

# A Case of Impaired Naming and Knowledge of Body Parts. Are Limbs a Separate Sub-category?

MARCELLA LAIACONA<sup>1</sup>, NADIA ALLAMANO<sup>1</sup>, LORENA LORENZI<sup>1</sup> and ERMINIO CAPITANI<sup>2</sup>

<sup>1</sup>*Division of Neurology, Aphasiology Unit, “S. Maugeri” Foundation, IRCCS, Rehabilitation Institute of Veruno, Italy*

<sup>2</sup>*Milan University, Clinic for Nervous Diseases, S. Paolo Hospital, Milan, Italy*

A left hemisphere stroke patient presented a disproportionate difficulty for body parts knowledge without autotopagnosia. The deficit concerned the lexical-semantic representation of body parts and was most severe for limbs. The ability to gesture was spared and action naming was not more impaired than object naming.

On the basis of normal naming latencies, we conclude that limbs are the most vulnerable component of the overall category of body parts. This vulnerability is not explained by unbalanced nuisance variables. More cognitive effort is probably required for the appropriate differentiation of limbs during semantic processing and lexical access.

## Introduction

Some neuropsychological abilities related to body parts can be impaired with disproportionate severity after brain lesions. Broadly speaking, these tasks can be grouped into two classes: (a) tasks where the patient is asked to point to body parts in the frame of the whole body (on his/her own body, on a third person's body, or on a picture), and (b) tasks where the patient is asked to name body parts, to describe their function or to identify them on verbal request. Early clinical descriptions introduced the term autotopagnosia with reference to patients who failed in the first class of tasks but were proficient when pointing was not requested. Since then, the nature of autotopagnosia has been widely discussed. De Renzi and Faglioni (1963) and De Renzi and Scotti (1970) hypothesized that autotopagnosia was part of a more general impairment in any task that requires the patient to divide a whole into its parts, but this account was not confirmed by successive studies. At variance, Semenza and Goodglass (1985) considered that the success in identifying body parts under all conditions depended on a common basic factor, identified as the strength and precision of the conceptual representation of individual body parts, whether indicated by name, visual pointing, or touch. This notion was based on the observation that, also in non-verbal tasks, the word frequency

of individual words strongly correlated with success in pointing to body parts; moreover, also in non-verbal tasks patients produced a preponderance of conceptually-related errors as functional and vicinity errors. The latter authors defined as “functional errors” eye-ear substitution, toe-thumb substitution, and joint-joint substitutions, and defined as “vicinity errors” failures within the same limb of the target or interchanged face-head constituents.

More recent studies have hypothesized that distinct cognitive representations of the body are called into play in different tasks. Sirigu *et al.* (1991) proposed that autotopagnosia affects visuospatial representations of the body schema in presence of an intact semantic and lexical representation of body knowledge. The patient they examined could not localise body parts on herself or on another person when requested verbally or otherwise, and was unable to describe their location verbally; however, she could name the same body parts and define their function. Consistent with this evidence, Denes *et al.* (2000) suggested that in autotopagnosia the spatial representation of the body (“body schema” or “conscious awareness of the body”) is lost, but the meaning of words related to the body is spared. The latter authors supported the view of Reed and Farah (1995) that a supramodal cognitive system is necessary for coding spatial relations among body parts, while other systems cater for the spatial encoding of extrapersonal items. More recently, Buxbaum and Coslett (2001) have interpreted autotopagnosia as an impairment in processing information about the shape and contours of the surface of the human body and, hence, an impairment in coding the local relationship between body parts (denoted with the term “body structural description”).

Interestingly, also the opposite phenomenon—preserved ability to localize body parts but defective recognition or naming of them—has been reported, although less frequently. A delimited body parts anomia was described by Dennis (1976)

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Address correspondence to Marcella Laiacona, S. Maugeri Foundation, Scientific Institute of Veruno, Division of Neurology, Aphasiology Unit, Veruno Medical Centre, via per Revislate, 28010 Veruno (Novara), Italy. E-mail: mlaiacona@fsm.it

in a patient who correctly identified body parts on herself or on a person in front of her and who was highly successful on non-verbal topographical judgements, but was impaired in the production and, to a lesser extent, comprehension of body part names. Errors involved the substitution of one body part for another. Dennis interpreted the disorder as a deficit of lexical selection within the semantic category of body parts when there were insufficient distinctive features. More recently, Suzuki *et al.* (1997) reported a case of comprehension deficit restricted to body parts. The patient's difficulty was not consistent with autotopagnosia or with a general part-whole deficit: It was the name itself of the body part that the patient found difficult to comprehend. These authors claimed that lexical knowledge of body parts has a category-specific organisation, and related its anatomical substrate to the left parietal lobe. This type of representation that includes lexical-semantic, prepositional information about the human body has been denoted as "body image" or "body semantics" (Buxbaum *et al.* 2001).

There are also descriptions of cases of selective sparing of the body parts category. The patient reported by Shelton *et al.* (1998) presented such sparing on several tests of verbal comprehension and production, and the authors suggested that body parts are a category with a distinct semantic representation that can fractionate as the result of brain damage. Coslett *et al.* (2002) reported another patient, affected by semantic dementia, showing a selective sparing of human body knowledge.

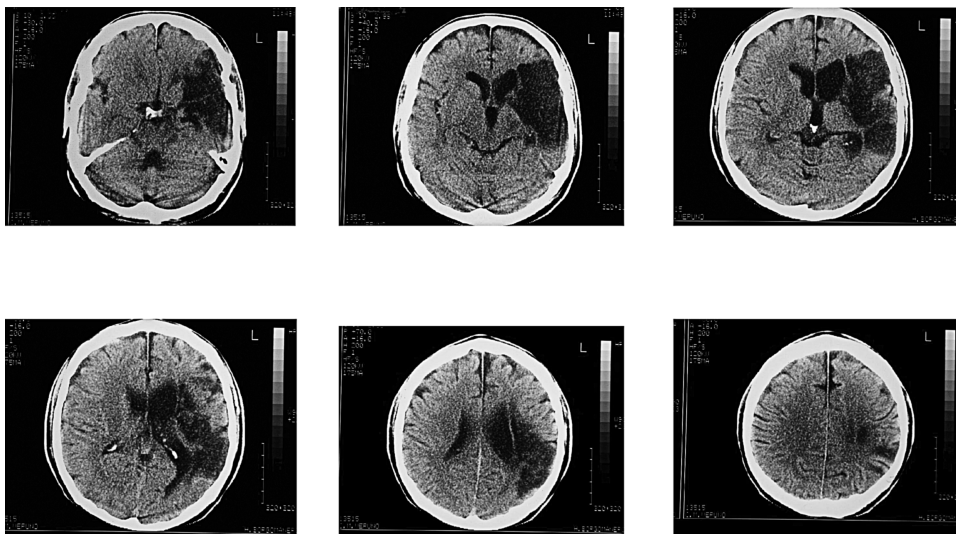
The comprehensive definition of what representations are necessary for the different cognitive activities centred on body parts, already attempted by Sirigu and colleagues, was recently reappraised by Schwoebel *et al.* (2004) and Schwoebel and Coslett (2005), who stressed again that there are at least 3 distinct types of representation of the human body. One representation is a topological map that codes body part location and defines body part boundaries and proximity relationships ("body structural description"),

another is a lexical-semantic representation that includes body part names and codes knowledge of body parts as their functions and their relations with artefacts ("body semantics" or "body image"), and the third provides a dynamic mapping of the current position of body parts relative to one another ("body schema"). This model provides an extensive frame for explaining the separate occurrence of autotopagnosia (as a disorder of the body structural description), and of the isolated sparing or impairment of body parts knowledge (as a disorder of the body semantics). The hypothesis of a dynamic mapping of body position during action, moreover, suggests a theoretical link between body parts deficits and apraxia.

In this study we describe a patient affected by a disproportionate naming difficulty for body parts on the basis of various tasks designed to check category-specificity of the impairment of naming, comprehension, and semantic knowledge. We analyzed if any error type was prevalent, and if any particular subset of body parts was more affected than others. We also checked if the motor skills related to the use of tools were affected, and if there was a relationship between body parts knowledge and action knowledge.

### Case report

FC, a 42-year-old right-handed male with a high school education, suffered in January 1996 an extensive left hemisphere infarction as a consequence of left carotid artery dissection. A CT scan performed in March 1996 disclosed a large softening covering a large cortical area and deep structures supplied by the left middle cerebral artery (Figure 1). FC presented right hemiplegia and right homonymous hemianopia. Early after stroke, language examination showed severe aphasia, verbal output was limited to single syllables, and auditory verbal comprehension was limited to single words.



**Fig. 1.** CT-scan showing a large cortical and sub-cortical hypodense area in the cerebral regions supplied by the left middle cerebral artery.

At the beginning of this study (Autumn 1999–Spring 2000), FC underwent a language examination.

### (i) Aachener Aphasia Test (AAT)

On AAT (Luzzatti *et al.*, 1994) FC's deficit could not be univocally classified, and was compatible with mild Broca's aphasia (63% probability) and with mild amnesic aphasia (27% probability). Spontaneous speech was reduced and slightly dysarthric, without overt articulatory impairment. Verbal communication was possible with minimal assistance from the examiner. The syntactic structure was poor as sentences were formed by only two or three words with few function words. Some verbal substitutions and word finding difficulties were present, but no phonemic substitutions were produced. On conversation he produced the following utterances: "... *I was drinking a coffee with ..., I felt unwell, .. the doctor .. one hour after, no a day after .. I went to ... Verbania and I do not recover ... .. (consciousness)*". Written language (reading aloud and spelling) was quite good, showing only mild syllabisations ("staccato") in reading and few letter omissions or substitutions on writing to dictation test.

### (ii) BADA Aphasia examination

On the more extensive Batteria per l'Analisi dei Deficit Afasici (BADA) examination (Miceli *et al.*, 1994) the output speech was reduced, with simple sentences, word finding difficulties, and few semantic substitutions. Telling the story of Little Red Riding-hood he said: "... *the bad wolf go to the (dal-dalla) grandmother ..... the grandmother eat the ....., the wolf eat the grandmother and then they .... disguise themselves ..... as grandmother .... Little Red Riding-hood eat .....no! the other, the beast, the wolf, wolf eat Little Red Riding-hood .....*". On phonological tasks, FC made few errors (9/232: 3.9%) at sublexical level. Similarly, on lexical decision, word transcoding, and word-picture matching few errors were present (6/160: 3.8%, 6/193: 3.1%, and 2/120: 1.7%, respectively). At the grammatical level FC made few errors (13/203: 6.4%) that in comprehension were confined to reversible sentences on auditory presentation.

On the BADA, most errors affected naming tasks (overall 35/118: 30%) where semantic substitutions and word finding difficulties were evident.

### (iii) Naming pictures of different categories

In order to better study the influence of lexical and semantic variables on naming, FC was given a battery based on strictly controlled material (Laiacona *et al.*, 1993). This includes 60 pictures from the Snodgrass and Vanderwart (1980) set for which the Italian lexical frequency (Bortolini *et al.*, 1972) and an objective index of precocity of acquisition (Barbarotto

*et al.*, 2006)<sup>1</sup> are available. These 60 stimuli include 10 pictures for each of the following categories: animals, fruit, vegetables, tools, vehicles, and furniture. FC was able to give the correct name to 46/60 stimuli (77%). Lexical frequency and the precocity of word acquisition were significant predictors of naming success. FC was impaired in naming stimuli from different categories, including both biological and man-made objects.

### The disproportionate impairment of body parts

FC underwent long-term, uninterrupted language rehabilitation. During rehabilitation, the naming problems of the patient, often consisting of semantic errors, were more marked with low frequency words but were noticeable even for body part names notwithstanding their high frequency. With the latter category, FC often made semantic errors both during rehabilitation and in everyday conversation. For instance, instead of arm he would say "elbow", instead of elbow "knee", and instead of foot "hand". Sometimes the patient made semantic errors also with verbs that denote body actions: Asked to name the picture of an onion, FC could not retrieve the correct name and pantomimed the action of crying, but after a short delay he said "... they make me cough".

To confirm our clinical impression of a relatively more severe impairment with body parts we submitted FC to a supplementary naming examination using the 10 Snodgrass and Vanderwart stimuli representing body parts. In order to contrast body parts with really comparable stimuli of different categories, we selected 20 stimuli from the subset of Laiacona *et al.* (1993)<sup>2</sup> matched to the 10 body parts items for frequency, precocity of acquisition (Barbarotto *et al.*, 2005), and item difficulty, as these proved to be significant predictors for naming success. In addition to picture naming, FC was given a pointing-to-pictures task and verbal semantic questionnaire based on the 10 body parts from the Snodgrass and Vanderwart set and 20 other stimuli from the subset of Laiacona *et al.* Table 1 shows that body parts stimuli still had a higher lexical frequency but presented a slightly later age of acquisition. In each task, the difficulty estimated from a control group was almost identical for body parts stimuli and for the other 20 stimuli.

On picture naming, the patient was asked to name the 30 pictures, presented individually in random order. We considered

<sup>1</sup>The precocity of acquisition index considered here for each stimulus was gender specific and was the percentage of 97 boys aged 3–6 years that correctly named a coloured picture representing the stimulus. Therefore, unlike a true age of acquisition measure, high values of our index correspond to words that are acquired early.

<sup>2</sup>The body parts stimuli were lips, ear, nose, finger, hair, leg, arm, foot, eye, and hand. The other stimuli were bed, train, truck, table, grapes, apple, vase, bicycle, motorbike, chair, sofa, airplane, car, lemon, tomato, lamp, nail, butterfly, rooster, and hammer.

**Table 1.** Variables potentially influential on the success rate for the different groups of stimuli

	Body Parts (n = 10)	Other stimuli (n = 20)
Lexical Frequency	Mean=126.0 (SD=119.4)	Mean=33.8 (SD=38.1)
Precocity of acquisition index (0 to 100, low value indicates late acquisition)	Mean=68.90 (SD=27.67)	Mean=84.50 (SD=16.14)
Difficulty index for naming (0 to 60, with top difficulty=0)	Mean=56.10 (SD=8.25)	Mean=58.20 (SD=3.20)
Difficulty index for the questions (0% to 100%, with top difficulty=0%)	Mean=98.03 (SD=3.74)	Mean=98.76 (SD=3.20)
Judgement about the difficulty of each question (0 to 5, with top difficulty=0)	Mean=4.83 (SD=0.20)	Mean=4.78 (SD=0.27)

as a correct response: the stimulus name, a synonymous name, or a non-synonymous name accepted as correct by at least 3 of 5 judges. We distinguished correct responses given immediately from correct responses given after a delay or self correction.

On the word-picture forced-choice matching task, the patient was asked to point to the picture representing the stimulus name given by the examiner. The target picture and four foils from the same semantic category were arranged vertically on a card.

On the standardized verbal semantic questionnaire we investigated the semantic knowledge of the same 30 items used for the study of naming and comprehension. For each stimulus, superordinate category and subordinate features were probed with six questions. For example, for the stimulus EAR, 1) a *general superordinate information* question was: Is it an object, a vegetable, or a body part? 2) *superordinate information within the same category*: Is it part of the bowels, a sense organ, or a limb? 3) *subordinate information about perceptual attributes*: Do we have one ear, two ears, or more? 4) *subordinate information about a comparison of perceptual attributes*: Is it smaller than a hand? 5) *subordinate information about associative functional aspects*: Is it used for looking, for tasting, or for hearing? 6) *subordinate information about associative contextual aspects*: Is it on the upper part of the trunk, on the lower part, or on the head?

The probes were presented orally in standardised random order. One point was given to every correct response. The 16 errors observed with body parts concerned 9 of the 10 stimuli: leg (4), foot (3), finger (3), and one error each for ear, hand, nose, eye, arm, and lip. The more general superordinate question was always correct; the errors concerned 5 superordinate questions within the same category, 6 perceptual questions, and 5 associative questions. The 13 errors observed with the remaining stimuli concerned 1 general superordinate question, 7 perceptual questions and 5 associative questions.

Table 2 reports the percentage of correct responses, separately for the two groups of stimuli.

On statistical analysis of immediate naming success, FC named body parts (40%) significantly worse than the other stimuli (80%), (chi-square = 4.800, df = 1, exact two-sided p = .045). Repeating the analysis with a logistic regression model and introducing the concomitant variables, the disadvantage of body parts was confirmed (chi-square = 6.246, df = 1, p = .012). A similar trend was found when responses given after long latencies or self-correction were included, yielding a chi-square of 3.400, df = 1, exact p = .065 (two-sided) and .035 (one-sided).

The analysis of the other tests had a similar outcome. On pointing to pictures on verbal command, FC showed errors with body parts only, and again the difference was significant (chi-square = 6.667, df = 1, exact two-sided p = .029). A significant impairment of body parts was observed also with the questionnaire (chi-square = 7.420, df = 1, two-sided exact p = .009).

In summary, the deficit that FC showed with body parts was of moderate severity but all tests confirmed its relative impairment with respect to other stimuli.

A preliminary question at this point was whether FC's relative impairment with body parts was peculiar to our patient or whether it might be common to other aphasic patients who were given the same material. To this end, we scrutinized our records of aphasic patients presenting a naming deficit of comparable severity. As FC was 46/60 correct on naming Snodgrass and Vanderwart stimuli, we selected all the male patients on record who were affected by vascular aphasia and presented a comparable immediate naming performance with the same 60 stimuli (46 ± 2 correct responses, i.e. from 44 to 48/60 correct). The suitable scores were 17. As these control examinations were strictly severity-matched for stimuli other than body parts, we contrasted the body parts naming performance of FC (7/10 correct even allowing long latencies and self corrections) with the body parts scores of the control

**Table 2.** Percentage of correct responses given by FC on the two groups of stimuli for the different tasks

	Body Parts (n = 10)	Other stimuli (n = 20)
Picture naming (short latency without self-corrections)	(4/10) 40%	(16/20) 80%
Picture naming (allowing long latency and self-corrections)	(7/10) 70%	(19/20) 95%
Pointing to a picture on verbal command	(7/10) 70%	(20/20) 100%
Verbal Semantic Questionnaire	(44/60) 73%	(107/120) 89%

patients. For the control group, we found 8 flawless performances, 8 performances with 1 error, and 1 performance with 2 errors, with a mean of 0.59 body parts errors for each examination (against 3 errors committed by FC). This finding clearly shows that, even admitting latencies and self-corrections, the body parts naming of FC was peculiar with respect to the control aphasic patients with the same general severity.

Given the contrast between body parts naming and other stimuli naming, and taking into account the unusual quality of FC's errors, we planned further tasks to examine this category. We now considered an extended set of 20 body parts items: lip, eyebrow, nose, teeth, neck, breast, back, belly, buttocks, eye, ear, fingers, arm, elbow, wrist, hand, leg, knee, ankle, and foot. The inquiry may be viewed under 2 complementary perspectives. The first was whether the body parts deficit is confined to verbal tasks or whether it includes non verbal tasks and is associated to autotopagnosia. The second question concerned the type of cognitive representation of body parts, in particular if body parts form a homogeneous set of items or need to be further distinguished.

**Was the body parts deficit confined to verbal tasks?**

**(a) Verbal tasks**

FC was given three naming tasks based on 20 body parts stimuli:

- Naming of body parts singled out by the examiner on the patient's body
- Naming of body parts singled out by the examiner on a third person's body
- Naming of body parts represented as isolated pictures

Table 3 shows the percentages of correct responses, allowing long latency and self correction. Five matched normal controls were flawless.

Overall, in these tasks FC correctly named 35/60 (58%) body parts stimuli. Here FC was slightly more impaired when the body part was indicated on a third person (chi-square = 4.149, df = 1, p = .042), suggesting that he was in some way facilitated by the perception of the part in relation to his own body or by isolation of the stimulus pictorially.

**Table 3.** Percentages of correct responses on body parts naming task

Task	Success rate
Naming of body parts indicated by the examiner on the patient's body	(12/20) 60%
Naming of body parts indicated by the examiner on a third person's body	(8/20) 40%
Naming of body parts represented as isolated pictures	(15/20) 75%

Then FC was given 4 comprehension tests on verbal command with the same 20 body parts. We asked him to point to body parts on verbal command. In addition, he was asked to judge the correctness of pointing to body parts performed by an actor on a third person after verbal command given by the examiner. For each stimulus the actor showed 1 time the correct body part, and another time a wrong body part, in randomised sequence. The tasks were:

- Pointing to body parts on patient's own body
- Pointing to body parts of a third person
- Pointing to pictures representing isolated body parts among four alternatives
- Judgements about the correctness of pointing to body parts after verbal command performed by a third person

Table 4 shows the percentages of correct responses given by FC. Five matched normal controls were flawless.

Overall, FC correctly pointed to the requested body part or correctly judged the pointing on 75/100 stimuli (75% correct). Regarding the judgment task, FC made 10 errors: On 2 occasions he judged that a right performance was wrong, and on 8 occasions he judged that a wrong response was right. In these comprehension tests no significant difference emerged whether the target was himself, another person, an isolated picture, or when the subject did not have to point to anything as in the last task (chi-square = 2.133, df = 3, ns).

**(b) Non verbal tasks**

FC was asked to identify body parts by pointing to each of the same 20 stimuli after non-verbal commands consisting of pictorial or tactile stimuli. Three tasks were devised:

- The examiner touched a part on the patient's body while the patient kept his eyes closed, and the patient was asked to point to the corresponding picture (among 4 alternatives).
- The subject had to point on his own body to the single part shown by the examiner in an isolated drawing.
- The subject pointed on a whole body drawing to the part which the examiner had presented him as a single part drawing.

**Table 4.** Percentages of correct responses on pointing to body parts after a verbal command

Task	Success rate
Pointing to own body part on verbal command	(13/20) 65%
Pointing to body part of a third person on verbal command	(15/20) 75%
Pointing to pictures representing isolated body parts (among 4 alternatives) on verbal command	(17/20) 85%
Judgements about the correctness of pointing to body parts performed by a third person after verbal command given by the examiner	(30/40) 75%

**Table 5.** Percentages of correct responses on pointing to body parts after a non-verbal command

Task	Success rate
The examiner touches a patient's body part, with the patient's eyes closed, and the patient then points to the corresponding picture (among 4 alternatives)	(18/20) 90%
The patient points on his own body to single parts shown by the examiner as isolated drawings	(20/20) 100%
The patient points on the drawing of a whole body to the part that the examiner has shown as a single part drawing	(20/20) 100%

Table 5 shows the percentages of correct responses of FC. Five matched normal controls were flawless.

Overall FC showed a very good performance (58/60 = 96.7% correct) on these non verbal task: this finding is consistent with the verbal nature of the deficit.

### (c) Conclusions

At this point we can contrast verbal and non-verbal tasks performed with the same stimuli. Table 6 summarises the results according to the mode of assessment used for identifying body parts.

Table 6 shows that verbal tasks were performed worse than non-verbal tasks (68.8% and 96.7% correct, respectively; chi-square = 18.841,  $df = 1$ ,  $p < .001$ ). Also, a comparison restricted to pointing tasks (verbal versus non-verbal) confirmed the same pattern: the verbal condition was significantly worse (chi-square = 12.550,  $df = 1$ ,  $p < .001$ ). Hence, it was the verbal nature of the task that determined the deficit: FC's deficit appeared when asked to retrieve the name of a body part or access its meaning starting from a verbal input.

The results of these tests permitted us to decide whether our patient presented autotopagnosia. FC was given verbal and non-verbal tasks on which he had to point to his own body parts. In the former type of task, he had to point on his own body to the part named by the examiner; in the latter task, he had to point on his own body to the single part shown by the examiner as an isolated drawing. As such, the output

**Table 6.** Verbal and non-verbal tasks in the assessment of body parts identification

Task	Type of demand	Success rate
Naming of body parts	Verbal	35/60 (58.3%)
Pointing to body parts on verbal command	Verbal	75/100 (75%)
Pointing to own body or to a drawing after pictorial or tactile stimulus	Non-verbal	58/60 (96.7%)

of these tasks was identical, i.e. pointing to a patient's body part; what distinguished the tasks was the input. In the case of autotopagnosia we would expect the patient to be impaired with both types of input, whereas in the case of a purely verbal deficit we would expect only verbal commands to impair performance. The performance of FC was consistent with the latter hypothesis. On verbal input the patient gave 13/20 correct responses (65%, see Table 4), whereas on pictorial input he was 20/20 correct (100%, see Table 5). This was a significant difference (chi-square = 8.760,  $df = 1$ ,  $p = .003$ ). This excludes the presence of autotopagnosia and shows that the deficit regarding body parts was linked to the verbal content of the task.

### Contrasting different body parts

In the set of tests reported above, FC was by inspection more impaired with limbs than with other body parts. The 20 stimuli included 9 limbs (arm, fingers, elbow, wrist, hand, leg, knee, ankle, and foot) and 11 non-limbs (lip, eyebrow, nose, teeth, neck, breast, back, belly, buttocks, eye, and ear).

Considering the above 11 tasks (3 verbal pointing and a double judgement on verbal pointing performed by an actor on a third person, 3 non-verbal pointing, and 3 naming tasks) limb stimuli were 60/99 (60.6%) correct, against 108/121 non-limb stimuli (89.3%). This difference was highly significant (chi-square = 24.760,  $df = 1$ ,  $p < .0001$ ). Splitting the tasks according to the verbal/non-verbal nature, on verbal tasks limbs were 34/72 correct (47.2%) and non-limbs 75/88 correct (85.2%). At the comparison, chi-square was 26.340, ( $df = 1$ ,  $p < .0001$ ). On non-verbal tasks, limbs were 26/27 correct (96.3%) and non-limbs 32/33 correct (97%). The latter comparison yielded a chi-square  $< 1$ , ns. We concluded that the deficit of our patient mainly concerned verbal tasks of limb stimuli.

Why were limbs more impaired than non-limbs on verbal tasks? Limbs might be semantically more related to one another, and in this case we should expect two empirically verifiable facts: (i) limbs should be more frequently interchanged with respect to non-limbs, and (ii) limb naming with the same material should prove more difficult also for normal subjects.

### (a) Error types

Following Semenza and Goodglass (1985), we grouped verbal task errors into 4 categories, separately for limbs and non-limbs. We excluded the judgment task, (where the patient made 8 errors with limbs and 2 errors with non-limbs stimuli) as only yes-no responses were allowed and in the test construction the wrong alternatives (foils) did not systematically include all the possible error types. Consequently, the error counts reported in Table 7 refer to 6 tasks: 3 pointing on verbal command and 3 naming tasks. Errors were classified as follows:

**Table 7.** Number of wrong responses classified by error type

	Functional errors	Vicinity errors	Circumlocutions	Random errors	No response
Limbs	15	8	0	6	1
Non-limbs	0	8	0	2	1

- Functional errors: joint substitution, limb substitution, eye-ear substitution
- Vicinity: a different part of the same limb, interchanged face-head constituents
- Random: neither of the above
- No Response

Obviously, functional errors are expected more frequently with limbs, but within limbs it is still interesting to see whether the patient showed more functional or vicinity errors, i.e. conceptually-related errors than random errors or no responses. Table 7 shows the overall distribution of error types on the verbal tasks.

Conceptually related errors, i.e. functional and vicinity errors (31/41=75.6%), clearly represented the majority of wrong responses. In particular, with limb stimuli the patient showed an impressive number of functional errors.

### (b) Naming latencies

To decide if limbs stimuli were basically more difficult also for normal subjects, we examined a group of normal subjects on a naming task based on the same stimuli and contrasted the naming latencies of limbs and non-limbs stimuli.

The normal control sample included 16 adult males matched to FC for education and age ( $42 \pm 5$  years). Controls were asked to name the above 20 body parts pictures (9 limbs and 11 non-limbs). Full-screen pictures were presented one at a time on a 19" colour TV screen, and the time of naming onset was recorded by a microphone connected to a PC and automatically evaluated. After the naming of each stimulus the picture disappeared, and the following stimulus appeared after 2000 msec. The median naming latencies for each stimulus, together with the lexical frequency of each stimulus, are displayed in Table 8.

The mean of the median values was 1305.4 msec for non-limbs ( $sd = 531.8$ ) and 1282.7 msec for limbs stimuli ( $sd = 302.2$ ). The difference was not significant ( $t < 1$ ,  $df = 18$ , ns). However, this could be due to the fact that different Italian terms exist for some body parts (e.g. "back" can be termed "dorso" or "schiena"). There were 5 such stimuli in our set (belly, buttock, back, breast and lips) and all of them represented non-limbs. Restricting the analysis to the remaining 15 stimuli, limbs showed a trend toward longer latencies (1287.7 vs. 1037.83) that yielded a t-point of 1.837 ( $df = 13$ ,  $p = .089$ ). To control for the effect of lexical frequency, we introduced the two lexical frequency values as covariates in

the comparison between limbs and non-limbs. The mean frequency values did not significantly differ between the two subgroups of body parts with a single name, but frequency was always higher for the limbs stimuli (95.2 vs. 77.7 for written frequency, and 613.9 vs. 363.3 for spoken frequency). After introducing the frequency measures as covariates, the contrast between the naming latency of limbs and non-limbs yielded an F value of 4.620 for the analysis adjusted for written frequency ( $df = 1, 12$ ,  $p = .053$ ) and of 5.027 for the analysis adjusted for spoken frequency ( $df = 1, 12$ ,  $p = .045$ )<sup>3</sup>.

It is not easy to explain why limbs stimuli, that present a higher lexical frequency, showed longer naming latencies. A possible reason could be "operativity". According to Gardner (1973), objects which can be readily operated upon ("operative elements") can be named more easily than other objects ("figurative elements") which are continuous with the surrounding context and thus known in a figurative or limited way. The former objects, defined as operative, are known through a variety of actions and sensory modalities, are relatively discrete and separate entities, have definite contours, and are easy to grasp, manipulate and operate upon. Body parts can be classified following this criterion, and we checked whether a possibly higher incidence of operativity among non-limbs items could explain their better performance.

The 20 stimuli employed in this study were classified as 11 operative (arm, fingers, hand, leg, foot, lip, nose, teeth, eye, ear, breast) and 9 figurative elements (elbow, wrist, knee, ankle, eyebrow, neck, back, belly, buttocks) based on the rating of 3 independent judges. Considering the 3 naming tasks above, operative stimuli were 22/33 (67%) correct, against 13/27 figurative stimuli (48%). Hit scores were not significantly different: chi-square = 2.095,  $df = 1$ ,  $p = .191$ , ns. With respect to the limbs/non-limbs contrast, 5/9 limbs (55%) and 6/11 non-limbs (54.4%) were endowed with operativity. As these figures are substantially similar, the principle of operativity cannot explain why limbs were more difficult for our patient.

In order to further check the relevance of operativity, we reanalysed FC's naming performance after introducing the operativity classification in the statistical model. Considering the three naming tasks referred to above, we carried out a logistic regression analysis where the number of correct responses (from 0 to 3) was the dependent variable, and the model variables were the classification of each stimulus as (i) limb/non-limb and (ii) operative/figurative, thus allowing to evaluate each factor considering the covariance with the other. This analysis confirmed the significance of the limb/non limb factor (chi-square = 13.757,  $p < .001$ ) and showed only a trend toward a better performance of operative stimuli

<sup>3</sup>Interestingly, a trend toward higher latencies in the naming of limbs with respect to non-limbs was observed in normal subjects by Barbarotto, Laiacina and Capitani (unpublished) using different pictures.

**Table 8.** Median naming latencies (msec) of the control group (upper cell). In the lower cell we report two measures of the lexical frequency of the stimulus in the Italian language: The written lexical frequency according to Bortolini, Tagliavini, and Zampolli (1972) from a corpus of 500,000 words, and, separated by a slash, the spoken lexical frequency from a different corpus of 500,000 words (Di Mauro, Mancini, Vedovelli, and Voghera, 1993)

Non-limbs	<i>Belly</i>	<i>Lips</i>	<i>Buttock</i>	<i>Ear</i>	<i>Eyebrow</i>	<i>Nose</i>	<i>Eye</i>	<i>Teeth</i>	<i>Neck</i>	<i>Back</i>	<i>Breast</i>
Latency	2655	904	1221	933	1257	954	906	1012	1165	1806	1547
Frequency	11/29	34/374	0/0	40/196	4/0	41/202	291/1491	45/194	45/97	24/67	14/230
Limbs	<i>Knee</i>	<i>Finger</i>	<i>Elbow</i>	<i>Hand</i>	<i>Ankle</i>	<i>Wrist</i>	<i>Arm</i>	<i>Leg</i>	<i>Foot</i>		
Latency	1164	1091	1423	819	1788	1490	1542	1219	1008		
Frequency	44/91	45/217	0/41	375/3250	7/0	16/89	112/573	84/278	174/986		

(chi-square = 2.832,  $p = .093$ ), without interaction between these factors. This outcome indicates that operativity is not relevant for explaining our findings.

### (c) Conclusions

The error analysis confirmed that limbs were semantically more inter-related than non-limbs. The former class of stimuli, in fact, showed an impressively large number of functional errors. The fact that limbs were more difficult to name also for normal controls is in line with their closer relatedness. This relative difficulty of limbs stimuli cannot be traced back either to an effect of lexical frequency (that was higher for limbs) or to an effect of operativity of the stimuli, which was balanced between limbs and non-limbs and was not a significant predictor of naming success.

### Other relevant aspects: apraxia and action naming

Was FC's semantic knowledge of limbs linked to his ability to use limbs for performing gestures? Was it and the ability to perform gestures linked to his semantic knowledge of actions? If any relationship existed, a blurred limbs representation at semantic level could imply either object use apraxia or, alternatively, an action naming impairment (reflecting a defective semantic knowledge of actions).

Regarding apraxia, our patient was not impaired in performing gestures. FC was 14/14 correct on the object use test by De Renzi *et al.* (1968). He also scored within the norm (64/72 correct) on the ideomotor apraxia test by De Renzi *et al.* (1980) that calls for imitation of 12 meaningful and 12 meaningless gestures not related to the use of objects: a maximum of 3 points is assigned for each gesture. Our patient was 32/36 correct on both the meaningful and meaningless sections. This argues against the hypothesis that a semantic impairment of limbs knowledge is sufficient to impair actual gestures performance, and this conclusion applied to all types of gesture investigated.

Concerning the influence of semantic representation of limbs on semantic representation of actions, we gained insight from an action naming test. The BADA test (Miceli

*et al.*, 1994) originally included 52 pictured objects and 50 pictures representing specific motor actions. Action naming was examined by asking the patient to utter the corresponding verb. From the objects set we excluded 23 stimuli that represented body parts, clothes and manipulable objects, and from the actions set we excluded 24 stimuli that were not clearly agentive verbs, i.e. verbs whose meaning implies the presence of an agent subject. The stimuli were presented one at a time.

FC named correctly 26/29 (89.7%) objects and 20/26 (77%) actions, presenting word finding difficulties and semantic substitutions with both classes of stimuli. No significant difference between the two set of stimuli was detected (Chi-square = 1.624,  $df = 1$ , ns). The same outcome was observed repeating the analysis by means of a logistic regression where lexical frequency was introduced as a covariate. These results do not corroborate the hypothesis that limb processing impairment implies a greater semantic deficit of actions with respect to non-manipulable objects.

### Discussion

In verbal tasks tapping naming and comprehension skills, FC was more severely impaired with body parts stimuli than with other categories. The disproportionate naming deficit was detected using different sets of stimuli, and a severity-matched group of aphasic controls showed that the relative deficit with body parts was not a general finding. FC was impaired with body parts on verbal tasks, but not on tasks devoid of verbal content: the normal performance on pointing tasks without verbal orders excluded autotopagnosia.

The dissociation between autotopagnosia and the verbal or semantic knowledge of body parts is well represented in the literature and forms the basis of the current theoretical models of how body parts are represented in our cognitive system. Buxbaum and Coslett (2001), Schwoebel *et al.* (2001, 2004) and Schwoebel and Coslett (2005) have suggested that there are three separate cognitive representations of the human body, namely "body schema", "body semantics" and "body structural descriptions". According to this model, the impairment of body structural description is associated to autotopagnosia,



while a deficit of the body schema impairs the use of body parts for actions, and the deficit of body parts semantics affects naming, verbal comprehension and other verbal tasks regarding body parts. Body semantics may also contribute to the performance of meaningful gestures. In this frame, our patient suffered from a selective impairment of body parts lexical-semantic knowledge, which Coslett *et al.* (2002) and Schwoebel *et al.* (2004, 2005) have defined as “body semantics” or “body image”.

The literature reports several cases of selective impairment or selective sparing of body parts semantics (see Introduction). Suzuki *et al.* (1997) traced back this selective impairment to a lesion of the left parietal lobe. Shelton *et al.* (1998) reported a selective *sparing* of body parts for case I.O.C: this patient presented a left occipital infarct with atrophy of the left posterior horn of the lateral ventricle and some involvement of the temporal lobe; no parietal lesion was reported. Coslett *et al.* (2002) reported another patient presenting body parts sparing, who was affected by mild generalised atrophy, most pronounced in the left anterior temporal lobe. In agreement with the latter reports is the fact that body parts as a category is often relatively spared among patients affected by basal temporal or occipital lesion associated to biological categories impairment (Capitani *et al.*, 2003). Our patient presented an extensive infarct in the areas supplied by the left middle cerebral artery, and a restricted localization was therefore not feasible. Moreover, his deficit with body parts was disproportionate but not selective, therefore a precise localization is perhaps not so crucial.

Moving to the cognitive aspects of this study, we found on verbal tasks that FC was more severely impaired with limbs than with other body parts. The contrast between limbs and non-limbs is intriguing. Why were limbs more impaired? It was neither due to lexical frequency, which was higher for limbs than non-limbs, nor to an operativity factor. Other variables, such as age of acquisition and concept familiarity, were not available for the extended set or their use was not plausible (as in the case of familiarity, because everybody is intrinsically familiar with his/her own body parts). However, we would guess that the limbs/non-limbs discrepancy would not change even if age of acquisition were taken into account, because the latter parameter is generally well correlated to lexical frequency.

We think that the higher difficulty of limbs stimuli likely arose at the level of internal representations that need to be activated during verbal tasks tapping body parts knowledge. The picture of a body part, after accessing the corresponding image in the structural description system, probably activates a chunk of knowledge which stores all the properties of that stimulus. It would be important to decide at this point whether FC's deficit was of a lexical or semantic nature.

Admittedly, adjudicating between a lexical or semantic origin is not an easy task. Some aspects of our patient, however, argue in favour of a semantic nature of the deficit, or at least would suggest that a purely lexical impairment is not

sufficient to explain our data. First, the impairment of FC was not confined to naming but also concerned pointing tasks on verbal command and, at the preliminary examination, extended to the semantic questionnaire. Therefore, his deficits were not confined to a single lexicon, but also affected semantic representations or, at least, the connections between the semantic system and the input- and output lexical stores. Only a multiple lexical impairment could account for this pattern, unless we postulate a disconnection between the semantic and lexical systems. Second, the body parts categorical effect was significant also taking into account the influence of word frequency, a variable generally associated to the lexical structure, and the body parts impairment was observed even using frequency-matched stimuli. Third, the error quality (vicinity and functional errors) seems more consistent with the presence of at least a semantic component of the deficit. Finally, on the semantic questionnaire on body parts, FC was invariably correct when he was requested to retrieve general superordinate information, and this demonstrates that the lexical entries were not impaired in themselves. If FC's deficit can be located at the semantic level, the next relevant question is whether the internal representation of limbs is different from that of non-limbs.

A first possible answer is that FC presented an *apparent* disproportionate impairment of *body parts overall*, but was affected by a *very* disproportionate impairment of *limbs only*. This is equivalent to supposing that limbs are a separate category from the remainder of body parts, and that in some patients (although no reports exist as yet) limbs could be even selectively spared. The alternative explanation is that body parts are a unique category, but within this category limbs are more vulnerable, for a reason different from the effect of nuisance variables.

How can we explore the possible dependence/independence of limbs semantics from that of other body parts? In theory, a special status for limbs could be hypothesized if sound limbs semantics were necessary for a wider realm of cognitive performances concerned with limbs use. To this end, we checked (i) whether FC was affected by apraxia and (ii) if he presented a greater impairment on action verb naming than object naming. If the limbs semantics impairment were associated with the latter deficit(s), limbs semantics could be pivotal for different aspects of cognition and it could be a latent variable well suited to endowing limbs with a distinct cognitive role.

Concerning apraxia, FC was flawless on the test of apraxia of use and was normal on a test of ideomotor apraxia, independently of the meaningfulness of the gestures that the patient was requested to imitate. This means that the resources necessary for performing gestures were distinct from the internal representations necessary for the verbal processing of information about limbs. This is partially at variance with the conclusions by Schwoebel *et al.* (2004): in terms of their model, the significant predictors of the performance of meaningful gestures were not only the scores of “body schema” but even “body semantics”

tasks. In our case, FC presented a “body semantics” impairment but was not impaired while performing meaningful gestures.

The second class of cognitive representations possibly associated to limbs semantics is actions semantics, since actions are mostly performed using limbs. If there were a common cognitive representation underlying limbs semantics and action semantics, limbs naming and action naming should be intertwined, and for FC the latter class of stimuli would be more defective than other categories, e.g. non-manipulable objects. Also in this case, however, action verbs were not defective with respect to nouns representing non-manipulable objects.

We can come back now to the question whether the semantic representation of limbs is clearly distinct from that of other body parts, or if there is a unique body parts category with an internal difficulty gradient. We are inclined to support the latter account. The first reason is that naming latency data of normal subjects indicate that limbs stimuli are more difficult than non-limbs stimuli, and this depends neither on lexical frequency nor on the peculiar set of pictures used. The second invokes a parsimony principle. The assumption that limbs are a distinct category could be supported if their semantic knowledge had a wider selective and distinctive role in the cognitive scenario. This could be the case, for instance, if sound limbs semantics were necessary for efficient gestures or a sound semantic representation of actions. The latter associations were not confirmed by our data. The reason why limbs are more difficult than non-limbs might be that proximate-limb pairs (hand-arm) or correspondent limbs (hand-foot) are more similar than any pairs of non-limb body parts (ear-neck, or eye-nose), and a greater cognitive effort is required for their appropriate differentiation during semantic processing and lexical access. This is witnessed by the frequent occurrence of semantic or vicinity errors with limbs stimuli, and not with non-limbs stimuli. Interestingly, this class of errors was reported in some detailed accounts of the error types of patients described in the literature (Semenza and Goodglass, 1985; Semenza, 1988).

In conclusion, our case is an example of a disproportionate impairment of semantic representation of the category of body parts. The fact that body parts can be disproportionately affected, or even selectively impaired or spared, after left hemisphere damage is well known from the literature. This study adds to the existing data the evidence that, within body parts, limbs can be impaired with particular severity, and that the impairment of body parts semantics, especially severe for limbs, does not affect the ability to gesture and does not impair action naming more than object naming. Since the published reports so far have generally neglected fine-grained distinctions *within* the body parts category, we hope that future studies and a formal comparison between limbs and non-limbs will provide further clarification on this topic.

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