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The role of insula in language: an unsettled question

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Abstract

In this paper some of Benson's ideas about the role of the insula in language are developed. It is proposed that the insula is involved in two different aspects of language. On one hand, the insula should be regarded as a part of the brain language area. Damage to the insula frequently results in aphasia. Among the various language disturbances associated with damage in the left insula are Broca's aphasia, conduction aphasia, and the word-deafness component of Wernicke's aphasia. Apraxia of speech and mutism have been also reported associated with insula damage. Then on the other hand, recent studies of anatomical connections of the insula point to an important viscero-limbic role and it has been suggested that the insula may influence verbal motivation and verbal affect.

Introduction

'Unfortunately, the problem of insular aphasia, which would be so important for our considerations, has not so far been clarified by clinical observation. Meynert, de Boyer, Wernicke himself and others maintain that the insula belongs to the speech area, while Bernard and others, following Charcot, emphatically deny such a relation. Nothing decisive concerning this problem emerged from Naunyn's survey. Although it seems highly probable that lesions of the insula cause speech disorders (not only because of anatomical contiguity to the so-called center), it is nevertheless impossible to state whether the speech disorder is of a specific type and if so of what type.' (Freud 1891, pp. 12–13).

The discussion regarding the participation of the insula in language has extended for over one century. Nonetheless, a final answer is not available yet. For a long time, it was supposed that the insula might be participating in language processes. However, when Dejerine (1914) proposed the concept of brain language area, the insula was not explicitly included. The brain language zone suggested by Dejerine included the left frontal (posterior part of the foot of F3, the frontal operculum, and the immediate surrounding zone, including the foot of F2, and *probably* extending to the anterior insula), temporal (encompassing the posterior first and second temporal gyri), and parietal (the angular gyrus) areas. The concept of brain language zone was largely accepted by virtually all researchers in the aphasia area (e.g. Head 1920, Nielsen 1936, Penfield and Roberts 1959, Luria 1966, Benson and Geschwind 1971, Goodglass and Kaplan 1972, Albert *et al*. 1981). It was assumed

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that the brain language zone corresponded to the perisylvian area of the left hemisphere. During the following decades few direct references to the role of the insula in language are found. Only recently, the potential participation of the insula in language processes has again attracted attention.

D. Frank Benson was intensively interested in the role played by the insula in language. The reason was evident: the insula is situated in the core of the brain language area. The major aphasic syndromes (perisylvian aphasias) are quite frequently associated with insula damage. The anterior segment of the insula extends to and interfaces with Broca's area while its posterior elements adjoin Wernicke's area. The left insula is notably larger than the right in most humans (Mesulam and Mufson 1985). Both the asymmetry and the location in the epicentre of the human language area (Luria 1970, Benson 1979, Benson and Ardila 1996) suggest that the insula may be active in language. The role of the insula in speech and language processing has long been noted (Wernicke 1874, Freud 1891).

For over 6 years I was with Benson reviewing and analysing relevant research studies concerning the potential participation of the insula in language. An attempt was made to integrate available literature. The final paper, unfortunately, was published only after Benson's death (Ardila *et al*. 1997). Our personal interpretations of the participation of the insula in language, however, were not totally coincidental. While Benson emphasized the motivational and affective role of the insula in linguistic processes, I personally preferred to consider the insula to be a true language area—in fact, the epicentre of linguistic processes. Benson's bias derived from the strong anatomical connections existing between the insula and the viscero-limbic system. Mine, on the other hand, emphasized the strategic location of the insula, and the numerous studies demonstrating that damage to the insula is quite frequently involved in the major aphasic syndromes. This difference, however, was a matter of perspective. We both agreed with each other's interpretation: the insula is located in the epicentre of the persylvian language region, and the insula quite likely plays a significant motivational and affective role in language.

Re-reviewing the classical literature, and considering recent research reports, my conclusion is that both sets of claims were correct. Indeed, the insula may play a significant role in major aphasic syndromes, and in consequence, the insula should be regarded as a part of the cortical language area. In addition, the insula also appears to play a crucial role in language motivation and verbal affect.

In this paper I will attempt to integrate available literature, emphasizing both aspects: language and motivation/affect. This paper represents an extension of our previously published paper (Ardila *et al*. 1997).

The insula as a part of the brain language area

Ever since Wernicke (1874), a solid and extensive body of clinical research has demonstrated that the insula is frequently involved in major aphasic syndromes: Broca's aphasia, conduction aphasia, and Wernicke's aphasia. As a matter of fact, Wernicke directly related insula damage with conduction aphasia. Involvement of the anterior part of the insula in Broca's aphasia was noted many years ago (Bernheim 1900, Dejerine 1914). The word-deafness component of Wernicke's aphasia has been long associated with posterior insula pathology (Liepmann and Storck 1902).

Table 1. Some selected studies demonstrating that the insula is involved in major language disturbances

Author	Year
Broca's aphasia	
Alexander *et al*.	1989
Ardila *et al*.	1989
Henderson	1985
Kertesz	1991
Kertesz *et al*.	1979
Levine and Sweet	1983
Mazzocchi and Vignolo	1979
Mohr	1976
Mohr *et al*.	1978
Murdoch	1988
Murdoch *et al*.	1986
Signoret *et al*.	1984
Conduction aphasia	
Ardila *et al*.	1989
Damasio and Damasio	1980, 1983
Goldstein	1911
Lichtheim	1885
Mazzocchi and Vignolo	1979
Murdoch *et al*.	1986
Wernicke's aphasia (phonemic imperception)	
Ardila *et al*.	1989
Benson	1979
Gazzaniga *et al*.	1973
Kertesz	1981, 1983
Liepmann and Storck	1902
Mazzocchi and Vignolo	1979
Yaqub *et al*.	1988

An extensive body of clinical research has corroborated that the insula is quite frequently involved in the major aphasic syndromes. This body of clinical research has been previously reviewed (Ardila *et al*. 1997) and it is summarized in table 1. These studies suggest a possible role for the insula in language processing and indicate that damage to the insula may frequently be a source of aphasia. Both the older autopsy-based studies and more recent brain image correlations suggest that anterior insula damage is often present in cases of moderate to severe Broca's aphasia, middle insula damage is frequently correlated with repetition defects (conduction aphasia), and posterior insula damage co-occurs with the word deafness features of Wernicke's aphasia.

Pathology involving only the insular cortex and immediate sub-cortical structures, however, is rarely reported. Alexander *et al*. (1987) presented two cases with CT evidence of pathology limited to the left insula and subjacent extreme/external capsules. An aphasia with mildly paraphasic production and agraphia was noted in both. Nielsen and Friedman (1942) reported several cases from the literature with autopsy and demonstrated left insula damage and mild 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. Starkstein *et al*. (1988) observed crossed aphemia associated with a right insular lesion. Fifer (1993) described a patient with a lesion involving the right insula and adjacent white matter. The patient presented with a unilateral auditory processing disorder when speech materials were presented to the left ear. 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 1 month, did not respond to any auditory stimuli, and made no effort to communicate.

As a matter of fact, mutism has been frequently observed in cases of insular pathology. Transient mutism is found in cases of left inferior motor cortex damage extending to the insula (Schiff *et al*. 1983, Alexander *et al*. 1989), whereas lasting mutism appears to be associated with bilateral lesions of the frontal operculum and anterior insula (Sussman *et al*. 1983, Cappa *et al*. 1987, Groswaser *et al*. 1988, Pineda and Ardila 1992). A case of crossed transient mutism in a right-handed patient has been reported. An ischemic lesion of the right insula with mild extension to the frontal operculum was demonstrated (Starkstein *et al*. 1988). Alexander *et al*. (1989) point out that left cortical and sub-cortical opercular lesions may result in a total speech loss associated with a right hemiparesis. Right hemiparesis rapidly recovers, while the oral apraxia responsible for the mutism improves only slowly. Articulation is slow and effortful, and syntactic errors are observed.

Shuren (1993) observed a patient who developed impaired speech initiation as a result of a left anterior insular infarct. The author proposed that dominant hemisphere anterior insular lesions impair the speech initiation loop. A possible interactive role of the left insula in speech initiation and language motivation could thus be conjectured. That is, disrupted motivation to speak will ipso facto affect initiation.

Impairment in motor organization of speech represents a central defect in Broca's aphasia (Benson and Ardila 1996). 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 motor planning of articulatory movements, which Dronkers labelled as 'apraxia of speech', were compared with 19 individuals without such deficits. A robust double dissociation was observed. All patients with articulatory planning impairments presented lesions including the anterior insula. This area was completely spared in all patients without these articulatory defects. Hence, anterior insula represents the 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 and Ardila 1992).

Table 2 summarizes some reports of insular damage associated with selective forms of language disturbances.

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 during word generation task performance (Baker *et al*. 1997, McCarthy *et al*. 1993) and naming (Price *et al*. 1996). Lexical knowledge and word retrieval represent central linguistic processes, and these processes are frequently impaired in aphasia. Rousseaux *et al*. (1990) on the other hand, correlated linguistic deficits with cerebral blood flow, relating verbal comprehension, naming, and paraphasias to an asymmetry index of the insula and the

Table 2. Relatively restricted insular damage associated with selective forms of language disturbances

Author	Characteristics
Alexander *et al*. (1987)	Aphasia with mildly paraphasic production and agraphia.
Dronkers (1996)	Motor planning of speech.
Habib *et al*. (1995)	Mutism. Patient did not respond to any auditory stimuli. Disruption of the motivational mechanisms preluding to the motoric aspects of human communication.
Shuren (1993)	Impaired speech initiation.
Starkstein *et al*. (1988)	Aphemia.

lenticular nucleus. The insula would accordingly not participate in some unique and isolated language dimension, but rather would be active in different linguistic aspects. These contemporary cerebral blood flow studies in consequence support the assumption that the insula may be considered as a crucial brain language area. Activation of the insula has also been reported during phonological decision tasks (Rumsey *et al*. 1997). This finding, however, is not totally unexpected, considering that insular damage has been frequently observed in cases with phoneme imperception (Liepmann and Storck 1902, Mazzocchi and Vignolo 1979, Kertesz 1981, 1983, Yaqub *et al*. 1988).

It may therefore be concluded that contemporary neuro-imaging studies lend support to the assumption of a significant participation of the insula in language. Futhermore, the insula would be involved not in a single linguistic activity, but in several verbal processes simultaneously. The anterior portion of the insula would be involved in the organization and planning of language articulation, while the middle and posterior portions would be involved with lexical knowledge, word retrieval, language understanding, and phonological discrimination.

Interestingly, it has even been suggested that the insula may be involved early in Alzheimer's disease and that atrophy of the insula may partially contribute to the cognitive deficits typical of early Alzheimer's disease (Foundas *et al*. 1997). Naming difficulties, word retrieval defects, semantic paraphasias, and a general decrease in lexical knowledge represent early linguistic defects in cases of Alzheimer's disease (Cummings and Benson 1992).

Taken together, all these observations support an active participation of the insula in linguistic processes.

Role of the insula in language motivation and affect

The insula has been further associated with a significant number of processes. These include: oesophageal sensation (Aziz *et al*. 1997), tactual memories (Bonda *et al*. 1996), vestibular projections (Bottini *et al*. 1994), spatial and temporal auditory processing (Griffiths 1997), gustatory processing (Kabayakawa *et al*. 1996), and pain perception (Xu *et al*. 1997). Interestingly, the insula possesses not only contralateral motor and sensory representation but also ipsilateral motor and sensory representation (see Flynn *et al*. in this issue).

Connections have been described between the insula and the orbital cortex, frontal operculum, lateral premotor cortex, ventral granular cortex, and medial

area 6 in the frontal lobe. The insula has been found to connect as well with the temporal pole and the superior temporal sulcus. Significant projections to the cingulate gyrus, amygdaloid nucleus, perirhinal cortex, entorhinal and periamygdaloid cortex have been observed (Augustine 1996). The insula in consequence maintains a complex system of interconnections not only with classical cortical language regions in the temporal and frontal lobe, but with a variety of limbic structures as well, including the cingulate gyrus and the perirhinal and entorhinal cortex. The assignment of a very complex role to the insula is accordingly fully justified, not only in purely linguistic terms but also in terms of affect and motivation.

Moreover, it can be proposed that the insula represents a major source of autonomic-visceral influence on the sensory-motor association cortex. Among the areas of dominant hemisphere sensory-motor cortex under this influence would be neuroanatomical structures crucial to language. From this it could be conjectured that the left insula would have a more direct influence on motivation and emotion as expressed in spoken/written language (verbal affect). The converse, a right insula influence on non-verbal affect, may also be considered. The insula may represent a crucial element participating in several distinct networks involved in verbal and non-verbal communication (Mesulam 1985). The anatomy and connections of the insula are revised in another paper in this issue (see Flynn *et al*. *Anatomy of the Insula*).

Recent reports have supported the hypothesis that the insula may play a significant role in verbal affect and linguistic motivation. Habib *et al*. (1995) have proposed that the insula may represent one key component of a finely tuned attentional system whose function would be not only to select the relevant information from the continuous flow of auditory inputs, but also to trigger an adequate inter-hemispheric balance according to the verbal or non-verbal nature of the current stimulus. Habib *et al*. (1995) have proposed that bilateral damage to the insula would disrupt the motivational mechanisms that lead to the motoric production of human communication, by depriving them of connections with various limbic structures. Anatomical studies suggest that the insula could well act as the cortical representation of the limbic (autonomic) nervous system and, as such, may provide a direct input from the limbic-emotion system that could in turn influence the affective tone and content of language output.

Conclusion

Classic studies and recent literature support the proposal that the insula is involved in language. Two major aspects could be separated: (1) On one hand, the insula should be regarded as a part of the neuroanatomical language area. Insula damage frequently results in aphasia. Among the various language disturbances associated with damage in the left insula are: motor planning and organization of speech in Broca's aphasia, repetition defects associated with conduction aphasia, and the word-deafness component of Wernicke's aphasia. Mutism and oral apraxia have been reported to be associated with left insula pathology. (2) Recent studies of anatomical connections of the insula point to an important viscero-limbic role, and it may accordingly be suggested that the insula influences verbal motivation and verbal affect.

The brain language zone should be reconsidered to include not only the perisylvian area of the left hemisphere but also the insula.

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