Journal of Neurolinguistics 29 (2014) 31–41

Contents lists available at ScienceDirect

Journal of Neurolinguistics

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

Participation of the insula in language revisited: A meta-analytic connectivity study

Alfredo Ardila [a,*], Byron Bernal [b], Monica Rosselli [c]

[a] Department of Communication Sciences and Disorders, 11200 SW 8th Street, AHC3-431B, Florida International University, Miami, FL 33199, USA
[b] Radiology Department/Research Institute, Miami Children's Hospital, Miami, FL, USA
[c] Department of Psychology, Florida Atlantic University, Davie, FL, USA

ARTICLE INFO

Article history:
Received 1 November 2013
Received in revised form 3 February 2014
Accepted 4 February 2014

Keywords:
Insula
Language
Meta-analysis
BrainMap
fMRI

ABSTRACT

Despite the insula's location in the epicenter of the human language area, its specific role in language is not sufficiently understood. The left insula has been related to a diversity of speech/language functions, including articulatory planning, language repetition ability, and phonological recognition. To further our understanding of the role of the insula in language, a meta-analytic connectivity study using the Activation Likelihood Estimation (ALE) technique was developed. By means of the BrainMap functional database, 26 papers corresponding to 39 paradigms, and including 522 participants were selected. Thirteen different activation clusters were found; insula connections included not only areas involved in language production (such as the Broca's area) and language understanding (such as the Wernicke's area), but also areas involved in language repetition (such as the supramarginal gyrus) and other linguistic functions, such as BA9 in the left prefrontal lobe (involved in complex language processes) and BA37 (involved in lexico-semantic associations). In conclusion, the insula represents a core area in language processing, as it was suggested during the 19th century.

* Corresponding author. Tel.: +1 305 348 2750; fax: +1 305 348 2710.
E-mail address: ardilaa@fiu.edu (A. Ardila).

0911-6044/$ – see front matter © 2014 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jneuroling.2014.02.001

1. Introduction

The insula (or Island of Reil) is a complex and not completely understood brain area. Its potential participation in language has been a topic of controversy since the 19th century (Freud, 1891; Wernicke, 1874/1970), even though currently it seems evident that it plays a crucial role in language processing (Price, 2010). The anterior segment of the insula extends to and interfaces with Broca's area while its posterior elements adjoin Wernicke's area (Flynn, Benson, & Ardila, 1999). The left insula is notably larger than the right in most humans (Greve et al., 2013; Mesulam & Mufson, 1985). Both the asymmetry and the location in the epicenter of the human language area (Benson & Ardila, 1996; Dejerine, 1914; Luria, 1976) suggest that the insula may be active in language processes. However, few papers have been specifically devoted to the analysis of the role of the insula in language (e.g., Ackermann & Riecker, 2004; Ardila, 1999; Ardila, Benson, & Flynn, 1997).

Since Wernicke (1874), the insula has frequently been implicated in the "major aphasic syndromes": Broca's aphasia, conduction aphasia, and Wernicke's aphasia. In fact, Wernicke (1874) directly related insula damage with conduction aphasia. Involvement of the anterior part of the insula in Broca's aphasia was noted by Bernheim (1900) and Dejerine (1914) at the beginning of the 20th century. Furthermore, Liepmann and Storck (1902) associated the word-deafness component of Wernicke's aphasia with posterior insula pathology.

Pathology involving only the insular cortex and immediate sub-cortical structures, has been rarely reported however. Alexander, Benson, and Stuss (1989) presented two cases of pathology limited to the left insula and subjacent extreme-external capsules. Aphasia with mildly paraphasic production and agraphia was noted in both cases. Nielsen and Friedman (1942) reported several autopsy findings illustrating the association between left insula damage and aphasia. They noted, however, from their own cases and others in the literature, that a similar language syndrome followed isolated extreme capsule damage and postulated that insular damage without extreme capsule involvement would not produce aphasia. Habib et al. (1995) reported a case of bilateral insular damage, extending to a small part of the striatum on the left side, and to the temporal pole on the right. The patient presented mutism for about one month, did not respond to any auditory stimuli, and made no effort to communicate.

It is noteworthy that mutism has been frequently observed in individuals who suffered from insular damage. Transient mutism is found in cases of left inferior motor cortex damage extending to the insula (Alexander et al., 1989; Schiff, Alexander, Naeser, & Galaburda, 1983), whereas lasting mutism appears to be associated with bilateral lesions of the frontal operculum and anterior insula (Cappa, Guidotti, Papagno, & Vignolo, 1987; Groswaser, Korn, Groswaser-Reider, & Solzi, 1988; Pineda & Ardila, 1992; Sussman, Gur, Gur, & O'Connor, 1983). Alexander et al. (1989) suggested that left cortical and sub-cortical opercular lesions frequently result in a total speech loss associated with a right hemiparesis. Shuren (1993) described a patient who developed impaired speech initiation as a result of a left anterior insular infarct and suggested that anterior insular lesions in the left hemisphere could impair speech initiation. A possible interactive role of the left insula in speech initiation and language motivation could thus be conjectured (Ardila et al., 1997).

Dronkers (1996) showed that the left precentral gyrus of the insula is involved in motor planning of speech. Twenty-five stroke patients with a disorder in planning of articulatory movements (apraxia of speech), were compared with 19 individuals without such deficits. It was found that all patients with articulatory planning impairments presented lesions including the anterior insula. This area was completely spared in all patients without these articulatory defects. It was concluded that anterior insula represents a crucial brain area in motor planning and organization of speech. Verbal articulatory disruptions in some cases may be so severe as to result in mutism (Alexander et al., 1989; Pineda & Ardila, 1992).

Contemporary neuroimaging technique studies have supported the hypothesis regarding an active involvement of the insula in linguistic processes. Activation of the insula has been demonstrated in a diversity of verbal tests, including word generation (Baker, Frith, & Dolan, 1997; Bohland & Guenther, 2006; Gurd et al., 2002; Kemeny, Ye, Birn, & Braun, 2005; McCarthy, Blamire, Rothman, Gruetter, & Shulman, 1993; Pihlajamaki et al., 2000; Rowan et al., 2004; Voets et al., 2006), naming (Berlingeri et al., 2008; Damasio et al., 2001; Price, Moore, Humphreys, Frackowiak, & Friston, 1996), and