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Review

Self-awareness and the left inferior frontal gyrus: Inner speech use during self-related processing

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Abstract

To test the hypothesis of a participation of inner speech in self-referential activity we reviewed 59 studies measuring brain activity during processing of self-information in the following self-domains: agency, self-recognition, emotions, personality traits, autobiographical memory, preference judgments, and REST. The left inferior frontal gyrus (LIFG) has been shown to sustain inner speech use. We calculated the percentage of studies reporting LIFG activity for each self-dimension. 55.9% of all studies reviewed identified LIFG (and presumably inner speech) activity during self-awareness tasks. Furthermore, the LIFG was more frequently recruited during conceptual tasks (e.g., emotions, traits) than during perceptual tasks (e.g., agency, self-recognition). This supports the view of a relative involvement of inner speech in self-reflective processes.

Keywords: Self-awareness; Self-referential activity; Inner speech; Left inferior frontal gyrus; Conceptual self-domains; Perceptual self-domains

Contents

Numerous studies looking into the neural basis of self-referential activity have been conducted since the publication of Craik et al.'s original paper in 1999. Convergent evidence strongly suggests that the medial prefrontal cortex (MPFC) plays an important role in self-related processes [43,44,86,87]. The MPFC is also frequently activated during "Theory-of-Mind" tasks [1,34,113], indicating that thinking about one's own and others' mental states probably recruits the same neuroanatomical structures [22,23,79]. The neural representation of self also includes the precuneus, anterior and posterior cingulate corticles, right inferotemporal cortex, inferior and posterior parietal corticles, basal ganglia, and insula [65].

Although the main focus of the aforementioned body of work has consisted in identifying brain areas specifically activated during processing of self-information, current studies are starting to examine underlying cognitive mechanisms that

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mediate self-perception. That is, by looking at peripheral structures that are additionally recruited during self-awareness tasks, researchers can infer what particular thought processes are engaged as well (see [101,102]). To illustrate, retrieval of autobiographical information frequently activates occipital regions (e.g., [36]); since these areas are known to support visuospatial imagery [11], it has been suggested that one forms mental images of the self in the past when accessing autobiographical memories [39,123]. Thus mental imagery would represent one cognitive process involved in self-awareness [80,81].

Language too has been linked to consciousness and self-reflective activities [7,13,24,103,115,127]. Some have proposed that inner speech in particular mediates self-awareness [6,9,59,77,84,119]. Inner speech represents the activity of talking to oneself in silence [134]. Related terms that can be found in the literature are self-talk, subvocal/covert speech, internal dialogue/monologue, subvocalization, utterance, self-verbalization, auditory imagery, and self-statement. Inner speech serves various cognitive functions, among which verbal rehearsal, planning, problem-solving, task switching, retrieval aid for task goals, and self-regulation (see [26,42,76,78,83,104,117]). Therefore one can talk to oneself about an unlimited number of things and for different reasons (e.g., "I should take my umbrella with me since it will probably rain"; "What is John's phone number again?"). When one talks to oneself about oneself, the function then is to gain access to information about the self. For example, one can utter "I think I'm a pretty punctual person" (thus assessing personality traits) or "I remember spending a month at my brother's place last summer" (thus retrieving autobiographical material). Various theoretical accounts of the role played by inner speech in self-referential activity have been put forward; these are beyond the scope of the present review (see [82,118]). Empirical evidence, although indirect and limited, has also been reported: a positive and significant correlation exists between frequency of self-focus and use of inner speech [110,116]. Ojemann [90] observed that in brain-damaged patients, conscious experience returns in parallel with inner speech. Conversely, healthy volunteers report inner speech inhibition when they transit from wakefulness to sleep [106]. Recent work by Whitehouse et al. [130] identifies inner speech deficits in autism, a condition in which self-awareness and Theory of Mind abilities are known to be impaired.

The goal of this paper is to further explore the hypothesis of an involvement of inner speech in the acquisition of self-information. Below we review brain-imaging studies of self-referential processing to determine if activation of areas known to sustain inner speech activity is reported. We propose that if such an activation is indeed frequently observed, one can infer that inner speech most probably was used by participants while working on self-awareness tasks. The left inferior frontal gyrus (LIFG—e.g., Broadmann's areas 44, 45, and 47; Broca's area; left ventrolateral PFC; left frontal operculum) has consistently been identified as the neuroanatomical basis of inner speech. That is, the LIFG reliably gets activated when participants are asked to silently articulate sentences [74] or single words [75]; furthermore, accidental destruction of the LIFG disrupts inner speech [129]. Although it has been suggested that the LIFG serves various additional functions (e.g., cognitive control, working memory, selection among competing alternatives, interpreting actions of others—see [5,27,50,93,94]), its connection to inner speech is well established [2,21,114]. It should also be noted that the LIFG exhibits functional heterogeneity: its most anterior part (BA 45) is involved in retrieval of words for their meaning while its posterior part (BA 46/47) is specialized in getting access to words through an articulatory code ([94]; also see [102]).

Self-referential processing includes numerous self-dimensions that can be organized along various lines. For instance, Gillihan and Farah [37] developed a taxonomy of self-domains where the physical self includes self-recognition and agency, and the psychological self comprises personality traits, autobiographical memory, and first-person perspective. Northoff et al. [87] instead suggest the following self-dimensions: verbal, spatial, memory, emotional, facial, social, and agency/ownership of movements. Based on our own review of the literature, we classified self-aspects as follows: agency (knowledge that one is the cause of one's actions), self-recognition, personality traits, autobiographical memory, emotions (including interoception—i.e., awareness of bodily states), and evaluative judgments (i.e., subjective choices and preferences). We also reviewed studies of the resting state (REST), which has been shown to coincide with introspective awareness [41,131]. Our main prediction is that activation of the LIFG (i.e., inner speech use) should be observed in a reasonable number of studies (i.e., more than 50%) investigating the neural correlates of self-related processes. We further hypothesize a *partial* participation of inner speech during self-awareness tasks, where the need to verbally label self-aspects should be greater in conceptual self-domains (e.g., emotions, traits) than in perceptual self-domains (e.g., agency, self-recognition). Perceptual (or sensory) self-information refers to products of one's direct experience with oneself (e.g., the body) or environmental stimuli (e.g., other persons, mirrors) that identify the self; conceptual self-information designates data about the self that is not available to immediate perceptual experience and that somehow has to be mentally represented to be accessible to the self. It seems plausible that not all forms of self-focus require self-verbalization of the information to be assessed. Perceptual self-aspects such as self-face recognition, because of the visual and concrete nature of the information, can most likely be captured without words. More conceptual self-dimensions such as emotions and personality traits however, probably entail that one talks to oneself about them (e.g., "I feel sad", "I'm funny") to be fully brought to consciousness.

1. Methods

English-language articles published prior to September 2006 were identified from searches using PubMed, Scirus, Cogprints, and PsycINFO.[1] The reference

[1] Keywords used were: agency, autobiographical memory, brain, emotions, fMRI, functional magnetic resonance imaging, intentions, interoceptive awareness, introspection, neural correlates, PET, positron emission tomography, personality traits, preference judgments, reflective self-awareness, resting state,