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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,

section of each paper was examined for additional studies. Review articles (e.g. [87,37,63]) were also carefully scrutinized. Inclusion criteria for selection of articles were all studies measuring brain activity using hemodynamic methods (PET and fMRI) during self-related tasks tapping into the seven aforementioned self-domains. Exclusion criteria were: (a) Theory-of-Mind studies—these will be examined in an independent project; (b) electrophysiological studies using event-related potentials or EEG (e.g. [58,91]), as well as Transcranial Magnetic Stimulation studies (e.g. [72]); (c) studies of clinical populations, including split-brain patients (e.g. [126,128]); and (d) studies not reporting all areas of activation (e.g. [19]). Some articles were also excluded because the tasks used, although self-related, did not involve genuine introspection. To illustrate, in Heinzel et al.'s report [45], participants were simply asked to view erotic and non-erotic emotional pictures while brain activity was assessed, as opposed to rate (i.e., focus, introspect on) their sexual arousal levels. Two other studies that were discarded on that basis are Kampe et al. [49] and Ochsner et al. [89].

By using this selection process, 59 articles were analyzed in order to identify the reported frequency of LIFG activation. Control conditions (i.e., non-self tasks) were not examined because our main focus consisted in calculating LIFG (and inner speech) involvement during self-tasks exclusively. Such a participation of the LIFG during non-self tasks does indeed occur (e.g., [17]), which is not surprising since (as mentioned previously) inner speech is known to serve many cognitive functions other than the one explored here—processing of self-information. Control tasks (e.g., encoding nonsemantic information, making decisions about statements of factual knowledge) often rely on these additional functions of inner speech.

2. Results and discussion

2.1. Overview

Fig. 1 presents the percentage of studies in which LIFG activity for each self-domain examined here was observed. Overall, 33 of the 59 studies (55.9%) reported LIFG activity during self-awareness tasks. This activity most likely reflects inner speech use, as opposed to other potential LIFG functions, namely, cognitive control (the ability to orchestrate thoughts and actions in accordance with internal goals), working memory (temporarily storing and manipulating information), selection among competing alternatives (choosing among competing sources of information to guide response—e.g., classifying pictures according to one of many different attributes), and interpreting others' actions (e.g., hand and mouth movements). We argue that none of the self-referential tasks described below engage these functions. Our finding, to the extent that one equates LIFG activation with inner speech use, supports the hypothesis of an inner speech involvement in some self-referential processing. Had we observed a very low percentage of LIFG recruitment during self-related tasks (e.g., 10%), obviously the aforementioned hypothesis would need to be rejected or significantly qualified; on the other hand, finding a very high percentage (e.g., 90%) was not expected given the likelihood that other competing processes (e.g., imagery) underlie self-reflection, and that some forms of self-awareness (e.g., agency) most probably do not require cognition (see below).

Many studies across self-domains employed identical tasks. For instance, four of the seven self-recognition tasks consisted in judging if faces presented on a screen were self or other; 7 of the

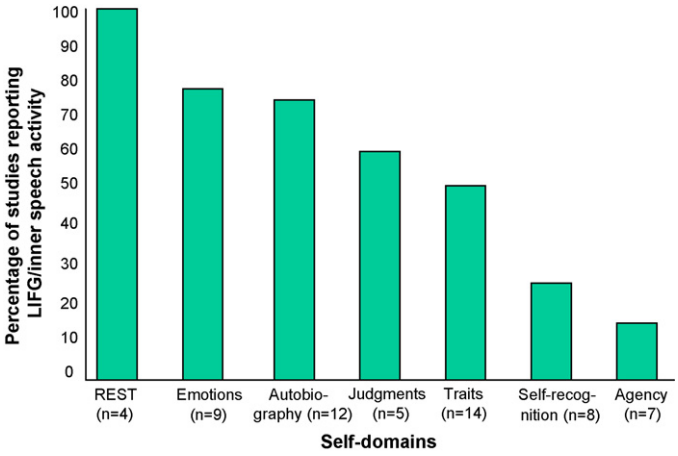

Fig. 1. Percentage of studies in which LIFG activity was observed as a function of self-domains.

14 personality trait tasks asked participants to decide if adjective traits were self-descriptive. It remains unclear why, using similar experimental tasks, some studies did find the target activation (e.g., [53,54]) while others did not (e.g., [31,122]). The only detectable difference between identical tasks was the time taken for image acquisition. One possibility might be that very short tasks (e.g., milliseconds) did not provide participants with enough time to genuinely self-reflect, whereas longer ones (e.g., minutes) did. That is, very short tasks might actually be seen as *recognition* tasks not entailing much introspection (and thus inner speech use). To test this idea, all studies specifying time taken for image acquisition during self-awareness tasks were divided into two groups: those reporting LIFG activity ($n = 30$) and those not reporting LIFG activity ($n = 24$). The studies were further divided into those with time taken for image acquisition above the median duration (Mdn = 4000 ms) and those below. A chi-squared analysis revealed no statistically significant relationship between time and the detection of LIFG activity ($\chi^2(1) = 0.087$, $p = 0.768$) (Fig. 1).[2]

Also consistent with our view, access to more conceptual self-information was linked to increased LIFG activation. 68.1% of all studies employing conceptual self-tasks ($n = 44$; i.e., REST, evaluating one's personality traits, emotions and judgments, and accessing one's autobiographical memory) reported LIFG activity, whereas only 20% of studies using perceptual self-tasks ($n = 15$; i.e., sense of agency and face/voice self-recognition) identified such activation. This difference was statistically significant ($\chi^2(1) = 11.363$, $p = .001$). This corroborates the notion of a *differential* involvement of inner speech across subtypes of self-processing, where perceptual self-aspects (e.g., one's face) can be brought to conscious awareness without words, whereas

self, self-awareness, self-reference, self-inferential processing, self-related processing, self-reflection, self-recognition.

[2] We also analyzed the median split by combining the median observations with the observations above the median and by combining the median observations with the observations below the median. In no case did the results approach statistical significance (lowest $p = 0.483$). In addition, we conducted a *t*-test comparing the recording durations of observations with/without LIFG activity, even though the distribution of recording durations is non-normal. This comparison also failed to reach significance ($t(54) = -1.04$, $p = 0.301$). A Mann–Whitney *U*-test on the same data also failed to reach significance ($p = 0.397$).

conceptual self-dimensions (e.g., one's current emotional state) most probably necessitate verbalization.

2.2. Agency and self-recognition

All Tables included below specify (1) the authors of individual articles, (2) the hemodynamic method used, (3) the self-task used, (4) the time required for image acquisition, and (5) LIFG activation—or not. Table 1 presents 15 studies that measured brain activity during agency tasks (e.g., deciding if one is responsible for the movement of one's hand) and self-recognition tasks (e.g., judging if a face seen on a screen is one's own or that of another person). In accordance with the discussion above on perceptual and conceptual self-domains, only one agency study out of seven (14.3%) reported LIFG activity. Two out of eight self-recognition studies (25%) showed a LIFG recruitment. The view that self-(face) recognition unlikely necessitates verbal labeling (i.e., inner speech use) is illustrated by Sugiura et al.'s observation [122] that "... covert naming often accompanies recognition of a familiar face, but rarely occurs during visual self-recognition" (p. 147).

2.3. Personality traits

Table 2 presents 14 studies that measured brain activity during personality trait tasks. In their review paper, Ochsner et al. [88] (p. 798) noted frequent left inferior PFC activation in many self-referential studies that included trait tasks. In our sample, 50% of the studies (seven out of 14) reported LIFG activation. Fossati et al.'s study [32] was excluded because in reporting their results, the "Self" and "Others" conditions were combined. Most tasks consisted in asking participants to judge if an adjective trait is self-descriptive. As indicated earlier, one can postulate that such a task will activate inner speech use—e.g., the presentation of the adjective "good-looking", for instance, could very well initiate the following internal verbal comment: "Yes, I'm rather attractive" or "Well, it varies, I have 'bad hair' days". Note that in Kjaer et al.'s study [56] participants were explicitly invited to silently think about their personality traits and physical appearance for 2 min: unsurprisingly, LIFG was reported.

2.4. Autobiographical memory

Table 3 reports 12 studies that measured brain activity during autobiographical memory tasks (e.g., remembering past personal experiences). Several articles were excluded (e.g., [8,20,10,85]), because *episodic* memory (recollection of past events), as opposed to *autobiographical* memory (recollection of past *personal* events), was tested. As noted before, autobiographical tasks typically recruit brain areas that are active when participants manipulate mental images. But the notion that language is also simultaneously used to access autobiographical memory has been discussed in the literature (see [15], pp. 10–11; [111]). Gilboa et al. [36] observe that "Both types of studies [autobiographical and episodic memory studies] report ventrolateral activations (BA 44/47) bilaterally" (p. 1341). Nolde et al. [85] suggest greater LPFC activation (which includes the LIFG) during more complex autobiographical remembering. In our sample, 9 studies out of 12 (75%) reported a recruitment of the LIFG. In phenomenological terms, one can propose that participants remembering a past personal experience often engaged in self-talk—e.g., "Yes, I remember that trip to South America, it was very pleasant and exciting, my wife and kids were with me...", etc.

Table 1
Agency and self-recognition studies

Paper	Imaging	Self-task	Time	LIFG (BA)
Agency				
Farrer and Frith [29]	PET	Driving a circle along a T-shaped path, either by oneself (agency) or by the experimenter (other)	5 s	NO
Farrer et al. [28]	PET	Providing accurate/inaccurate visual feedback to participants performing hand movements	70 s	NO
Leube et al. [60]	fMRI	See above	2 s	NO
Leube et al. [61]	fMRI	Deciding if there is a temporal delay between hand movements and visual feedback of those movements	3 s	NO
McGuire et al. [73]	PET	Providing accurate/inaccurate auditory feedback while reading aloud	250 ms	NO
Ruby and Decety [105]	PET	Imagining self vs. other movements	5 s	NO
Wraga et al. [132]	fMRI	Imagining rotating one's body about a sphere until one's eyes line up behind the horizontal line of a prompt	500 ms	47 (but 45 deactivated)
Self-recognition				
Kircher et al. [54]	fMRI	Judging if faces are self or other	3 s	45
Kircher et al. [55]	fMRI	See above	3 s	45
Perrin et al. [95]	PET (and ERPs)	Passively listening to one's first name, unfamiliar names, and common first names	600 ms	NO
Platek et al. [99]	fMRI	Judging if faces are self or other	20 s	NO
Platek et al. [100]	fMRI	Judging if faces are self or other (known/unknown persons)	775 ms	NO
Sugiura et al. [121]	PET	Judging if faces are self or other	Unspecified	NO
Sugiura et al. [122]	fMRI	See above	11 s	NO
Uddin et al. [128]	fMRI	Deciding if faces presented are composites of oneself or others	2 s	NO

Table 2
Personality trait studies

Paper	Imaging	Self-task	Time	LIFG (BA)
Blackwood et al. [4]	fMRI	Judging if various ambiguous self-referent elements (traits, activities and emotions) are self-descriptive (Yes/No)	7.5 s	NO
Craik et al. [17]	PET	Judging if adjective traits are self-descriptive (Likert scale)	4 s	47
Fossati et al. [31]	fMRI	Judging if adjective traits are self-descriptive (Yes/No)	5 s	NO
Johnson et al. [47]	fMRI	Judging if adjective traits, abilities and attitudes are self-descriptive (Yes/No)	4 s	NO
Kelly et al. [53]	fMRI	Judging if adjective traits are self-descriptive (Yes/No)	2 s	47
Kircher et al. [54]	fMRI	Judging if adjective traits and physical characteristics are self-descriptive (Likert scale)	3 s	44
Kjaer et al. [56]	PET	Silently thinking about one's traits and physical appearance	2 ms	45/47 (physical appearance only)
Lieberman et al. [64]	fMRI	Judging if adjective traits are self-descriptive in high/low experience domains (Yes/No)	3 s	44 (nonschematics only)
Lou et al. [66]	PET	Judging if adjective traits are self-descriptive (Yes/No)	Unspecified	47
Macrae et al. [67]	fMRI	See above	750 ms	Near 44/45/47
Ochsner et al. [88]	fMRI	See above	2.2 s	NO
Schmitz et al. [108]	fMRI	See above	4 s	NO
Schmitz et al. [109]	fMRI	See above	4 s	NO
Zhang et al. [133]	fMRI	Judging if adjective traits are self-descriptive (Likert scale)	3 s	NO

2.5. Emotions

Table 4 reports nine studies that measured brain activity during emotion tasks (e.g., evaluating one's emotional response to an auditory or visual stimulus). 77.8% of the studies (seven out of nine) detected LIFG activation. As Ochsner et al. [89] put it, "... the MPFC and the inferior lateral PFC might work in concert to mediate interference between, and select the appropriate, *semantic* description of emotional states" (p. 1750; emphasis added). Of all the self-domains examined here, awareness of one's emotional experiences most likely requires inner speech. We suggest that one needs to verbally label one's current emotions in order to accurately identify them [82]. In a typical experiment assessing one's emotional reaction to a set of pictures, it is conceivable that participants covertly verbalized "That one feels warm, nice colors" or "No. Too much repetition, boring".

2.6. Evaluative judgments

Table 5 presents five studies that measured brain activity during evaluative judgment tasks (e.g., judging if one likes or dislikes various food items). Such tasks are self-referential in nature because one first has to assess one's own preferences in order to produce a judgment. Here too it is reasonable to assume that evaluative judgment tasks depend on inner speech. As Johnson et al. [48] suggest in their own study, "The finding in the inferior frontal gyrus, left more than right on both the subjective [evaluative judgments] tasks relative to the [control tasks],

Table 3
Autobiography studies

Paper	Imaging	Self-task	Time	LIFG (BA)
Cabeza et al. [12]	fMRI	Remembering if sets of pictures where taken by participants or by others	15 s	47
Conway et al. [16]	PET	Generating AM following the presentation of cue words	5 s	44/45/47
Fink et al. [30]	PET	Listening to and visualizing personal and non-personal AM	Unspecified	NO
Gilboa et al. [36]	fMRI	Remembering the entire context (emotional, physical, cognitive) of recent/remote personal episodes depicted in photographs of self	30 s	47
Levine et al. [62]	fMRI	Listening to verbal descriptions of AM	Unspecified	45/47
Maguire and Mummery [69]	PET	Indicating if read statements representing past personal episodes (collected earlier to scan) were participants' own AM (Yes/No)	4 s	NO
Maguire et al. [70]	fMRI	See above	4 s	NO
Maguire and Frith [68]	fMRI	See above	8 s	47
Piefke et al. [97]	fMRI	Remembering positive/negative and old/recent past personal events	30 s	LIFG (BA unspecified)
Piolino et al. [98]	PET	Verbally instructing participants to mentally relive personal episodes in details	45 s	47
Ryan et al. [107]	fMRI	Remembering past old/recent personal events following the presentation of cues	20 s	47
Steinvorth et al. [120]	fMRI	Mentally re-experiencing autobiographical memories (AM) following the presentation of cue words formulated by family members; participants were asked to confirm retrieval	8 s	44/45 (remote AM only)

Table 4
Emotion studies

Paper	Imaging	Self-task	Time	LIFG (BA)
Critchley et al. [18]	fMRI	Perceiving (or not) a feedback delay of one's heartbeat (Interoception)	100 ms	LIFG (BA unspecified)
Goldberg et al. [38]	fMRI	Evaluating up to what point images and music produce an emotional experience (High/Low)	12 s	LIFG (BA unspecified)
Gusnard et al. [41]	fMRI	Evaluating one's emotional responses to pictures (positive, negative or neutral)	4100 ms	LIFG (BA unspecified)
Jackson et al. [46]	fMRI	Imagining various levels of pain by viewing normal and distorted limbs	3 s	LIFG (BA unspecified)
Lane et al. [57]	PET	Evaluating one's emotional responses to pictures (positive, negative or neutral)	500 ms	44/45
Ochsner et al. [89]	fMRI	Evaluating one's emotional responses to pictures (Likert scale)	3.5 s	45
Phan et al. [96]	fMRI	Indicating up to what point participants emotionally associated with pictures (Likert scale)	5 s	NO
Takahashi et al. [124]	fMRI	Judging if guilt and embarrassment are present in short sentences (Likert scale)	4 s	47 (embarrassment only)
Taylor et al. [125]	PET	Rating aversive and nonaversive pictures (Likert scale)	2.8 s	NO

Table 5
Evaluative judgment studies

Paper	Imaging	Self-task	Time	LIFG (BA)
Johnson et al. [48]	fMRI	Choosing which color one prefers	4 s	LIFG (BA unspecified)
Paulus and Frank [92]	fMRI	Determine which one of two items (e.g., drinks) one prefers	8 s	NO
Seger et al. [112]	fMRI	Judging if one likes or dislikes food	2500 ms	NO
Zysset et al. [135]	fMRI	Making evaluative judgments of people (e.g., Bush is a good president) (Yes/No)	6 s	45/47
Zysset et al. [136]	fMRI	See above	6 s	LIFG (BA unspecified)

may reflect a *verbal* reasoning strategy during those conditions that may not have been employed during the [control] condition" (p. 1990; emphasis added). In our sample, three studies out of five (60%) reported LIFG activation. For example, a participant asked to select which of two drinks he or she prefers may covertly verbalize "The first one is too sweet—I prefer the second drink".

2.7. Rest

Table 6 reports four studies that measured brain activity during REST. Note that Laufs et al.'s experiment [58] was not included because results are reported in terms of correlations between fMRI activity and power in EEG bands. Greicius et al.'s study [40] was also discarded because results are presented in terms of functional connectivity. In a typical resting state condition participants are simply requested to stay still and do nothing. Although the resting state has repeatedly been used as a control condition in neuroimaging experiments, Gusnard et al. [41] recently proposed that REST actually represents a particularly active state in which participants think about their current, past, or future goals, emotions, needs, behavior, physiological sensations, etc. As such, REST consists of an introspective state that recruits most brain sites that have also been shown to be active during self-referential tasks. In our sample, all studies found LIFG activation. Binder et al. [3] explicitly measured inner speech use in their study and observed that ". . . conscious resting subjects frequently experience thoughts (consisting variously of mental images, *auditory verbal images*, 'ideas,' and other similar phenomena) that are relatively unrelated to external perceptual events. In the pilot study conducted here, subjects reported such phenomena at the conclusion of a 15- to 24-s period of rest on 62.8% of queries . . ." (p. 85; emphasis added). Mazoyer et al. [71] and Fransson [33] also report inner speech use by participants in their experiments.

Table 6
REST studies

Paper	Imaging	Self-task	Time	LIFG (BA)
Binder et al. [3]	fMRI	Resting still with eyes closed	3 s	45
Christoff et al. [14]	fMIR	Unspecified	16 s	46
Fransson [33]	fMRI	Resting still with eyes closed	10 m	47
Mazoyer et al. [71]	PET	See above	Unspecified	45/46

3. Conclusion

The notion that language, and more specifically inner speech, are an integral part of self-referential activities is both intuitively appealing and largely accepted in the literature (but see [51], p. xxiii). Empirical evidence nonetheless is sparse, and the present review provides additional (albeit indirect) support to this hypothesis. 55.9% of the 59 studies we examined found LIFG activity during various self-awareness tasks. We suggest that this activity most likely consists in the use of introspective inner speech by the participants. Clearly this represents a tentative inference that requires further corroboration given the fact that the observed LIFG activity may reflect the use of other processes. To the extent that LIFG activity signifies inner speech use, our review further qualifies the hypothesis by suggesting that inner speech is increasingly recruited as self-information to be assessed becomes less perceptual and more conceptual—hence, a *differential* involvement of inner speech across self-domains. One persistent debate in the study of self-awareness is the neuroanatomical localization of self-processes. Three main views have been proposed so far: self-awareness is mainly located (1) in the right prefrontal lobe [52], (2) in the left hemisphere exclusively [35], and (3) in a widespread fashion throughout the brain [127,37]. The present review strongly suggests that the left prefrontal lobe plays a role in self-awareness and thus favors the last two views.

While most current brain-imaging experiments aim at identifying the exact sites correlated to self-related activities, our novel approach rather looks at tangential activations—the LIFG in the present case—in order to isolate the underlying cognitive processes implicated in self-awareness. We believe that this method should be extended to include other peripheral brain regions (e.g., occipital regions) activated during various additional self-domains (e.g., intentions), as well as to other complex social cognitive activities—e.g., Theory-of-Mind.

Conflicts of Interest

None.

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References

[1] D.M. Amodio, C.C. Frith, Meeting of minds: the medial frontal cortex and social cognition, Nat. Rev. Neurosci. 7 (4) (2006) 268–277.
[2] M.V. Baciu, C. Rubin, M.A. Decorps, C.M. Segebarth, fMRI assessment of hemispheric language dominance using a simple inner speech paradigm, NMR Biomed. 12 (1999) 293–298.
[3] J.R. Binder, J.A. Frost, T.A. Hammeke, P.S.F. Bellgowan, S.M. Rao, R.W. Cox, Conceptual processing during the conscious resting state: A functional MRI study, J. Cogn. Neurosci. 11 (1) (1999) 80–93.
[4] N.J. Blackwood, R.P. Bentall, H.H. Ffytche, A. Simmons, R.M. Murray, R.J. Howard, Persecutory delusions and the determination of self-relevance: an fMRI investigation, Psychol. Med. 34 (2004) 591–596.
[5] M. Brass, C. Heyes, Imitation: is cognitive neuroscience solving the correspondence problem? Trends Cogn. Sci. 9 (10) (2005) 489–495.
[6] G. Briscoe, Language, inner speech, and consciousness, in: Paper presented at the Association for the Scientific Study of Consciousness, Barcelona, Spain, 2002.
[7] N. Budwig, Language and the construction of self: developmental reflections, in: N. Budwig, I.C. Uzgiris, J.V. Wertsch (Eds.), Communication: An Arena of Development, Ablex, Stamford, 2000.
[8] N. Burgess, E.A. Maguire, H.J. Spiers, J. O'Keefe, A temporaparietal and prefrontal network for retrieving the spatial context of lifelike events, NeuroImage 14 (2001) 439–453.
[9] T. Burns, E. Engdahl, The social construction of consciousness Part 1: collective consciousness and its socio-cultural foundations, J. Cons. Stud. 5 (1) (1998) 67–85.
[10] R. Cabeza, J.K. Locantore, N.D. Anderson, Lateralization of prefrontal activity during episodic memory retrieval: evidence for the production-monitoring hypothesis, J. Cogn. Neurosci. 15 (2) (2003) 249–259.
[11] R. Cabeza, L. Nyberg, Imaging cognition II: an empirical review of 275 PET and fMRI studies, J. Cogn. Neurosci. 12 (1) (2000) 1–47.
[12] R. Cabeza, S.E. Prince, S.M. Daselaar, D.L. Greenberg, M. Budde, F. Dolcos, K.S. LaBar, D.C. Rubin, Brain activity during episodic retrieval of autobiographical and laboratory events: An fMRI study using a novel photo paradigm, J. Cogn. Neurosci. 16 (9) (2004) 1583–1594.
[13] P. Carruthers, The cognitive functions of language, Behav. Brain Sci. 25 (6) (2002) 657–674.
[14] K. Christoff, J.M. Ream, J.E.D. Gabrieli, Neural basis of spontaneous thought processes, Cortex 40 (2004) 623–630.
[15] M.A. Conway, Memory and the Self, J Mem Lang. 53 (4) (2005) 594–628.
[16] M.A. Conway, D.J. Turk, S.L. Miller, J. Logan, R.D. Nebes, C.C. Meltzer, J.T. Becker, A positron emission tomography (PET) study of autobiographical memory retrieval, Memory 7 (1999) 679–702.
[17] F. Craik, T. Moroz, M. Moscovitch, D. Stuss, G. Winocur, E. Tulving, S. Kapur, In search of the self: a positron emission tomography study, Psychol. Sci. 10 (1999) 26–34.
[18] H.D. Critchley, S. Wiens, P. Rotshtein, A. Ohman, R.J. Dolan, Neural systems supporting interoceptive awareness, Nat. Neuroci. 7 (2) (2004) 189–195.
[19] A. D'Argembeau, F. Collette, M. Van der Linden, S. Laureys, G. Del Fiore, C. Degueldre, A. Luxen, E. Salmon, Self-referential reflective activity and its relationship with rest: a PET study, NeuroImage 25 (2005) 616–624.
[20] S.M. Daselaar, D.J. Veltman, S.A.R.B. Rombouts, J.G.W. Raaijmakers, C. Jonker, Neuroanatomical correlates of episodic encoding and retrieval in young and elderly subjects, Brain 126 (2003) 43–56.
[21] R. De Bleser, J.C. Marshall, Egon Weigl and the concept of inner speech, Cortex 41 (2005) 249–257.
[22] J. Decety, J. Grezes, The power of simulation: imagining one's own and other's behavior, Brain Res 24 (1) (2006) 4–14.
[23] J. Decety, J.A. Sommerville, Shared representations between self and other: a social cognitive neuroscience view, Trends Cogn. Sci. 7 (12) (2003) 527–533.
[24] D.C. Dennett, Consciousness Explained, Little Brown, Boston, MA, 1991.
[26] M.J. Emerson, A. Miyake, The role of inner speech in task switching: A dual-task investigation, J. Mem. Lang. 48 (2003) 148–168.
[27] L. Fadiga, L. Craighero, M.F. Destro, L. Finos, N. Cotillon-Williams, A.T. Smith, U. Castiello, Language in shadow, Soc Neuro. 1 (2) (2006) 77–89.
[28] C. Farrer, N. Franck, N. Georgieff, C.D. Frith, J. Decety, M. Jeannerod, Modulating the experience of agency: a positron emission tomography study, NeuroImage 18 (2003) 324–333.
[29] C. Farrer, C.D. Frith, Experiencing oneself vs. another person as being the cause of an action: the neural correlates of the experience of agency, NeuroImage 15 (2002) 596–603.
[30] G.R. Fink, H.J. Markowitsch, M. Reinkemeier, T. Bruckbauer, J. Kessler, W.D. Heiss, Cerebral representation of one's own past: Neural net-

works involved in autobiographical memory, J. Neurosci. 16 (13) (1996) 4275–4282.
[31] P. Fossati, S.J. Hevenor, S.J. Graham, C. Grady, M.L. Keightley, F. Craik, H. Mayberg, In search of the emotional self: an fMRI study using positive and negative emotional words, Am. J. Psychiatry 160 (2003) 1938–1945.
[32] P. Fossati, S.J. Hevenor, M. LePage, S.J. Graham, C. Grady, M.L. Keightley, F.I.M. Craik, H.S. Mayberg, Distributed self in episodic memory: neural correlates of successful retrieval of self-encoded positive and negative personality traits, NeuroImage 22 (4) (2004) 1596–1604.
[33] P. Fransson, Spontaneous low-frequency BOLD signal fluctuations: an fMRI investigation of the resting-state default mode of brain function hypothesis, Hum. Brain Mapp. 26 (2005) 15–29.
[34] U. Frith, C.D. Frith, Development and neurophysiology of mentalizing, Phil Trans Royal Soc Bio Sci. 29 (1431) (2003) 459–473.
[35] M. Gazzaniga, The bisected brain, Appleton, Century, Crofts, New York, 1970.
[36] A. Gilboa, G. Winocur, C.L. Grady, S.J. Hevenor, M. Moscovitch, Remembering our past: functional neuroanatomy of recollection of recent and very remote personal events, Cereb. Cortex 14 (2004) 1214–1225.
[37] S.J. Gillihan, M.J. Farah, Is self special? A critical review of evidence from experimental psychology and cognitive neuroscience, Psychol. Bull. 131 (2005) 76–97.
[38] I.I. Goldberg, M. Harel, R. Malach, When the brain loses its self: Prefrontal inactivation during sensorimotor processing, Neuron 50 (2006) 329–339.
[39] D.L. Greenberg, D.C. Rubin, The neuropsychology of autobiographical memory, Cortex 39 (4/5) (2003) 687–728.
[40] M.D. Greicius, B. Krasnow, A.L. Reiss, V. Menon, Functional connectivity in the resting brain: a network analysis of the default mode hypothesis, Proc. Natl. Acad. Sci. U.S.A. 100 (2003) 253–258.
[41] D.A. Gusnard, E. Akbudak, G.L. Shulman, M.E. Raichle, Medial prefrontal cortex and self-referential mental activity: relation to a default mode of brain function, Proc. Natl. Acad. Sci. U.S.A. 98 (2001) 4259–4264.
[42] K.R. Harris, Developing self-regulated learners: the role of private speech and self-instructions, Educ. Psychol. 25 (1) (1990) 35–49.
[43] T.F. Heatherton, C.N. Macrae, W.M. Kelley, What the social brain sciences can tell us about the self, Curr. Dir. Psychol. Sci. 13 (5) (2004) 190.
[44] T.F. Heatherton, C.L. Wyland, C.N. Macrae, K.E. Demos, B.T. Denny, W.M. Kelley, Medial prefrontal activity differentiates self from close others, Scan 1 (2006) 18–25.
[45] A. Heinzel, A. Walter, F. Schneider, M. Rotte, C. Matthiae, C. Tempelmann, H.J. Heinze, B. Bogerts, G. Northoff, Self-related processing in the sexual domain: a parametric event-related fMRI study reveals neural activity in ventral cortical midline structures, Soc Neuro. 1 (1) (2006) 41–51.
[46] P.L. Jackson, E. Brunet, A.N. Meltzoff, J. Decety, Empathy examined through the neural mechanisms involved in imagining how I feel versus how you feel pain, Neuropsychologia 44 (2006) 752–761.
[47] S.C. Johnson, L.C. Baxter, L.S. Wilder, J.G. Piper, J.E. Heiserman, G.P. Prigatano, Neural correlates of self-reflection, Brain 125 (2002) 1808–1814.
[48] S.C. Johnson, T.W. Schimitz, T.N. Kawaraha-Baccus, H.A. Rowley, A.L. Alexander, J. Lee, R.J. Davidson, The cerebral response during subjective choice with and without self-reference, J. Cogn. Neurosci. 17 (2005) 1897–1906.
[49] K.K.W. Kampe, C.D. Frith, U. Frith, "Hey John": Signals conveying communicative intention toward the self activate brain regions associated with "Mentalizing," regardless of modality, J. Neurosci. 23 (12) (2003) 5258–5263.
[50] I.P. Kan, S.H. Thompson-Schill, Effect of name agreement on prefrontal activity during overt and covert picture naming, Cogn. Affect. Behav. Neurosci. 4 (1) (2004) 43–57.
[51] J.P. Keenan, D. Falk, G.G. Gallup, The Face in the Mirror: the search for the origins of consciousness, Harper Collins Publishers, 2003.
[52] J.P. Keenan, J. Rubio, C. Racioppi, A. Johnson, A. Barnack, The right hemisphere and the dark side of consciousness, Cortex 41 (2005) 695–704.
[53] W.M. Kelly, C.N. Macrae, C.L. Wyland, S. Caglar, S. Inati, T.F. Heatherton, Finding the Self? An event-related fMRI study, J. Cogn. Neurosci. 14 (2002) 785–794.
[54] T.T.J. Kircher, C. Senior, E. Bullmore, P.J. Benson, A. Simmons, M. Bartel, A.S. David, Towards a functional neuroanatomy of self-processing: effects of faces and words, Cogn. Brain Res. 10 (2000) 133–144.
[55] T.T.J. Kircher, C. Senior, E. Bullmore, M.J. Brammer, P.J. Benson, A. Simmons, M. Bartel, A.S. David, Recognising one's own face, Cognition 78 (2001) B1–B15.
[56] T.W. Kjaer, M. Novak, H.C. Lou, Reflective self-awareness and conscious states: PET evidence for a common midline parietofrontal core, NeuroImage 17 (2002) 1080–1086.
[57] R.D. Lane, G.R. Fink, P.M.l. Chau, R.J. Dolan, Neural activation during selective attention to subjective emotional responses, NeuroReport 8 (1997) 3969–3972.
[58] H. Laufs, K. Krakow, P. Sterzer, E. Eger, A. Beyerle, A. Salek-Haddadi, A. Kleinschmidt, Electroencephalographic signatures of attentional and cognitive default modes in spontaneous brain activity fluctuations at rest, Proc. Natl. Acad. Sci. U.S.A. 100 (19) (2003) 11053–11058.
[59] M.R. Leary, The Curse of the Self: Self-Awareness, Egotism, and the Quality of Human Life, Oxford University Press, 2004.
[60] D.T. Leube, G. Knoblich, M. Erb, T.T.J. Kircher, Brain networks for identifying one's own actions, Neuropsychologia 266–289 (2003).
[61] D.T. Leube, G. Knoblich, M. Erb, W. Grodd, M. Bartels, T.T.J. Kircher, The neural correlates of perceiving one's own movements, NeuroImage 20 (2003) 2084–2090.
[62] B. Levine, G.R. Turner, D. Tisserand, S.J. Hevenor, S.J. Graham, A.R. McIntosh, The functional neuroanatomy of episodic and semantic autobiographical remembering: a prospective functional MRI study, J. Cogn. Neurosci. 16 (9) (2004) 1633–1646.
[63] M.D. Lieberman, Social cognitive neuroscience: a review of core processes, Ann. Rev. Psychol. 58 (2007) 259–289.
[64] M.D. Lieberman, J.M. Jarcho, A.B. Satpute, Evidence-based and intuition-based self-knowledge: an fMRI study, J. Pers. Soc. Psychol. 87 (2004) 421–435.
[65] M.D. Lieberman, J.H. Pfeifer, The self and social perception: three kinds of questions in social cognitive neuroscience, in: A. Easton, N. Emery (Eds.), Cognitive Neuroscience of Emotional and Social Behavior, Psychology Press, Philadelphia, 2005, pp. 195–235.
[66] H.C. Lou, B. Luber, M. Crupain, J.P. Keenan, M. Novak, T.W. Kjaer, H.A. Sackeim, S.H. Lisaby, Parietal cortex and representation of the mental self, Proc. Natl. Acad. Sci. 101 (2004) 6827–6832.
[67] C.N. Macrae, J.M. Moran, T.F. Heatherton, J.F. Banfield, W.M. Kelley, Medial prefrontal activity predicts memory for self, Cereb. Cortex 14 (2004) 647–654.
[68] E.A. Maguire, C.D. Frith, Aging affects the engagement of the hippocampus during autobiographical memory retrieval, Brain 126 (1) (2003) 1–13.
[69] E.A. Maguire, C.J. Mummery, Differential modulation of a common memory retrieval network revealed by positron emission tomography, Hippocampus 9 (1) (1999) 54–61.
[70] E.A. Maguire, C.J. Mummery, C. Buchel, Patterns of hippocampal–cortical interaction dissociate temporal lobe memory subsystems, Hippocampus 10 (4) (2000) 475–482.
[71] B. Mazoyer, L. Zago, E. Mellet, S. Bricogne, O. Etard, O. Houde, F. Crivello, M. Joliot, L. Petit, N. Tzourio-Mazoyer, Cortical networks for working memory and executive functions sustain the conscious resting state in man, Brain Res. Bull. 54 (3) (2001) 287–298.
[72] P.A. McDonald, T. Paus, The role of parietal cortex in awareness of self-generated movements: a transcranial magnetic stimulation study, Cereb. Cortex 13 (2003) 962–967.
[73] P.K. McGuire, D.A. Silbersweig, D.A. Frith, Functional neuroanatomy of verbal self-monitoring, Brain 119 (1996) 907–917.
[74] P.K. McGuire, D.A. Silbersweig, R.M. Murray, A.S. David, R.S.J. Frackowiak, C.D. Frith, Functional anatomy of inner speech and auditory verbal imagery, Psychol. Med. 26 (1996) 29–38.

[75] P.K. McGuire, D.A. Silbersweig, I. Wright, R.M. Murray, R.S.J. Frackowiak, C.D. Frith, The neural correlates of inner speech and auditory verbal imagery in schizophrenia: relationship to auditory verbal hallucinations, Br. J. Psychol. 169 (2) (1996) 148–159.
[76] J.A. Meacham, The role of verbal activity in remembering the goals of actions, in: G. Zivin (Ed.), The Development of Self-Regulation Through Private Speech, Wiley, New York, 1979.
[77] G.H. Mead, The mechanism of social consciousness, in: A.J. Reck (Ed.), Selected writings: George Herbert Mead, University of Chicago Press, Chicago, 1912/1964.
[78] A. Miyake, M.J. Emerson, F. Padilla, J.-C. Ahn, Inner speech as a retrieval aid for task goals: the effects of cue type and articulatory suppression in the random task cuing paradigm, Acta Psychol. 115 (2004) 123–142.
[79] Y. Moriguchi, J. Decety, T. Ohnishi, M. Maeda, T. Mori, K. Nemoto, H. Matsuda, G. Komaki, Empathy and judging other's pain: an fMRI study of alexithymia, Cereb. Cortex 5 (2006) 1047–3211.
[80] A. Morin, Imagery and self-awareness: a theoretical note, Theory Rev. Psychol. (1998) [Electronic journal].
[81] A. Morin, A neurocognitive and socioecological model of self-awareness, Genet. Soc. Gen. Psychol. Monogr. 130 (3) (2004) 197–222.
[82] A. Morin, Possible links between self-awareness and inner speech: theoretical background, underlying mechanisms, and empirical evidence, J Cons. Stud. 12 (4/5) (2005) 115–134.
[83] A. Morin, Inner speech. Invited paper for the 2006 Oxford Companion to Consciousness, in press.
[84] K. Nelson, Emerging levels of consciousness in early human development, in: H.S. Terrace, J. Metcalfe (Eds.), The Missing Link in Cognition: Origins of Self-Reflective Consciousness, Oxford University Press, Oxford, 2005.
[85] S.F. Nolde, M.K. Johnson, M. D'Esposito, Left prefrontal activation during episodic remembering: an event-related fMRI study, NeuroReport 9 (1998) 3509–3514.
[86] G. Northoff, F. Bermpohl, Cortical midline structures and the self, Trends Cogn. Sci. 8 (3) (2004) 102–107.
[87] G. Northoff, A. Heinzel, M. de Greck, F. Bermpohl, H. Dobrowolny, J. Panksepp, Self-referential processing in our brain: a meta-analysis of imaging studies on the self, Neuroimage 15 (1) (2006) 440–457.
[88] K.N. Ochsner, J.S. Beer, E.R. Robertson, J.C. Cooper, J.D. Gabrieli, J.F. Kihsltrom, M. D'Esposito, The neural correlates of direct and reflected self-knowledge, Neuroimage 28 (4) (2005) 797–814.
[89] K.N. Ochsner, K. Knierim, D.H. Ludlow, J. Hanelin, T. Ramachandran, J. Glover, S.C. Mackey, Reflecting upon Feelings: an fMRI study of neural systems supporting the attribution of emotion to self and other, J. Cogn. Neurosci. 16 (2004) 1746–1772.
[90] G. Ojemann, Brain mechanisms for consciousness and conscious experience, Can. Psych./Psyc. Can. 27 (2) (1986) 158–168.
[91] M. Overgaard, M. Koivisto, T.A. Sorensen, S. Vangkilde, A. Revonsuo, The electrophysiology of introspection, Conscious Cogn. 15 (4) (2006) 662–672.
[92] M.P. Paulus, L.R. Frank, Ventromedial prefrontal cortex activation is critical for preference judgments, Brain Imaging 14 (10) (2003) 1311–1315.
[93] E. Paulesu, C.D. Frith, R.S.J. Frackowiak, The neural correlates of the verbal component of working memory, Nature 362 (1993) 342–345.
[94] E. Paulesu, B. Goldacre, P. Scifo, S.F. Cappa, M.C. Gilardi, I. Castiglioni, D. Perani, F. Fazio, Functional heterogeneity of left inferior frontal cortex as revealed by fMRI, NeuroReport 8 (1997) 2011–2016.
[95] F. Perrin, P. Maquet, P. Peigneux, P. Ruby, C. Degueldre, E. Balteau, G. Del Fiore, G. Moonen, A. Luxen, S. Laureys, Neural mechanisms involved in the detection of our first name: a combined ERPs and PET study, Neuropsychologia 43 (2005) 12–19.
[96] K.L. Phan, S.F. Taylor, R.C. Welsh, S.H. Ho, J.C. Britton, I. Liberzon, Neural correlates of individual ratings of emotional salience: a trial-related fMRI study, NeuroImage 21 (2004) 768–780.
[97] M. Piefke, P.H. Weiss, K. Zilles, H.J. Markowitsch, G.R. Fink, Differential remoteness and emotional tone modulate the neural correlates of autobiographical memory, Brain 126 (2003) 650–668.
[98] P. Piolino, G. Giffard-Quillon, B. Desgranges, G. Chetelat, J.C. Baron, F. Eustache, Re-experiencing old memories via hippocampus: a PET study of autobiographical memory, NeuroImage 22 (2004) 1371–1383.
[99] S.M. Platek, J.P. Keenan, G.G. Gallup, F.B. Mohamed, Where am I? The neurological correlates of self and other, Cogn. Brain Res. 19 (2004) 114–122.
[100] S.M. Platek, J.W. Loughead, R.C. Gur, S. Busch, K. Ruparel, N. Phend, I.S. Panyavin, D.D. Langleben, Neural substrates for functionally discriminating self-face from personally familiar faces, Hum. Brain Mapp. 27 (2) (2006) 91–98.
[101] R.A. Poldrack, Can cognitive processes be inferred from neuroimaging data? Trends Cogn. Sci. 10 (2) (2006) 59–63.
[102] R.A. Poldrack, A.D. Wagner, What can neuroimaging tell us about the mind? Insights from prefrontal cortex, Curr. Dir. Psychol. Sci. 13 (2004) 177–181.
[103] K.R. Popper, J.C. Eccles, The Self and Its Brain: An Argument for Interactionism, Springer International, Berlin, 1977.
[104] R.N. Roberts, Private speech in academic problem-solving: a naturalistic perspective, in: G. Zivin (Ed.), The Development of Self-Regulation Through Private Speech, Wiley, New York, 1979.
[105] P. Ruby, J. Decety, Effect of subjective perspective taking during simulation of action: a PET investigation of agency, Nat. Neurosci. 4 (5) (2001) 546–550.
[106] M.N. Rusalova, Characteristics of Interhemisphere Interactions at Different Levels of Consciousness, Neurosci. Behav. Physiol. 35 (8) (2005) 821–827.
[107] L. Ryan, L. Nadel, K. Keil, K. Putnam, D. Schnyer, T. Trouard, M. Moscovitch, Hippocampal complex and retrieval of recent and very remote autobiographical memories: evidence from functional magnetic resonance imaging in neurologically intact people, Hippocampus 11 (2001) 707–714.
[108] T.W. Schmitz, T.N. Kawahara-Baccus, S.C. Johnson, Metacognitive evaluation, self-relevance, and the right prefrontal cortex, NeuroImage 22 (2004) 941–947.
[109] T.W. Schmitz, H.A. Rowley, T.N. Kawahara, S.C. Johnson, Neural correlates of self-evaluative accuracy after traumatic brain injury, Neuropsychologia 44 (2006) 762–773.
[110] J.F. Schneider, M. Pospeschill, J. Ranger, Self-consciousness as a mediator between self-talk and self-knowledge, Psychol. Rep. 96 (2005) 387–396.
[111] R.W. Schrauf, Bilingual inner speech as the medium of cross-modular retrieval in autobiographical memory, Behav. Brain Sci. 25 (2002) 698–699.
[112] C.A. Seger, M. Stone, J.P. Keenan, Cortical activations during judgment about the self and an other person, Neuropsychologia 42 (2004) 1168–1177.
[113] T. Shallice, Theory of mind and the prefrontal cortex, Brain 124 (2001) 247–248.
[114] S.S. Shergill, M.J. Brammer, R. Fukuda, S.C.R. Williams, R.M. Murray, P.K. McGuire, Engagement of brain areas implicated in processing inner speech in people with auditory hallucinations, Br. J. Psychol. 182 (2003) 525–531.
[115] Shi-xu, Mind, self, and consciousness as discourse, New Ideas Psychol. 24 (1) (2006) 63–81.
[116] M. Siegrist, Inner speech as a cognitive process mediating self-consciouness and inhibiting self-deception, Psychol. Rep. 76 (1995) 259–265.
[117] A.N. Sokolov, Inner Speech and Thought, Plenum Press, New York, 1972.
[118] M. Stamenov, Language and self-consciousness: modes of self-presentation in language structure, in: T. Kircher, A. David (Eds.), The Self in Neuroscience and Psychiatry, Cambridge University Press, Cambridge, 2003.
[119] L. Steels, Language re-entrance and the inner voice, J. Cons. Stud. 10 (4/5) (2003) 173–185.
[120] S. Steinvorth, S. Corkin, E. Halgren, Ecphory of autobiographical memories: an fMRI study of recent and remote memory retrieval, Neuroimage 30 (1) (2006) 285–298.

[121] M. Sugiura, R. Kawashima, K. Nakamura, K. Okada, T. Kato, A. Nakamura, K. Hatano, K. Itoh, S. Kojima, H. Fukuda, Passive and active recognition of one's own face, NeuroImage 11 (2000) 36–48.
[122] M. Sugiura, J. Wanabe, Y. Maeda, Y.H. Fukuda, R. Kawashima, Cortical mechanisms of visual self-recognition, Neuroimage 24 (2005) 143–149.
[123] E. Svoboda, M.C. McKinnon, B. Levine, The functional neuroanatomy of autobiographical memory: a meta-analysis, Neuropsychologia 44 (12) (2006) 2189–2208.
[124] H. Takahashi, N. Yahata, M. Koeda, T. Matsuda, K. Asai, Y. Okubo, Brain activation associated with evaluative processes of guilt and embarrassment: an fMRI study, NeuroImage 23 (2004) 967–974.
[125] S.F. Taylor, K.L. Phan, L.R. Decker, I. Liberzon, Subjective rating of emotionally salient stimuli modulates neural activity, NeuroImage 18 (2003) 650–659.
[126] D.J. Turk, T.F. Heatherton, W.M. Kelley, M.G. Funnell, M.S. Gazzaniga, C.N. Macrea, Mike or me? Self-recognition in a split-brain patient, Nat. Neurosci. 5 (2002) 841–842.
[127] D.J. Turk, T.F. Heatherton, C.N. Macrae, W.M. Kelley, M.S. Gazzaniga, Out of Contact, Out of Mind: The Distributed Nature of the Self, Ann. N Y Acad. Sci. 1001 (2003) 1–14.
[128] L.Q. Uddin, J. Rayman, E. Zaidel, Split-brain reveals separate but equal self-recognition in the two cerebral hemispheres, Conscious Cogn. 14 (3) (2005) 633–640.
[129] P. Verstichel, C. Bourak, V. Font, G. Crochet, Langage intérieur après lésion cérébrale gauche: Etude de la représentation phonologique des mots chez des patients aphasiques et non aphasiques [Inner speech and left brain damage: study of the phonological analysis of words in aphasic and non-aphasic patients], Revue de Neuropsyc. 7 (3) (1997) 281–311.
[130] A.J.O. Whitehouse, M.T. Maybery, K. Durkin, Inner speech impairments in autism, J. Child Psychol. Psychiatry 47 (8) (2006) 857–865.
[131] B. Wicker, P. Ruby, J.P. Royet, P. Fonlupt, A relation between rest and the self in the brain? Brain Res. Rev. 43 (2003) 224–230.
[132] M. Wraga, J.M. Shephard, J.A. Church, S. Inati, S.M. Kosslyn, Imagined rotations of self versus objects: an fMRI study, Neuropsychologia 43 (9) (2005) 1351–1361.
[133] L. Zhang, T. Zhou, J. Zhang, Z. Liu, J. Fan, Y. Zhu, In search of the Chinese self: an fMRI study, Sci. in China: Ser. C Life Sci. 49 (1) (2006) 89–96.
[134] G. Zivin, Removing common confusions about egocentric speech, private speech, and self-regulation, in: G. Zivin (Ed.), The development of self-regulation through private speech, Wiley, New York, 1979.
[135] S. Zysset, O. Huber, E. Fersti, D.Y. Von Cramon, The anterior frontomedian cortex and evaluative judgment: an fMRI study, NeuroImage 15 (2002) 983–991.
[136] S. Zysset, O. Huber, A. Samson, E. Fersti, D.Y. Von Cramon, Functional specialization within the anterior medial prefrontal cortex: a functional magnetic resonance imaging study with human subjects, Neurosci. Lett. 335 (2003) 183–186.