The Anterior Temporal Lobes: New Frontiers Opened to Neuropsychological Research by Changes in Health Care and Disease Epidemiology

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Changes in health care and disease epidemiology have shifted the attention of neuropsychologists and cognitive neuroscientists from vascular lesions to degenerative diseases or other bilateral brain lesions. This displacement of attention from vascular patients to patients with degenerative brain diseases allowed the discovery of hitherto unexplored and unheralded aspects of the neural substrates of human cognition. Three aspects of research on the anterior parts of the temporal lobes (ATLs) are the focus of the present review. The first aspect is category-specific semantic disorders, including current accounts of categorical brain organization, the anatomical substrate of different categories (stressing the role of the ATLs with respect to the biological categories), and the "sources of knowledge" that contribute to construction of those categories. The second aspect is the role of the ATLs in conceptual knowledge, including the "hub-and-spokes" model of semantic representation and semantic control. The third aspect is the role of the right ATL in recognition of familiar people, including the distinction made between associative prosopagnosia and multimodal disorders of person recognition. Consistencies and inconsistencies of results obtained across these different domains are discussed, and the clinical implications of these findings are considered.

J Neuropsychiatry Clin Neurosci 2018; 30:22–30;
doi: 10.1176/appi.neuropsych.17010002

For more than a century, classical neuropsychological research, aiming to clarify the neural substrates of the human mind, derived from the study of aphasia and other instrumental cognitive disorders (such as limb apraxia, constructional apraxia, or unilateral spatial neglect) due to unilateral vascular lesions, most of which have a fairly typical brain distribution.[1] In recent years, however, changes in health care and disease epidemiology have facilitated a shift away from the study of the neuropsychological consequences of vascular lesions and toward the study of such problems due to degenerative diseases or other bilateral lesions. After the introduction of the "diagnosis-related group" (DRG) system,[2] the number of studies dealing with neuroanatomical and pathophysiological aspects of aphasia and other cognitive disorders resulting from vascular lesions dramatically decreased within the acute hospital setting. This reduction was due to the time constraints (e.g.,[3–5]) and diminished funding (e.g.,[6]) related to the introduction of the DRG system. Researchers of the neural substrates of cognitive functions were, therefore, pushed to shift the study of interesting patients from hospitals to rehabilitation facilities.

This displacement had two negative implications for research. First, rehabilitation techniques modify the structure of the observed cognitive defects, confounding their interpretation. Second, rehabilitation structures rarely have easy access to advanced structural and functional neuroimaging technologies, thereby hampering the study of precise anatomo-clinical correlations among persons admitted for neurorehabilitation.

Along with the introduction of the DRG system, population aging in economically developed countries (e.g.,[7]) also shifted the attention of neuropsychologists and cognitive neuroscientists from vascular lesions to age-related neurodegenerative diseases. This shift of scientific attention from patients with unilateral vascular lesions to patients with degenerative brain diseases or other conditions producing bilateral brain lesions and/or dysfunction facilitated the exploration of the neural substrates of previously unexplored aspects of human cognition and behavior.

Brain-behavior relationships of anterior parts of the temporal lobes therefore are the principal focus of this work. These cortical areas are rarely (and almost never bilaterally) damaged in vascular patients, as they receive a dual blood supply from the anterior temporal branches of the middle cerebral artery and from the anterior temporal branch of the posterior cerebral artery.[8–10] Accordingly, the neurobehavioral aspects of the anterior temporal lobe (ATL) has not been a major focus of research in neuropsychology and cognitive neuroscience until the present era. Studies in this area have provided insight into three areas, each of which will be considered in the present review: a) category-specific

semantic disorders, b) the role of the ATL in conceptual representations, and c) the role of the right ATL in recognition of familiar people.

CATEGORY-SPECIFIC SEMANTIC DISORDERS

Since Lichtheim's[11] classical paper proposing a neuroanatomy of language, it has been generally assumed that conceptual representations (being based on a convergence of different perceptual attributes) should be evenly distributed across the cerebral cortex. Warrington et al.[12–14] first challenged this assumption, showing that conceptual knowledge (instead of being evenly distributed across the cerebral cortex) is organized by categories and that the selective disruption of these categories is due to the lesion of well-defined brain structures. In particular, Warrington and Shallice[11] noticed that in four patients affected by herpes simplex encephalitis (HSE) with lesions involving the ATLs, the semantic impairment preferentially disrupted the biological categories of animals, fruits, and vegetables. On the other hand, Warrington and McCarthy[12,13] remarked that in two patients affected by vascular lesions involving the left fronto-temporo-parietal cortices, tools and other artifact categories were slightly but significantly more affected than items belonging to biological categories.

The "Differential Weighting" Account of Category-Specific Semantic Disorders

Warrington et al.[12–14] claimed that the different neural substrate of biological and artifact categories is due to the "differential weight" that visual and functional/somatosensory attributes have in the construction of these categories of knowledge (the "differential weighting hypothesis"). The distinction between members of biological categories are, indeed, mainly based upon subtle visual-perceptual features, such as the plain, striped, or spotted skin that distinguishes a lion from a tiger or a leopard, whereas tools and other artifacts are distinguished more by the different functions for which they were designed and by the fact that their knowledge is mainly based on actions and somato-sensory information than by their visual features. These pioneering observations were confirmed in the following years by other clinico-pathological reports, attesting the selective disruption of biological categories in patients with HSE lesions encroaching upon the ATL structures (e.g.,[15–17]) and the prevalent impairment of man-made artifacts in patients with vascular lesions involving the left fronto-temporo-parietal areas (e.g.,[18,19]). Drawing on the "differential weighting hypothesis," Gainotti[20] posited that the brain structures disrupted in patients with a given type of category-specific semantic disorder correspond to the convergence zones[21] of sensory-motor information integral to construction of that category.

The Study of the "Sources of Knowledge" for Semantic Categories

The influence of different "sources of knowledge" (i.e., perceptual and motor activities) on mental representation of animate and inanimate biological objects and of artifacts (man-made objects such as tools, clothing, furniture, vehicles) has been studied in healthy subjects by means of feature lists (e.g.,[22–25]) or Likert scales (e.g.,[26–29]) in which subjects are asked to assess the relevance that different sensory modalities have in the representation of various category members. These studies have consistently shown that a) the visual modality is usually considered as the main source of knowledge for all (biological and artifact) categories and b) in biological categories the most important source of knowledge after vision is represented by other perceptual modalities, whereas in artifact categories it is represented by the actions performed with the target artifact. The anterior parts of the temporal lobes should, therefore, play a critical role in the representation of biological categories, because they are placed in the rostral part of the ventral stream of visual processing, where highly processed visual data converge with auditory, olfactory, and gustatory inputs, which are also very important in the representation of biological entities.[30] On the other hand, the left fronto-parietal cortices should play a major role in the representation of artifacts because in these areas the dorsal stream of visual processing converges with body-related and action-oriented sources of knowledge.[31]

The Distinction Within Biological Entities Between Animals and Plant-Life Categories

The simple dichotomy between biological entities and man-made objects cannot account for the brain substrate of different semantic categories, since some differences have been found, within the biological entities, between the neural correlates of defects mainly affecting animals and plant-life categories. Gainotti[32,33] and Capitani et al.[34] demonstrated neuroanatomical and gender-related differences between patients with temporal lobe lesions showing prevalent impairments for animals versus plant-life categories. A prevalent impairment of the fruits and vegetables category was observed in men with lesions in the left posterior cerebral artery territory encroaching upon the caudal and the inferomesial aspects of the left temporal lobe,[34] whereas a prevalent impairment of the animals category was observed in women showing bilateral lesions of the anterior temporal cortices.[33] Different "sources of knowledge," such as the importance of colors for flowers, fruits, and vegetables,[35,36] and of movement and sounds for animal knowledge,[29] could explain the abovementioned anatomical differences, whereas social role-related familiarity factors could account for the gender-linked asymmetries.[37] Furthermore, the presence of bilateral anterior temporal lesions in patients with category-specific disorders for animals and of left unilateral (parietal and occipital) lesions in patients with defects affecting man-made objects and fruits and vegetables could arise from bilateral representations of the main sources of knowledge about animals (visual, sounds, and other perceptual inputs). By contrast, in right-handed individuals, the motor and somato-sensory functions, which provide an important

source of knowledge not only about artifacts but also about fruits and vegetables, are mainly represented in the left hemisphere, which controls the actions performed with the right side of the body.[20,33]

The Inborn or Experience-Dependent Nature of Categorical Brain Organization

An important theoretical aspect of the categorical brain organization that is still highly controversial concerns its innate or experience-dependent nature.[38] In contrast to the "differential weighting hypothesis" offered by Warrington et al.,[12–14] Caramazza et al.[39–42] proposed a model (the "domains of knowledge hypothesis") that assumes the existence of an innate categorical organization of conceptual knowledge. More specifically, the domains of knowledge hypothesis posit a) that category-specific impairments for animals (potential predators), plant life (possible source of food), and artifacts reflect the disruption of innate brain networks, shaped by natural selection to support rapid identification of objects very relevant for survival, and b) that innate connectivity patterns may underlie categorical organization. Strong empirical data supporting the innate nature of these patterns of connectivity come from work indicating that congenitally blind subjects show activation for words (presented in Braille) in the same regions of the ventral stream that are activated by visually presented words in sighted individuals.[43] Mahon et al.[44] showed that the same medial-to-lateral bias in category preferences for artifacts versus animals, which is present in the ventral surface of the temporo-occipital cortex in sighted individuals,[45–47] is also present in congenitally blind subjects. On the basis of this observation, Mahon et al.[44] suggested that if visual experience is unnecessary for the emergence of category-specificity in the ventral stream, then innate connectivity between regions of the ventral stream and other regions of the brain could drive category-specificity.

On the other hand, several recent investigations (e.g.,[48–52]) have convincingly proved the importance of prior perceptual and motor experience in the cortical representation of previously familiar or unknown objects, whose knowledge had been learned through intensive training. A discussion of this complex problem exceeds the scopes of the present review (for a detailed review, see Gainotti[38]). For the present review, it suffices to say that, irrespectively of the inborn or experience-dependent nature of the brain categorical organization, the critical role of the ATL in processing animal knowledge has also been acknowledged by authors belonging to Caramazza's group.[53]

THE ROLE OF THE ANTERIOR TEMPORAL LOBES IN CONCEPTUAL REPRESENTATIONS

Warrington[54] was probably the first author to describe patients with a degenerative brain disease, who presented a selective disruption of semantic knowledge, in a context of intact day-to-day memory, perceptual and spatial abilities, and syntactic and phonological processing. Some years later, Snowden et al.[55] and Hodges et al.[56] attributed this selective impairment of semantic knowledge to a bilateral atrophy of the ATLs. They proposed the term "semantic dementia" (SD) to denote this new pathological entity, which corresponded to the temporal variant of fronto-temporal dementia (FTD).[57] From the neuropsychological point of view, several papers have established that, in the moderate to severe forms of this disease, SD patients show semantic defects for items presented in every verbal and nonverbal modality and that this defect concerns not only the meaning of common words, but also that of the corresponding pictorial images.

The "Hub-and-Spoke" Model of Conceptual Representation

Starting from data gathered in SD patients, Rogers et al.[58] developed a computational "hub-and-spoke" model, in which modality-specific regions provide the basic sensory, motor, and verbal ingredients ("spokes") and are networked neuroanatomically to a "hub" that supports additional amodal representations. Some years later, Patterson et al.[59] proposed that the neural network for semantic memory requires a single convergence zone (i.e., a "hub") and that the ATLs bilaterally serve this role by supporting the interactive activation of representations in all modalities and for all semantic categories.

Gainotti[60,61] noted, however, that it is only in the moderate to advanced stages of diseases that affect the ATLs bilaterally that semantic impairment is "multimodal." In the early stages of such diseases, when important asymmetries can be observed at the level of the ATLs, semantic impairments can be modality-specific. In these cases, the impairment mainly involves lexical-semantic knowledge when the left temporal lobe is more affected and pictorial representations when the disease process is predominantly right-sided. These data suggest that the semantic disorder observed in SD is due to the co-occurrence of verbal and nonverbal defects, resulting from left and right ATL atrophy, and that the multimodal semantic impairment observed in advanced stages of SD is due to the combined disruption of pictorial and verbal representations, rather than to the loss of amodal knowledge, bilaterally stored in the ATL.

A similar model has been more recently proposed in studies conducted by Lambon Ralph and colleagues[62–65] and framed as the "graded hub hypothesis." This hypothesis posits that multimodal, cross-categorical semantic representations are jointly supported by both left and right ATLs, but maintains that subtle functional gradations may emerge as a consequence of their differential connectivity with primary sensory/motor/limbic regions. In particular, it is suggested that stronger connections with the language areas explain impairments of lexical-semantic knowledge when the left temporal lobe is principally affected. Assuming that the ATL functions are at least in part connectivity-driven, this hypothesis also provides a possible explanation for other graded functional specializations within the ATLs. Thus, the

anterior parts of the left superior temporal gyrus could contribute more to abstract words and verbal semantic processing by virtue of their greater connectivity to the language areas,[66] whereas the temporal pole could mainly contribute to social concepts by virtue of its connectivity to the amygdala and other structures supporting social cognition and affects.[67,68]

The Distinction Between Semantic Representation and Semantic Control Disorders

Since nonverbal conceptual disorders (e.g., the inability to recognize meaningful sounds,[69] to understand simple symbolic gestures,[70] or to draw objects from memory[71]) have also been reported in individuals with poststroke aphasia, Lambon Ralph and colleagues[65,72–74] have suggested that the semantic disturbances observed in SD are distinct from those observed in semantic aphasia (SA). Semantic disturbances in SD reflect loss of semantic representations stored in the ATLs, whereas semantic disturbances in SA result from defects in semantic control (i.e., impairment of the executive processes that direct and control semantic activation in a task-appropriate fashion). Several qualitative features (e.g., consistency of performance across tests, sensitivity to the frequency and familiarity of stimuli, effects of cuing and miscuing on task performance, degree of inhibition produced by weak versus strong competitors) distinguish disorders of semantic representation from disorders of semantic control (for a review, see[55,75]). Furthermore, and at variance with the unitary location of semantic representations within the ATLs, Lambon Ralph and colleagues describe a distributed semantic control network that includes, among other structures, the ventrolateral prefrontal cortex,[75] the temporo-parietal cortex,[76] the dorsal angular gyrus, and the posterior middle temporal gyrus.[77] The evidence they provide undermines the thesis that there is a unitary location for semantic representations within the ATLs and further suggests that each component of this distributed semantic control network may have a graded functional specialization.

THE ROLE OF THE RIGHT ATL IN RECOGNIZING FAMILIAR PEOPLE

Bodamer[78] first described a specific form of visual agnosia selectively affecting face recognition, which he labeled "prosopagnosia" (from the Greek: "prosopon"="face," "agnosia"="not knowing"). The study of prosopagnosia has been, for many decades, the almost exclusive context for the study of the neural bases of recognition of familiar people.

The Modality-Specific Forms of Disorders of Recognition of Familiar People

In each social species, identification of individuals belonging to a social group is a fundamental biological function that is accomplished mainly through face recognition in the visual modality and voice recognition in the auditory modality. For some decades, prosopagnosia was the most recognized, and almost uniquely described, disturbance of recognition of familiar faces/people. More than 40 years after Bodamer's description of prosopagnosia, de Renzi et al.[79] proposed a distinction between "apperceptive" and "associative" prosopagnosia. According to this distinction, the apperceptive prosopagnosia is an impairment not only in the recognition of familiar faces but also in the discrimination of unfamiliar faces and in processing non-person-specific information (e.g., age, gender, emotional expression); as such, it is regarded as a higher-level (i.e., cortical) visual disorder. By contrast, associative prosopagnosia is an impairment in the recognition of familiar faces in the absence of problems discriminating them from unfamiliar faces and of other subtle visual disorders; as such, this form of prosopagnosia reflects an associative disturbance or a mnestic disturbance.

From a neuroanatomical perspective, Kanwisher and colleagues' seminal paper[80] explained prosopagnosia in relation to the disturbances in the structure and/or function of the lateral portion of the mid-fusiform gyrus of a processing module specialized for faces, termed the fusiform face area (FFA). More recent studies suggest that prosopagnosia may be due to lesion of a larger network represented in the right hemisphere[81,82] that includes, in addition to the FFA, the occipital face area (OFA),[83] the ATLs,[84] and their interconnections[85]. It is generally acknowledged that the inferior occipital areas mainly subsume the first stages of face perception, the fusiform face areas shape the holistic face configuration, and the ATLs store individual face templates and/or integrate information concerning the face, voice, and name of a familiar person.

As for voice recognition disorders, Van Lanker and Canter[86] first described this problem as "phonagnosia." Pure phonagnosia has been described in a very small number of patients with bilateral or right temporal lesions, and the methods used in their description limit their interpretation. Hailstone et al.[87] offer the only case of "associative phonagnosia" in a patient with behavioral variant of FTD and lesions involving bilaterally the superior temporal gyrus.

The Multimodal Forms of Impaired Recognition of Familiar People

The "dominance" of faces in the study of the process of recognizing familiar people led the neuropsychology community to neglect the description by Ellis et al.[88] and Hanley et al.[89] of patients with ATL lesions, mainly right-sided, who showed a multimodal defect in the ability to recognize famous people. In these patients, inability to recognize familiar people included recognition by face, voice, and (to a lesser extent) personal name. Even if their recognition disorders were not limited to the visual (face) modality, they were considered as having associative prosopagnosia (e.g.,[90–92]). Several authors[93–95] have highlighted the fact that individuals with degenerative lesions of the right ATL who are unable to recognize familiar persons from face do not have "associative prosopagnosia" alone because their inability to identify familiar persons extends to recognition

of familiar persons by voice and, to a lesser extent, by proper names.

Gainotti[96] therefore undertook a review of all reported cases of "associative prosopagnosia" associated with right ATL lesions for the purposes of determining whether their impairments were circumscribed to the visual modality or instead extended to other modalities ordinarily supporting person recognition. This review revealed that most reports limited their study to the visual modality; however, when other modes of people recognition were evaluated, the defect was often multimodal, affecting voice (and, to a lesser extent, name) in addition to face.

The multimodal nature of person recognition disorders shown by patients with right ATL atrophy was recently confirmed by Luzzi et al.[97] These authors investigated recognition of famous faces and voices in SD and dementia due to Alzheimer's disease (AD) in order to determine whether these conditions differed with respect to the pattern of impairment of famous faces and voices recognition and to test the hypothesis that face and voice recognition disorders prevail in patients with atrophy mainly affecting the RTL. Results showed a differential performance profile in the two diseases: AD patients were significantly impaired in the naming tests but showed preserved recognition, whereas SD patients were profoundly impaired both in naming and in recognition of famous faces and voices. Additionally, among the 12 SD patients in whom positron emission tomography was performed, a strong correlation between FDG uptake and face and voice recognition disorders was found in the right but not in the left ATL.

Controversies About the Nature of Face Recognition Disorders in Patients With Right ATL Lesions

The findings reported in Gainotti's[96] review suggest that describing neuropsychological consequences of structural or functional disturbances of the right ATL requires not only evaluation of famous face recognition but also formal testing of the ability to recognize others by voice. Case reports[95,98] have shown that patients with multimodal person recognition disorders are often unaware of their voice recognition disorders. Liu et al.[99] studied whether face recognition disorder in ATL must be viewed as an associative variant of prosopagnosia or as part of a multimodal disorder of person recognition by assessing voice perception and short-term recognition of recently heard voices in 10 subjects with impaired face recognition. Deficits indicating a multimodal person recognition disorder were found in two subjects with bilateral ATL lesions, whereas three subjects with right ATL lesions had normal voice perception. They concluded that right ATL lesions can cause a modality-specific form of associative prosopagnosia.

An objection that can be raised to these conclusions stems from the fact that voice recognition disorders have been evaluated in this study with a test of short-term recognition of recently heard voices. However, Gobbini and Haxby,[100] as well as Blank et al.,[101] have demonstrated that there are two separate networks for recognition of newly learned persons and for famous or personally-familiar persons. A direct comparison of recognition disorders through face and voice of well-known people would have been, therefore, preferable, but a direct comparison between the two modalities is hindered by the fact that voice recognition is more difficult than face recognition[102–105] and that complex batteries devised to assess people recognition across different modalities are not currently available, because their construction is time consuming and they are culture-specific.

To circumvent these difficulties, Quaranta et al.[106] have recently constructed the Famous People Recognition Battery, which tasks subjects with recognizing persons, well-known at the national level, through both their faces and their voices, thereby evaluating familiarity and identification processes. They developed normative data with which to clarify the nature of person recognition disorders observed in patients affected by right ATL lesions, and set the scene for a clearer view of hemispheric asymmetries in familiar people recognition. However, since patients with right ATL atrophy are uncommon, gathering a sufficient sample of such patients is unlikely to be done quickly.

CONSISTENCIES AND INCONSISTENCIES OF FINDINGS FROM STUDIES OF THE ANTERIOR TEMPORAL LOBES

Due to the relative recency of research on the ATL, findings from this literature must be regarded as evolving rather than completed. Indeed, at least one consistency and one inconsistency drawn from the three main areas of research on the ATL may be described. The consistency concerns the fact that both conceptual and familiar people recognition disorders prevail in the verbal modality when the atrophy mainly affects the left ATL and in the pictorial modality when it mostly affects the right ATL. The apparent inconsistency concerns the presence of category-specific semantic disorders in many HSE patients and the presence of a general semantic impairment in SD patients (e.g.,[65,107,108]), in spite of the fact that both diseases affect the ATLs.

Consistency Between the Format of Conceptual and Familiar People Representations in the Right and Left ATL

Snowden et al.[109,110] studied person-specific semantic information obtainable from visual (face) and verbal (name) stimuli in patients with degenerative lesions of the right and left ATL, administering to the same subjects also the picture and the word version of the semantic memory "Pyramids and Palm Trees" (PPT) test.[111] They showed that SD patients with predominantly left temporal lobe atrophy identified faces better than names and performed better on the picture than on the word version of the PPT test; by contrast, patients with right temporal lobe atrophy showed the opposite pattern of performance. Similar data were recently reported by Luzzi et al.[97]

These findings support the thesis that conceptual and personal representations are linked to the verbal modality in the left ATL and to nonverbal modalities in the right ATL.[50,51] It remains, however, very difficult to say whether the differences between left and right ATLs are due to the verbal versus nonverbal formats of semantic representations they support[60,61] or instead result from the greater connectivity of the left ATL with language areas and of the right ATL with perceptual areas.[65]

Inconsistency Between HSE and SD Patients With Respect to Category-Specific Semantic Disorders

As for the inconsistency between presence of category-specific semantic disorders in HSE but not in SD patients, Lambon Ralph et al.[107] reported a direct comparison of semantic deficits in two groups of patients suffering from HSE and SD. They confirmed that a selective impairment of biological categories is rarely observed in SD, though it is commonly found in HSE patients. On the other hand, Noppeney et al.[108] compared the structural damage in four herpes simplex virus encephalitis patients shoving a semantic deficit that particularly affected the biological categories and six SD patients with semantic impairment across all categories tested. According to Noppeney et al.,[108] this apparent inconsistency could be due to the fact that in patients with HSE the gray matter loss prevailed in the medial parts of the ATLs, whereas in SD patients the abnormalities extended more laterally and posteriorly in either the left, right, or both temporal lobes. Lambon Ralph et al.[65] have recently explained the neuroanatomical correlates of category-specific semantic disorders in terms of their connectivity-constrained hub-and-spokes model. For example, the fronto-parietal areas could store the representations of man-made objects because they are directly connected to the medial ventral occipito-temporal regions that according to some authors (e.g.,[45–47]) exhibit greater activation for artifacts.

CONCLUSIONS AND CLINICAL IMPLICATIONS

Prior to the discovery of the category-specific semantic disorders for biological entities due to HSE-related ATL lesions and the semantic disorders associated with bilateral ATL atrophy in SD, the functions of the ATLs were completely unknown, and knowledge of the clinical disorders resulting from ATL damage was very limited. The only source of information about the functions of the ATLs and the symptomatology resulting from their damage was the Klüver-Bucy syndrome in monkeys, which consisted of tameness and diminished fear, hyperorality, hypersexuality, blunted affect, visual agnosia, and social withdrawal[112,113] and which was reproduced in man by bilateral removal of the temporal lobes.[114]

Data reported in the present survey demonstrate that the ATLs critically contribute to some of the most important human cognitive functions, including representation of general conceptual knowledge or of specific biological categories and the recognition of familiar people, and tend to restrict to the right ATL the emotional and social functions stressed by the Klüver-Bucy syndrome. Among patients with right and left ATL atrophy, the Klüver-Bucy-like symptoms differ: Those with right ATL atrophy often present some of the striking social and emotional deficits of the Klüver-Bucy syndrome, whereas these symptoms are typically absent in patients with left ATL atrophy. Several groups[57,115,116] describe semantic disorders with relatively preserved socio-emotional function in association with left ATL involvement and severe behavioral disturbances with relatively preserved semantic skills in association with right ATL involvement. A recent study[117] also differentiated right-lateralized SD and behavioral-variant FTD (bvFTD) with respect to semantic and behavioral profiles: Patients with right ATL atrophy demonstrated face recognition disorders and an increased rigidity with obsessive personality/behavioral changes, whereas patients with bvFTD demonstrated pronounced deficits in attention/working memory, increased apathy, and greater executive dysfunction.

The coexistence of social and emotional defects with familiar people recognition disorders in patients with right ATL atrophy and the presence within the ATLs of a general system of semantic representations has suggested to some authors[118–120] that part of the ATLs may support a special form of knowledge (i.e., social cognition) and that the corresponding structures may be engaged when tasks demand access to social conceptual knowledge. This model has been critically reviewed by Gainotti,[61] who demonstrated that behavioral data gathered in patients with right and left ATL lesions and results of neuroimaging investigations using tasks drawn from the "Theory of Mind" or involving moral judgments and emotional or social tasks do not support the social cognition hypothesis, but instead simply suggest a superiority of the right ATL for emotional and social functions.

Clinically, identifying patients with functionally-relevant right ATL atrophy is difficult, and the social and behavioral disorders of patients with right ATL involvement often overshadow semantic disturbances. Administering a "famous faces" test and/or semantic category tests to such patients may be very useful: A finding of deficits on these or similar tests may suggest a neurodegenerative disease affecting the ATLs rather than the frontal lobes[117] and clarify involvement of the right versus left ATL.[121] Unfortunately, simple and reliable international tasks of this kind are not easily available, for the reason that their construction is time consuming and that faces (and, even more, voices) of famous people are recognized only in a well-defined linguistic and cultural context. The recent construction and standardization in Italy of a "Famous People Recognition Battery,"[106] in which subjects are requested to recognize through their faces and voices the same persons (well-known at the national level), could be a first step in this direction. Following on the development of such tests and elucidation of the underlying neurobiology of ATL-related neuropsychiatric

disturbances may improve diagnosis and facilitate advances in the care and lives of persons with these conditions.

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Prof. Gainotti reports no financial relationships with commercial interests.

Received Jan. 2, 2017; revision received Jan. 25, 2017 and April 20, 2017; accepted April 21, 2017; published online Aug. 4, 2017.

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