

# Nouns and verbs: neurological correlates of linguistic processing

Stefano F. Cappa & Daniela Perani

This paper provides a comprehensive review of neuropsychological, neurophysiological and neuroimaging studies dealing with the neural correlates of noun and verb processing. There is considerable clinical evidence from patient studies indicating the existence of a double dissociation between noun and verb processing. This dissociation appears to be reflected in differences in the site of brain damage. Patients with a selective verb impairment usually have lesion centred on the fronto-parietal areas, while isolated noun impairments are observed in patients with damage limited to the temporal lobe. Imaging studies in normal subjects have provided further information, indicating that, while the left temporal neocortex plays a crucial role in all tasks involving lexical-semantic processing, additional regions of the left dorsolateral prefrontal cortex are recruited during the processing of words related to actions. One crucial question is whether the observed neurological correlates are related to conceptual differences (prototypical nouns and verbs being related, respectively, to objects and actions), or to the grammatical distinction between nouns and verbs. The aim of future studies should be to tease apart the contribution of semantic and grammatical differences to the observed neurological dissociation.

## *1. The noun-verb dissociation after brain damage: a "classic" finding*

The observation that brain damage can affect differentially the ability to retrieve nouns and verbs is not new, and can be traced back to Giovanbattista Vico. In the *Principj di Scienza Nuova* (1744), Vico writes: "Finalmente gli autori delle lingue si formarono i verbi, come osserviamo i fanciulli spiegar nomi, particelle, e tacer i verbi. Perché i nomi destano idee che lasciano fermi vestigi; le particelle, che significano esse modificazioni, fanno il medesimo; ma i verbi significano moti, i quali portano l'innanzi e l' dopo, che sono misurati dall'indivisibile del presente, difficilissimo ad intendersi dagli stessi filosofi. Ed è un'osservazione fisica che di molto approva ciò che diciamo, che tra noi vive un uomo onesto, tòcco da gravissima apoplezia, il quale mentova nomi e sì è affatto dimenticato de' verbi". Several studies have unequivocally indicated that a double dissociation between noun and verb processing can be observed in selected aphasic patients. For example, after brain damage, some individuals have a

disproportionate difficulty in naming objects, while their ability to name actions is largely unaffected, while other show the reverse pattern of impairment (see, for example, Miceli, Silveri et al. 1988). These observations are important not only for psycholinguistics, but also for neuroscience, as they suggest that the noun-verb distinction be honoured also at the level of brain structure and function. In particular, these findings are compatible with the idea that there are different neural correlates for noun and verb processing in the human brain.

The aim of the present paper is to review the available evidence, stemming from neuropsychological, neurophysiological and functional imaging, about the neural correlates of noun and verb processing, and to discuss the possible implications for models of language organization in the human brain.

## *2. Modern evidence from neurological patients*

This section will consider evidence coming from investigations of patients with focal and with degenerative brain pathologies.

### *2.1. Focal lesions*

The first hints about a possible different localisation of the lesions associated with defective processing of nouns and verbs can be derived from group investigations in aphasic patients, in which the ability to name objects and actions was compared. A group study by Goodglass, Klein et al. (1966) showed that Broca's aphasics are more impaired in naming actions, fluent aphasics in naming objects. Within the limits of the localisation of aphasic syndromes, these findings indicate that posterior (retrorolandic) lesions affect object naming more than action naming, while an involvement of pre-rolandic areas appears to be required for the presence of defective action naming. This early study was based on a limited number of test items, and was missing any direct information about the localisation of neurological damage. Subsequent reports (see Miceli, Silveri et al. 1988) established, using adequate testing material, the existence of patients with selective, or relatively selective, disorders in naming and comprehension of nouns and verbs. While these case studies were not aimed at the definition of the anatomical correlates of the observed dissociation, an analysis of the reported lesion sites, assessed with computerised brain tomography, appeared in general

to support the anatomical localisation suggested by the Goodglass, Klein et al. (1966) study. Most of the patients with selective disorders of noun processing had lesions centred on the left temporal lobe, while verb impairment was associated to damage involving, or limited to, the left prefrontal cortex. The first careful anatomical study was reported by Damasio & Tranel (1993), using structural Magnetic Resonance Imaging (MRI). Two patients had selective impairments for nouns: one had bilateral mesial and lateral temporal lesions; the other had a left anterior temporal lesion. The patient with selective action naming impairment had a left premotor frontal lesion. These observations were expanded in a recent lesion study (Tranel et al. 2001). The aim of this investigation was to test the hypothesis of the existence of a double dissociation between action naming and naming of concrete entities, such as animals and tools. The a priori hypothesis was that selective action naming disorders were expected to be associated with lesions in the left premotor/prefrontal region, while selective disorders of the naming of concrete entities were expected to be associated with left anterior/inferior temporal lesions. The results were more complex. While damage to a region involving the left frontal operculum, the inferior sector of the pre-central and post-central gyri and the anterior part of the insula was actually associated to severe action-naming impairment, patients with lesions involving this area were often impaired also in object naming. Moreover, damage to other posterior areas (mesial occipital cortex, white matter underlying the posterior temporo-parietal region) was associated with action naming impairment. On the other hand, lesions limited to the left anterior-inferior temporal lobe affected object naming in a selective way, sparing action naming. Other case reports further indicate the complexity of the pattern of anatomical correlations. The lesion of the patient, reported by De Renzi & Di Pellegrino (1995), with spared action naming and verb generation, involved the temporal lobe, but extended to the frontal cortex. Lesions centred in the left parietal lobe were observed in several patients with a disproportionate deficit in verb processing (see, for example, Silveri & Di Betta 1997).

What can be concluded from the lesion studies is that lesions circumscribed to the left anterior-inferior temporal lobe result in disordered object naming, and spared action naming. Conversely, patients with a selective difficulty in action naming and, maybe, also of other aspects of language processing involving the grammatical category of verbs are as a rule affected by lesions which involve the frontal and parietal part of the left perisylvian language areas, and spare the

anterior temporal lobe. The investigation of patients with category-specific semantic disorders has indicated that an anatomical correlation can be observed in the same regions within the category of nouns. Damage to the anterior part of the temporal lobe selectively affects the naming of animals, while defective naming of man-made entities is usually associated with damage to the perisylvian temporo-fronto-parietal areas (Saffran and Schwartz 1994; Damasio, Grabowski et al. 1996). These findings indicated a possible relationship between tool naming and action naming, which is compatible also with neuroimaging evidence (see below).

## *2.2. Degenerative conditions*

In degenerative conditions, usually associated with dementia, brain damage is progressive, affecting multiple brain regions in a sequence. Daniele, Giustolisi et al. (1994) reported three cases of noun-verb dissociations in patients with degenerative conditions. Two patients with evidence of frontal lobe involvement were more impaired in naming actions than in naming objects; one patient, with left temporal involvement, showed the reverse dissociation. Cappa, Binetti et al. (1998) reported action naming was more impaired than object naming in patients with probable Alzheimer's disease, the most common cause of dementia, associated with involvement of associative cortices. The discrepancy between action and object scores was however much larger in patients with a clinical diagnosis of fronto-temporal dementia. These two conditions, which are associated with a distinct neuropathology at the microscopic level, usually differ quantitatively in the extent of involvement of the frontal lobe at the macroscopic level. The specificity of this correlation is supported by the observation of a severe disorder of action naming and comprehension in motor neuron disease patients, with pathologically verified involvement of Ba 44 and 45 (Broca's area) (Bak, O'Donovan et al. 2001).

In conclusion, the results from investigations of patients with degenerative brain disorders are in agreement with the evidence from patients with localised lesions, suggesting a link between frontal involvement and action naming impairment.

## *3. Imaging the function of the normal brain*

The neural correlates of noun and verb processing in the normal brain can be investigated using functional neuroimaging methods,

which allow a direct visualisation of the brain areas which are engaged during the performance of a cognitive task. As in the case of clinical studies, it must be underlined that many investigations have been concerned with the retrieval of knowledge about actions. An early PET study by Petersen, Fox et al. (1989) used the generation of a verb associated with a presented noun as “semantic processing task”. This was followed by several studies of word retrieval, which can be actually considered as investigations of the neural correlates of action knowledge. These studies have reliably shown extensive activations in the left dorsolateral frontal cortex. Similar patterns of activation have also been observed when the subjects had to generate object names on the basis of phonemic and semantic cues (Paulesu, Goldacre et al. 1997). A direct comparison between noun generation and verb generation revealed only minor differences in activation in the temporo-parietal and frontal areas (Warburton, Wise et al. 1996). A comparison between colour naming and action naming (Martin, Haxby et al. 1995) indicated selective activations related to action naming in the left fronto-parietal cortex, the middle temporal gyrus and the cerebellum. Damasio, Grabowski et al. (2001) have recently reported another PET study of action naming. Naming actions, compared to a perceptual baseline (verbal judgement of the orientation of unknown faces) resulted in left frontal, temporal and parietal activations. A comparison of naming actions performed with an implement, with naming tools and implements resulted in bilateral activations in area MT in the temporal lobe, a region associated with motion processing.

Two more recent imaging studies have investigated the noun-verb difference using tasks, which allow going beyond the retrieval of action knowledge typically elicited by visual naming and generation task. In a PET experiment with lexical decision Perani, Cappa et al. (1999) compared respectively, nouns referring to tools and psychological states, and manipulation and psychological verbs. The results indicated the existence of incompletely overlapping neurological substrates for verb and noun processing. There was no double dissociation between frontal and temporal cortex, but only the presence of “verb specific” areas (Broca’s, left middle temporal gyrus). Noun and verb processing equally activated the other areas, associated with the lexical task. No significant interactions between grammatical class and semantic content were observed, suggesting that the observed difference is verb-specific. A similar study has been recently reported by Tyler, Russell et al. (2001), with negative results. No differences were found between closely matched nouns and verbs, both in a lexi-

cal decision and in a semantic judgement task. The reason for this discrepancy is unclear, and deserves further investigation.

Another interesting source of evidence for possible differences between noun and verb processing are evoked potential studies. Different topographies of brain responses have been reported during lexical decision on object names and action verbs, with a frontal positivity at 200 ms specific for verbs (Preissl, Pulvermueller et al. 1995). Similarly localised differences in high-frequency bands were observed in a later time window (Pulvermueller, Lutzenberger et al. 1999). In an attempt to clarify the meaning of these differences, Pulvermueller, Mohr et al. (1999) used a similar task, dividing nouns in a group with strong visual association, and another with strong action association. The lack of difference between the latter nouns and the action verbs led to the suggestion that the frontal difference is related to semantic content (i.e. action) rather than to grammatical differences. Using subcategories of action verbs referring to different body parts, the same group (Pulvermueller, Haerle et al. 2000) was able to estimate (on the basis of current source density) somatotopically arranged differences in cortical activity, again in favour of a semantic origin of the differences. One of the few studies using nouns and verbs in sentential contexts, and not limited to action verbs is reported by Federmeier, Segal et al. (2000). A left anterior early positivity was specifically observed for unambiguous verbs, but only in verb-appropriate contexts (i.e. when following a “to”).

Finally, reversible interference with brain activity using transcranial magnetic stimulation (TMS) has also been used to assess noun-verb differences. A recent study by Shapiro, Pascual-Leone et al. (2001) reports a selective lengthening of response latencies in the production of tense markers of verbs, while number markers of nouns were unaffected. An important finding of the study was the replication of the observed effect in the case of pseudoverbs (compared to pseudonouns). This appears to rule out an interpretation of the interference effect as due only to semantic factors, and suggests that the left prefrontal cortex be preferentially engaged by verbs as “grammatical objects”. On the other hand, it must be underlined that we have observed a selective effect of high-frequency repetitive TMS on action naming after left, but not right, prefrontal stimulation (Cappa, Sandrini et al., 2002).

#### *4. Conclusions*

Taken together, the available evidence leads to the conclusion that there is consistent evidence for the existence of different cerebral correlates for the processing of object nouns and action verbs. Whether it is possible to consider this result as a “grammatical class” effect remains however an open question.

In the first place, the hypothesis that a strong determinant of the observed differences is actually the conceptual reference should be carefully considered. The results of several investigations related to action observation and action representation may provide some relevant evidence. Recognition of actions is an ability, which is highly developed in humans and non-human primates. In primate, “mirror neurones”, which become active when the same action is actively performed by the monkey or when it is made by the experimenter and observed by the monkey have been observed (Gallese, Fadiga et al. 1996). Many neurones with these features have been described in the left rostral part of the inferior area 6 (the so-called F5), in the prefrontal cortex. Imaging studies have provided evidence for similar neural mechanisms in humans. Broca’s area (Ba 44 and 45) has been found to be active during a task in which normal subjects were required to form a mental imagery of the hand and rotate it (Parsons, Fox et al. 1995) and during the mental simulation of actions (Decety, Perani et al. 1994). An activation was present in a comparable location in the human brain while the subjects were observing the grasping of real objects with the right hand (Rizzolatti, Fadiga et al. 1996). The same area was also active during the observation of meaningful pantomimes (Decety, Grèzes et al. 1997). The observation/execution matching system (“mirror neurones”) identified both in monkeys and in man, can thus be considered as a putative system specialised both for the encoding and the production of actions, and may form the basis of the recognition of meaningful motor events. Additionally, Perani, Cappa et al. (1995) found that, while animal picture recognition activated the inferior temporo-occipital areas, bilaterally, artefact recognition (tools) engaged a predominantly left hemispheric network, involving also the left dorsolateral frontal cortex. The network of neural structures activated by artefact recognition was lateralised to the left hemisphere and involved the prefrontal cortex, in particular the inferior frontal gyrus. This pattern of activation might be related to the functional knowledge or to cognitive strategy related to object manipulation. All these findings are compatible with the hypothesis

that the link between prefrontal cortex and verb processing is at least in part due to the activation of action representations.

There is however considerable evidence that other factors, besides semantic content may result in verb-specific neural representations. In the area of clinical studies, there are patients showing modality-specific grammatical class effects, i.e. only in written or in oral production (Caramazza & Hillis 1991; Hillis & Caramazza 1995; Rapp & Caramazza 1998). These observations cannot be easily explained in term of a semantic difference between nouns and verbs, and indicate that, at least in some patients, the defective performance is due to grammatical differences. Similarly, the observation reported by Shapiro, Shelton et al. (2000), of two patients with selective impairment in morphological processing of nonwords in, respectively, a nominal and a verbal context, indicates that a noun/verb dissociation can be observed on a purely grammatical basis.

Also in the case of imaging studies, the observed differences in the pattern of brain activation may be attributed to other factors, besides semantics. Phonological and morphological factors should be taken into account: for example, the presence of verb-specific suffixes in the Italian language may be hypothesised to play a role in the experiment of Perani, Cappa et al. (1999). It is however noteworthy that the verb-specific area observed in the latter investigation is localised in a part of Broca's area which has been found to be activated by the detection of syntactic anomalies, suggesting that the difference may actually be due to syntactic factors. In addition, the results of Shapiro, Pascual-Leone et al. (2001) with pseudoverbs can be hardly accounted by semantic factors.

The neurological model recently proposed by Caramazza & Finocchiaro (in press) may be able accommodate this complex pattern of neurological correlations. These authors postulate the existence of two separate processing pathways specialised for noun and verb processing: a fronto-temporal and a fronto-parietal route. Specific sub-components of Broca's area are supposed to be involved in verbal and nominal morphology. An anterior-superior region, with prevalent connections to the parietal lobe, is responsible for verb processing, while an inferior region, connected to the temporal region, is specialised for nouns. Damage to selective components of these networks may result in cases of noun/verb dissociation which can be attributed to different mechanisms of linguistic impairment. Imaging studies can test the details of this model directly, with the final aim to tease apart the contribution of conceptual, lexical and grammatical factors to the anatomical and functional specificity for nouns and verbs.

*Address of the Author:*

Stefano F. Cappa, M.D., Dept of Psychology, Vita Salute San Raffaele, S. Raffaele University, DIBIT, Via Olgettina 58, 20132 Milano  
<cappa.stefano@hsr.it>

Daniela Perani, Dept of Psychology, Vita Salute San Raffaele, S. Raffaele University, DIBIT, Via Olgettina 58, 20132 Milano.

*Bibliographical References*

- BAK, Thomas H., Dominic G. O'DONOVAN, John H. XUEREB, Simon BONIFACE & John R. HODGES (2001), "Selective impairment of verb processing associated with pathological changes in Brodmann areas 44 and 45 in the motor neurone disease-dementia-aphasia syndrome", *Brain* 124: 103-120.
- CAPPA, Stefano F., Giuliano BINETTI, Alessandra PEZZINI, Alessandro PADOVANI, Luca ROZZINI & Marco TRABUCCHI (1998), "Object and action naming in Alzheimer's disease and fronto-temporal dementia", *Neurology* 50: 351-355.
- CAPPA, Stefano F., Marco SANDRINI, Paolo M. ROSSINI, Katuscia SOSTA & Carlo MINIUSI (2002), "The role of the left frontal lobe in action naming. rTMS evidence", *Neurology* 59, 720-723.
- CARAMAZZA, Alfonso & Chiara FINOCCHIARO (2002) "Classi grammaticali e cervello", *Lingue e Linguaggio* 1: 3-37.
- CARAMAZZA, Alfonso & Argye E. HILLIS (1991), "Lexical organization of nouns and verbs in the brain", *Nature* 349: 788-790.
- DAMASIO, Antonio R. & Daniel TRANEL (1993), "Nouns and verbs are retrieved with differently distributed neural systems", *Proceedings of the National Academy of Science USA* 90: 4957-4960.
- DAMASIO, Hanna, Thomas J. GRABOWSKI, Daniel TRANEL, Richard D. HICHA & Antonio R. DAMASIO (1996), "A neural basis for lexical retrieval", *Nature* 380: 499-505.
- DAMASIO, Hanna, Thimas J. GRABOWSKI, Daniel TRANEL, Laura L.B. PONTO, Richard D. HICHA & Antonio R. DAMASIO (2001), "Neural correlates of naming actions and of naming spatial relations", *Neuroimage* 13: 1053-1064.
- DANIELE, Antonio, Laura GIUSTOLISI, Maria Caterina SILVERI, Cesare COLOSIMO & Guido GAINOTTI (1994), "Evidence for a possible neuroanatomical basis for the lexical processing of nouns and verbs", *Neuropsychologia* 32: 1325-1341.
- DE RENZI, Ennio & Giuseppe DI PELLEGRINO (1995), "Sparing of verbs and preserved, but ineffectual reading in a patient with impaired word production", *Cortex* 31: 619-636.
- DECTY, Jean, Julie GREZES, Nicolas COSTES, Daniela PERANI, Marc JEANNEROD, Emmanuel PROCYK, Franco GRASSI & Ferruccio FAZIO (1997), "Brain activity during observation of actions. Influence of action content and subject's strategy", *Brain* 120: 1763-1777.

- DECETY, Jean, Daniela PERANI, Marc JEANNEROD, Valentino BETTINARDI, Bernard TADARY, Roger WOODS, John C. MAZZIOTTA & Ferruccio FAZIO (1994), "Mapping motor representations with positron emission tomography", *Nature* 371: 600-602.
- FEDERMEIER, Kara D., Jessica B. SEGAL, Tania LOMBROZO & Martha KUTAS (2000), "Brain responses to nouns, verbs and class-ambiguous words in context", *Brain* 123: 2552-2566.
- GALLESE, Vittorio, Luciano FADIGA, Leonardo FOGASSI & Giacomo RIZZOLATTI (1996), "Action recognition in the premotor cortex", *Brain* 119: 593-609.
- GOODGLASS, Harold, B. KLEIN, P. CAREY & K. JONES (1966), "Specific semantic word category in aphasia", *Cortex* 2: 74-89.
- HILLIS, Argye E. & Alfonso CARAMAZZA (1995), "Representation of grammatical knowledge of words in the brain", *Journal of Cognitive Neuroscience* 7: 396-407.
- MARTIN, Alex, James V. HAXBY, Francois M. LALONDE, Cheri L. WIGGS & Leslie G. UNGERLEIDER (1995), "Discrete cortical regions associated with knowledge of color and knowledge of action", *Science* 270: 102-105.
- MICELI, Gabriele, Maria Caterina SILVERI, Ugo NOCENTINI & Alfonso CARAMAZZA (1988), "Patterns of dissociation in comprehension and production of nouns and verbs", *Aphasiology* 2: 251-258.
- PARSONS, Lawrence M., Peter T. FOX, J. Hunter DOWNS, Thomas GLASS, Traci B. HIRSCH, Charles C. MARTIN, Paul A. JERABEK & Jack L. LANCASTER (1995), "Use of implicit motor imagery for visual shape discrimination as revealed by PET", *Nature* 375: 54-8.
- PAULESU, Eraldo, Ben GOLDACRE, Paola SCIFO, Stefano F. CAPPÀ, Maria Carla GILARDI, Isabella CASTIGLIONI, Daniela PERANI & Ferruccio FAZIO (1997), "Differential activation of left frontal cortex during phonemic and semantic word fluency. An EPI-fMRI activation study", *Neuroreport* 8: 2011-2016
- PERANI, Daniela, Stefano F. CAPPÀ, Valentino BETTINARDI, Sergio BRESSI, Maria Luisa GORNO TEMPINI, Marco MATARRESE & Ferruccio FAZIO (1995), "Different neural networks for the recognition of biological and man-made entities", *Neuroreport* 6: 1637-1641.
- PERANI, Daniela, Stefano F. CAPPÀ, Tatiana SCHNUR, Marco TETTAMANTI, Simona COLLINA, Miguel M. ROSA & Ferruccio FAZIO (1999), "The neural correlates of verb and noun processing: A PET study", *Brain* 122: 2337-44.
- PETERSEN, Steve E., Peter T. FOX, Michael I. POSNER, Mark MINTUN & Marcus E. RAICHEL (1989), "Positron emission tomographic studies of the processing of single words", *Journal of Cognitive Neuroscience* 1: 153-170.
- PREISSEL, Hubert, Friedemann PULVERMUELLER, Werner LUTZENBERGER & Niels BIRBAUMER (1995), "Evoked potentials distinguish between nouns and verbs", *Neuroscience Letters* 197: 81-83.
- PULVERMUELLER, Friedemann, Max HAERLE & Friedhelm HUMMEL (2000), "Neurophysiological distinction of verb categories", *Neuroreport* 11: 2789-2793.
- PULVERMUELLER, Friedemann, Werner LUTZENBERGER & Hubert PREISSEL (1999), "Nouns and verbs in the intact brain: evidence from event-relat-

- ed potentials and high-frequency cortical responses”, *Cerebral Cortex* 9: 497-506.
- PULVERMUELLER, Friedemann, Bettina MOHR & Hans SCHLIECHERT (1999), “Semantic or lexico-syntactic factors: what determines word-class specific activity in the human brain?”, *Neuroscience Letters* 275: 81-84.
- RAPP, Brenda & Alfonso CARAMAZZA (1998), “A case of selective difficulty in writing verbs”, *Neurocase* 4: 127-140.
- RIZZOLATTI, Giacomo, Luciano FADIGA, Massimo MATELLI, Valentino BETTINARDI, Eraldo PAULESU, Daniela PERANI & Ferruccio FAZIO (1996), “Localization of grasp representations in humans by PET: 1. Observation versus execution”, *Experimental Brain Research* 111: 246-252.
- SAFFRAN, Eleanor M. & Myrna F. SCHWARTZ (1994), “Of cabbages and things: semantic memory from a neuropsychological perspective - a tutorial review”, 507-535, in *Attention and Performance XV: Conscious and Unconscious Processes*. Carlo Umiltà and Morris Moscovitch. Cambridge, MA, MIT Press.
- SHAPIRO, Kevin, Jennifer SHELTON & Alfonso CARAMAZZA (2000), “Grammatical class in lexical production and morphological processing: evidence from a case of fluent aphasia”, *Cognitive Neuropsychology* 17: 665-682.
- SHAPIRO, Kevin A., Alvaro PASCUAL-LEONE, Fred M. MOTTAGHY & Massimo GANGITANO (2001), “Grammatical distinctions in the left frontal cortex”, *Journal of Cognitive Neuroscience* 15: 713-720.
- SILVERI, Maria Caterina & Anna Maria DI BETTA (1997), “Noun-verb dissociations in brain-damaged patients: further evidence”, *Neurocase* 3: 477-488.
- TRANIEL, Daniel, R. ADOLPHS, Hanna DAMASIO & Antonio R. DAMASIO (2001), “A neural basis for the retrieval of words for actions”, *Cognitive Neuropsychology* 18: 655-670.
- TYLER, Lorraine K., Richard RUSSELL, M. JALAL FADILI & Helen E. MOSS (2001), “The neural representation of nouns and verbs: PET studies”, *Brain* 124: 1619-1634.
- WARBURTON, Eleonor, Richard S. J. WISE, Cathy. J. PRICE, Cornelius WEILLER, Uri HADAR, Stuart RAMSAY & Richard S.J. FRACKOWIAK (1996), “Noun and verb retrieval by normal subjects. Studies with PET”, *Brain* 119: 159-179.