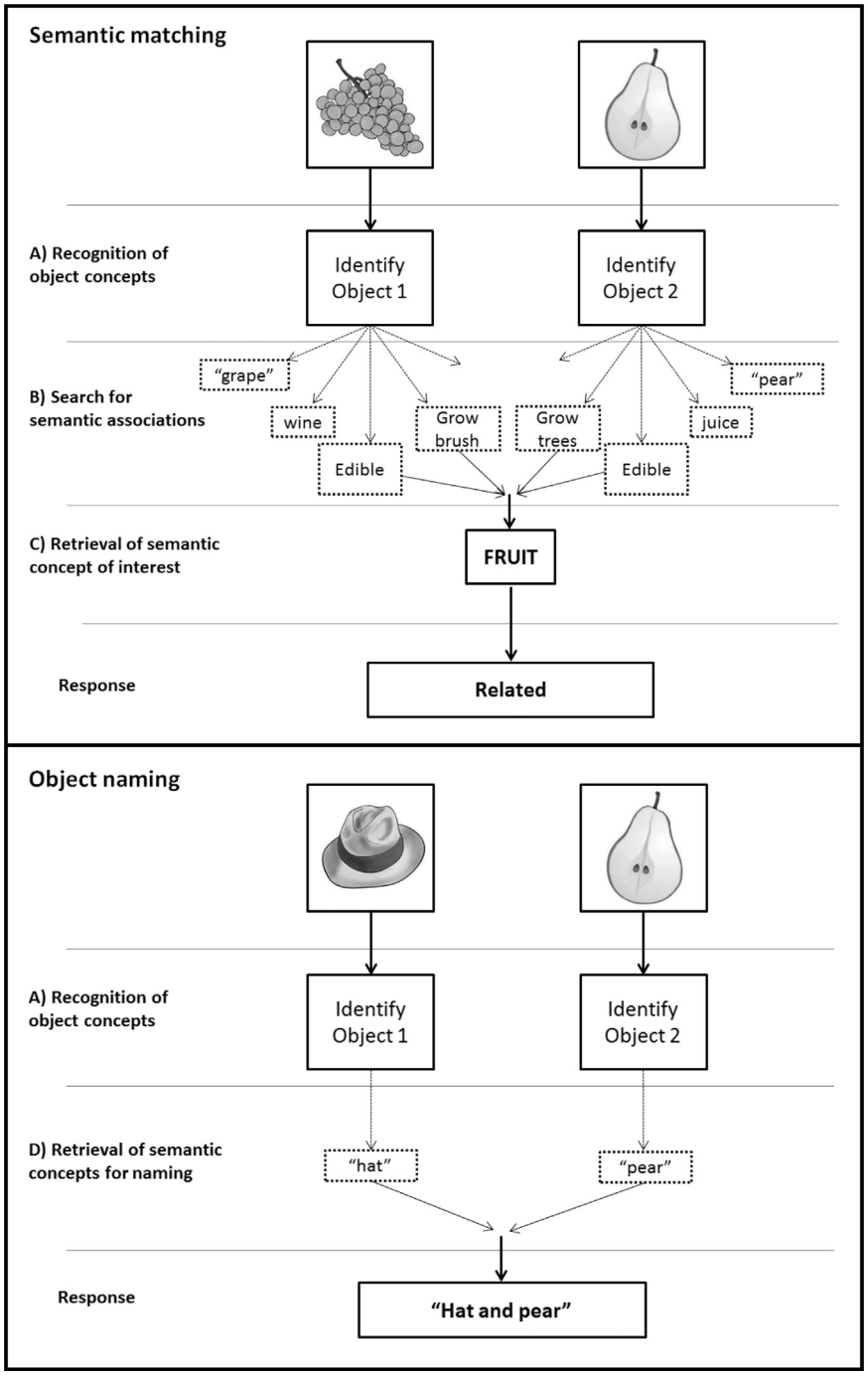

Fig. 1. Task analysis for a single semantic matching and object naming trial. Top panel: Semantic matching trial: Deciding whether two stimuli are related or unrelated, involves (A) recognising object concepts; (B) searching for associations related to each object concept; and C) retrieving a specific semantic concept for matching. Bottom panel: Object Naming trial: Naming a concept involves(A) recognising object concepts; and (D) retrieving a specific concept for naming.

'grapes' and 'pears'). See top panel of Fig. 1 for further details.

Other neuroimaging studies of lexical and semantic processing have identified additional anterior temporal lobe areas where activation increases during semantic categorisation (Bright et al., 2004; Devlin et al., 2000;Kellenbach et al., 2005 ; Phillips et al., 2002; Mummery et al., 1998; Noppeney and Price 2002a, 2002b; Thierry et al., 2003; Thierry and Price, 2006; Vandenberghe et al., 1996; Visser et al., 2010a; Visser and Lambon Ralph 2011). However, the reported locations of these activations varied across studies. Most of the reported effects were more mesial, more posterior or more superior to the LATL region reported in the Pobric et al. (2010) and Visser et al. (2012) studies discussed above. More specifically, the LATL area identified in Pobric et al. (2010) is located just in front of the AC vertical line ($x=-53$, $y=+4$, $z=-32$, in MNI space) and lies in the temporo-polar cortex. In contrast, Vandenberghe et al. (1996) reported more posterior semantic matching activation at [$x=-44$, $y=-10$, $z=-28$]; Bright et al. (2004) reported more medial and posterior semantic matching activation at [$x=-30$, $y=-18$, $z=-26$]; and Thierry and Price (2006) reported more superior semantic matching activation at [$x=-58$, $y=+8$, $z=-16$].

From our review of the literature, the lateral ATL area reported in Pobric et al. (2010) at [$x=-53$, $y=+4$, $z=-32$] was closest to that reported by Rogers et al. (2006) at [$x=-54$, $y=+6$, $z=-26$]

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