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MULTIPLE REPRESENTATIONS CONTRIBUTE TO BODY KNOWLEDGE PROCESSING

EVIDENCE FROM A CASE OF AUTOTOPAGNOSIA

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SUMMARY

Body schema disturbances were studied in a 62-yr-old woman with Alzheimer's disease. She was severely impaired in verbal and nonverbal tasks requiring her to localize body parts (on her own body, the examiner's body or a doll's body) even though she correctly named the same parts when pointed at by the examiner. Pointing responses were misdirected mainly to parts contiguous with the target area and, to a lesser extent, to functionally equivalent body parts. We also found that the patient was able to define body part names functionally but not spatially. In another series of tasks, and in contrast to the above results, performances were normal when small objects, attached to the patient's body, served as pointing targets. Furthermore, on subsequent testing she pointed correctly at the remembered position of these objects. The fact that the same point in 'body space' is localized correctly when it corresponds to an external object and erroneously when it corresponds to a body part contradicts the idea of the body schema as a unitary function. Learning the position of objects on the body surface requires access to some form of body-reference system on which this information can be mapped. We argue that such a system can be available in autotopagnosia and is independent from the visuospatial representations of the body structure that are postulated to be damaged or inaccessible in this syndrome. An integrated account of the present results and of those reported by other authors suggests that multiple levels of representation (e.g., sensorimotor, visuospatial, semantic) are involved in the organization of body knowledge.

INTRODUCTION

Autotopagnosia (Pick, 1922), an incapacity to localize body parts on verbal command (De Renzi, 1982), has classically been considered to reflect an alteration of the mechanisms involved in the generation and maintenance of a spatial representation of the body or body schema. It usually does not occur in isolation as a 'pure' disturbance but is often observed in association with aphasia, apraxia, reaching disorders and unilateral spatial neglect (for reviews *see* Poeck and Orgass, 1971; Denes, 1989).

Despite this association, single case reports indicate that autotopagnosia cannot be reduced to body awareness disturbances (such as hemiasomatognosia) or to a verbal comprehension impairment. De Renzi and Scotti (1970) and Poncet *et al.* (1971) have described patients who were unable to point to body parts (on their own body, a picture or a doll) on verbal command but were capable of naming the same parts when touched

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by the examiner. However, contrary to the classical conception of a disorder specific to the body schema, both De Renzi and Scotti and Poncet *et al.* interpreted the deficit as an incapacity to analyse any whole into its parts, because equally severe difficulties were observed when the patients pointed to different parts of inanimate objects.

The existence of a defect in localizing specific body parts has been demonstrated more recently by Ogden (1985) in a patient who could name body parts, as in the above cases, and who could point to parts of inanimate objects while being unable to point to parts of his own body. Ogden argued that this case supports the idea of a 'discrete body image'. Ogden's case is interesting because it suggests that autotopagnosia is a distinct neuropsychological deficit, body-specific and independent from other impairments of spatial localization. However, it remains unclear what a 'discrete body image' is, and this notion faces the same objections that have been levelled at the body schema concept (Poeck and Orgass, 1971). How is the 'body image' organized and what cognitive operations are necessary to process a representation of the body and/or its parts?

An attempt to clarify these issues has been made by Semenza (1988) who described a case analogous to that of Ogden's. Different verbal and nonverbal body parts localization tasks developed by Semenza and Goodglass (1985) were used. A qualitative analysis of this patient's errors showed that most of her errors consisted of pointing to a body part which shared a functional similarity with the target (i.e., knee for elbow), or to a body part 'contiguous' with the target (i.e., calf for knee). On the basis of these results Semenza proposed that body knowledge is organized 'conceptually'. According to his view, single body parts that are functionally similar are closely related to each other, independently of their actual distance on the body.

However, Semenza did not make clear whether this conceptual organization can be assimilated in the body image or if it is a unitary category of representations. It could be suggested, for instance, that body knowledge may distinguish between nonspatial semantic information such as the functional equivalence between body parts ('joint', 'sense organ', etc.) and other sorts of representations that specify the local and global spatial relationships between body parts. A somewhat similar distinction between semantic and topographic body knowledge has been suggested by Dennis (1976) who described a patient unable to define and understand body part names despite localizing the same body parts in a nonverbal task.

We had the opportunity to study a patient presenting with a striking autotopagnosia in the context of a dementing illness. We used various tasks designed to provide evidence for or against the idea of multiple representations of body knowledge. The results are discussed in terms of a model as to how the body knowledge might be organized.

CASE REPORT

D.L.S. was a 62-yr-old, right-handed housewife with 12 yrs of education. She was referred to the NIH clinical center for the first time in August 1986, because of 'problems with vision' and impaired reading and counting. On the basis of a neurological and neuropsychological evaluation, she received a diagnosis of probable dementia of Alzheimer's type and remained in hospital during her participation in a clinical drug trial. Her cognitive functions became progressively more impaired over the following 3 yrs. We examined her between December 1988 and May 1989. All results (neurological and neuropsychological) reported below refer to this period.

The patient was alert, cooperative, oriented in space but not in time. She complained about difficulty in reading and writing and showed a severe dressing apraxia resulting not from neglect of one side of the body, but from an incapacity to match correctly body parts and parts of clothes. Clinically, she was mildly amnesic in spite of poor performances on standardized tests of memory functioning, since she could recall the names of other patients and medical staff and was able to remember the tests administered during the various sessions. Neurological examination showed normal visual fields. Somatosensory examination was normal; there was no neglect for personal or extrapersonal space; there was no misreaching for objects shown in the foveal or in the peripheral visual field with either hand. A CT scan (fig. 1) in December 1988 showed diffuse cerebral atrophy.

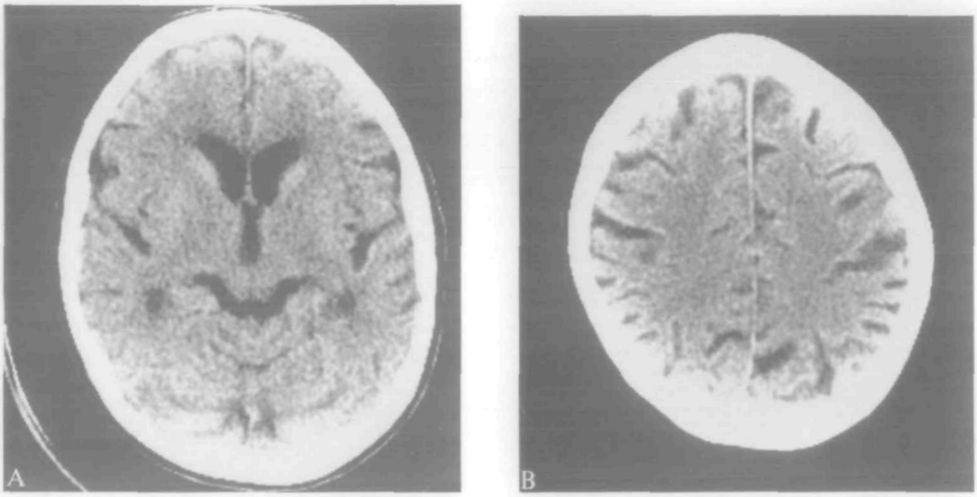

FIG. 1. A, B, CT scan of patient showing diffuse cerebral atrophy.

The general neuropsychological findings are summarized in Appendix I. There were wide-ranging cognitive impairments. Visuospatial abilities were severely affected, in agreement with the major problems of the patient in everyday life as reported by the clinical staff. In addition she presented with a complete Gerstmann syndrome, with agraphia, acalculia, finger agnosia (in both naming and recognition), right-left confusion, and the deficit in which we were most interested, autotopagnosia. The following example is typical of the patient's difficulties with body parts. When she was requested to show where her elbow was, she looked at her body, searching for the elbow and repeating 'yeah elbow, the elbow must be over here', while she was pointing near to the wrist and along the arm. Most of the time, she seemed to be uncertain about the *exact* location of the body part we requested her to point to. The following sections of the paper will focus on our investigation of this disorder.

INVESTIGATIONS

Investigation of body parts

We tested D.L.S.'s ability to localize body parts using verbal and nonverbal instructions.

Verbal instruction. The patient was asked to point to a body part named by the examiner in three different conditions (1) on her own body with the eyes closed/open, (2) on the examiner's body, (3) on a doll's body.

Nonverbal instruction. We asked the patient to point on the examiner's body to the same part that the examiner touched on the patient's body with the eyes closed/open. For example, the examiner touched the patient's shoulder (with the patient's eyes closed) then the patient (with the eyes open) had to touch the examiner's shoulder.

Naming body parts. These were indicated by the examiner on patient's body (with her eyes open/closed) and on the examiner's body as a control task for the comprehension of body part names.

General procedure

In our tasks we used 25 body parts (*see* Appendix 2) distributed over the entire body surface, with the exception of the fingers. No requirements were made concerning the side, left or right, of the body part to be localized. We performed several replications of each condition in order to assess the reliability of the patient's performances: *verbal—own body* (n = 5, 4 times with eyes open and once with eyes closed); *verbal—examiner's body* (n = 3); *verbal—doll's body* (n = 3); *nonverbal* (n = 5, 4 times with eyes open and once with eyes closed). Across replications, the patient alternated hands in pointing to the targets. The examiner and patient were always sitting in front of one another. Finally, 10 normal subjects matched for age, sex and education level (mean age and SD: 69.1, 5.2; mean educational level in yrs and SD: 12.9, 1.9), and 2 patients with Alzheimer's disease (both females, aged 75 and 76 yrs, respectively; Global Deterioration Scale Scores of 4, indicating moderate impairment in both cases) were used as controls in all localization tasks except 'verbal-doll's body' and in the naming tasks. One of the Alzheimer patients was not administered the nonverbal version of the pointing task.

Results

The results of the *verbal* conditions (Table 1) showed that the patient's performance was impaired in localizing body parts on herself, on the examiner and on a doll. This deficit was most severe when the patient was required to point to targets located on her own body. Her performance was remarkably constant from one administration to another. The results were not affected by the hand used to respond to whether her eyes were open or closed. Performances of normal and patient controls with Alzheimer's disease were perfect in all conditions tested.

TABLE 1. NUMBER OF ERRORS MADE BY THE PATIENT, 2 PATIENTS WITH ALZHEIMER'S DISEASE (AD) AND 10 NORMAL CONTROLS (NCs) IN LOCALIZING BODY PARTS ON VERBAL AND NONVERBAL COMMAND AND IN NAMING BODY PARTS*

	Patient					*AD1*		*AD2*		*NCs (mean)*	
	I	*II*	*III*	*IV*	*V***	*I*	*II***	*I*	*II***	*I*	*II***
Verbal											
Own body	10	9	10	8							
					10	0	0	0	0	0	0
Examiner's body	6	5	5	–		0		0		0	
Doll's body	5	5	5	–		–		–		–	
Nonverbal	12	10	13	13							
					13	0	0	–	–	0	0
Naming											
Own body	2	2**	–	–	–	1	2	1	1	1	0.6
Examiner's body	2	–	–	–		2		3		0.4	

* Roman numerals refer to the replications of the task (n = 25). ** Tested with eyes closed.

In the *nonverbal* modality (Table 1) D.L.S. was also very impaired relative to control subjects. These results were highly reliable and again were not affected by handedness or vision. A comparison of the 5 replications of the verbal and nonverbal conditions showed that significantly more errors were made in the latter than in the former trials ($t(4) = 4.2$, $P < 0.02$). This suggested that the availability of the verbal label for the target may have facilitated its localization.

In contrast to these results, relatively few errors were made in naming body parts indicated by the examiner in either condition. On this task, her performances were similar to those of the 2 Alzheimer's disease controls (Table 1).

Analysis of error types

In order to determine whether the patient's errors were made randomly or whether there existed a relationship between the target and the area to which she pointed, we performed a qualitative analysis of the localization errors for both verbal and nonverbal localization tasks across the different administrations. Three types of errors were scored according to a classification scheme inspired by Semenza and Goodglass (1985): (1) *contiguous*: when the area pointed to is immediately adjacent to the target, i.e., shoulder for upper arm, eyebrow for eye, leg for calf, etc.; (2) *substitution of functionally similar parts*: segments substitution such as upper arm for thigh, forearm for leg, forearm for upper arm, thigh for leg; joint substitutions, such as wrist for ankle, elbow for knee, elbow for wrist, hip for knee, knee for ankle; substitution of eye-ear-nose; (3) *other*: errors that fit in neither of the above categories.

The observed proportions for each of these three error categories must be evaluated against their probability of occurrence by chance, that is, if those errors were produced by random pointing. In order to do so we divided the body surface into 25 nonredundant body parts, only 1 of which could be considered a correct response on a particular trial. In the majority of trials only 2 out of the 24 remaining body parts could fall into the 'contiguous error' category. This implies that random pointing could hit a part contiguous to the target with a probability of about 0.08. The probability is of course smaller for an extremity (only 1 possible contiguous error) and greater for a target located in the middle of the face. The number of possible functional substitutions for limb joints and segments is 5, which means that these errors could occur by chance with about 0.21 probability. Since there are only 2 possible substitutions when either eye, ear and nose are targets, the chance probability of this error type for these targets is much smaller than for limbs and joints. Some of the targets had a zero probability for the functional substitution error type (neck, chest). Of course, 'other' errors were the category with the largest probability of chance occurrence. By calculating weighted averages on the entire set of targets for each error category, the following probabilities were obtained: 0.09 for contiguous errors, 0.12 for functional substitutions, and 0.79 for 'other' errors.

Results

In order to facilitate comparisons, only the results for the *verbal-own body* and the *nonverbal* conditions are presented. The distribution of errors of each type is shown in Table 2. It is readily seen that most errors were responses on the area adjacent to the target (contiguous errors): 30 (64%) in the verbal condition and 43 (71%) in the nonverbal condition, proportions much higher than would be expected by chance (7.1:1 and 7.8:1, respectively). In the verbal condition, 'functional substitutions' were more frequent than 'other' errors, with 15 (32%) and 2 (4%) errors respectively. In the nonverbal condition 8 (13%) 'functional substitution' and 10 'other' (16%) errors were found.

TABLE 2. QUALITATIVE ANALYSIS OF PATIENT'S PERFORMANCE IN THE VERBAL (OWN BODY) AND NONVERBAL POINTING TASKS AND ACROSS TRIALS*

	Substitution of functionally similar parts	*Contiguous*	*Other*
Verbal			
I	4	6	0
II	3	6	0
III	2	7	1
IV	3	5	0
V**	3	6	1
Total	15	30	2
Nonverbal			
I	2	8	2
II	0	10	0
III	1	10	2
IV	2	8	3
V**	3	7	3
Total	8	43	10

* No. of errors for each error type. ** Tested with eyes closed.

It is clear that in both verbal and nonverbal conditions the proportion of 'other' errors is much lower than would be expected by chance. However, there is one interesting difference between these two experimental conditions: the proportion of 'functional substitution' errors was higher in the verbal than in the nonverbal condition ($\chi^2 = 8.02$, $P < 0.01$). Although the proportion of this error type is greater than expected by chance by a 2.7:1 ratio for the verbal condition, the proportion of errors of this type in the nonverbal condition is close to the chance level (13% observed, 12% expected).

Additional control experiments

Localization of different parts of objects. In order to determine whether the localization problem was specific to body parts or whether it could be interpreted as an 'incapacity to analyse a whole into its parts' (De Renzi and Scotti, 1970; Poncet *et al.*, 1971), we tested the patient's capacity to point to different parts of objects in verbal and in nonverbal conditions. In the verbal condition, the patient had to point to a part of an object named by the examiner. In the nonverbal condition, both patient and examiner held similar objects, but of different sizes. The examiner pointed to a part of the object she was holding and the patient had to point to the same part on the other object. We used 4 small objects in both tasks; in parentheses is indicated the number of parts tested for each object: telephone (n = 5), truck (n = 9), table (n = 3 verbal, n = 4 nonverbal), blouse (n = 5).

D.L.S's performance on this task was near perfect; only 1 error occurred in the verbal condition when pointing to a part of a telephone. Thus her deficit cannot be explained by a general problem in identifying part/whole relationships.

Body part names: spatial vs functional definition. We were also interested to know if D.L.S. was able to define *spatially* and *functionally* body parts that she could not localize. This might provide some information on the status of the patient's conceptual knowledge about body parts in a situation that does not require an explicit localization response.

The examiner stood behind the patient to minimize visual cues, and asked her to define verbally the location of 6 body parts (ear, nose, mouth, eyes, knee, wrist). The questions were formulated in this way: where are the ears located?, where is the wrist located? If no answer was obtained, we used a two-choice forced recognition probe task administered in the following way: 'Are the ears next to the mouth?' or 'Is the wrist next to the forearm?' D.L.S. failed completely on this task, despite being allowed to inspect her own body visually throughout the task. Not only could she not describe body parts locations verbally, but she performed at chance on the recognition probe task.

We then asked her to define the functions of 6 body parts (ear, nose, mouth, eyes, hands, arms). The questions were posed in the following manner: 'What is the mouth for?' or 'What are the hands for?', etc. She answered quickly and adequately to all questions.

Localization of objects on the body

The results presented thus far seem to indicate the presence of specific difficulties in mapping identified body parts on a global map of the body. This raises the question as to whether *any* spatial information can be coded using a body map as a reference system. Ogden's (1985) informal observation that her autotopagnosia patient remained able to point to different parts of clothes he was wearing speaks to this issue. In order to address this question systematically, we submitted the patient to a task which used her body as a reference for the localization of *objects* attached to her body and not for the localization of the body parts themselves.

Methods

A subset of 10 body parts was taken from the previous tasks and the same general procedure was followed but with a variation: the target could be either a body part or a small object attached on the patient's body (fig. 2). The following pairs were made: car-right forearm, bed-left shoulder, soldier-right upper arm, square-left elbow, earring-left wrist, rubber band-left hand, figurine-left knee, paper sticker-left calf, chair-chest, toothbrush-right thigh.

D.L.S. was requested to point to a body part or to an object attached on the same location. Two types of instructions, verbal and nonverbal, were used. The patient either had to point to the object *named* by the examiner (verbal), or was requested to point on the examiner's body to the same object that had been

FIG. 2. Picture showing arrangement of targets on the patient's body in the object pointing task (*see* text for details).

touched by the examiner on the patient's body (nonverbal; note that both examiner and patient had identical objects attached on the same parts of their bodies). This was contrasted with the same tasks performed with body parts as targets without any object being present on anyone's body. Several replications of each condition were obtained in order to assess the patient's reliability.

Results

The results shown in Table 3 are consistent with the previous results in that a large number of errors were made when body parts were used as targets. However, when the targets were objects attached to the same body parts, the patient's performance was virtually perfect.

Pointing from memory to the position of the objects

It can be argued that the patient's success in this task was the result of an efficient visual search strategy. In order to determine whether this was the explanation, or whether she could actually locate the objects purely on the basis of knowledge of their position on the body surface, the patient was subsequently asked to point to the remembered location of these objects in their absence.

Methods

We performed 4 replications of this task. A delay of 24 h separated the task with objects attached to the patient's body and the first administration of this location memory task. A delay of 14 days separated the first administration of this memory task from the last, with intervening tests at 2 and 7 days. During that period the objects were never attached to the patient's body, so there was no possibility of relearning during this interval.

TABLE 3. NUMBER OF ERRORS MADE BY THE PATIENT IN POINTING ON VERBAL AND NONVERBAL COMMAND TO BODY PARTS AND TO OBJECTS ATTACHED ON THE SAME BODY PARTS*

Verbal	*I*	*II*	*III*	*IV*	*V*	
Body parts	6	5	6	6	6	
Objects on body parts	1	1	1	0	0	
Nonverbal	*I*	*II*	*III*	*IV*	*V*	*VI*
Body parts	5	5	6	5	7	6
Objects on body parts	0	1	0	0	0	0

* Roman numerals refer to the replications of the task (n = 10).

Results

D.L.S.'s performance was perfectly accurate and remained so up to the 15 day retest. She always pointed quickly and without hesitation to the remembered positions of the objects. She did not make right-left confusions for targets not located close to the body midline. Interestingly, she never named, spontaneously or on request, the body parts objects were attached over, suggesting that she was not using a verbal strategy (e.g., the names of the body parts) in the retrieval of the objects' position.

Thus the results of this task show that the patient had coded in long-term memory the position of the objects onto a map of the body surface.

Localization of body parts in the presence of the objects

In the final task the capacity of the patient to localize the same 10 body parts was reassessed while the objects were still attached to her body. This was done in order to test the possibility that she might improve her performance by using the objects as landmarks for the target body parts.

Methods

We once more attached the objects to the patient's clothing, but gave her verbal instructions, stressing that this time she was to point to different body parts on command and ignore the objects. We administered this task 3 times on separate days.

Results

D.L.S.'s performance on this task indicated that the presence of objects did not facilitate the localization of the corresponding body parts and this finding was confirmed for all replications of the task. She made 6/10 errors for the first replication and 9/10 for the second and third.

DISCUSSION

Our study suggests that the breakdown of what has classically been called the 'body schema' may occur at particular stages or levels of body knowledge processing and supports the idea of a body image composed of multiple representations. Specifically, our results demonstrated that D.L.S. could not localize body parts on herself or on another person either on verbal or nonverbal command, but that she could name body parts. She could not define body part names spatially but she could define body part names functionally. The patient made two main types of localization error: contiguity errors and functional substitutions. Contiguity errors were the most frequent across all task conditions. In the verbal task the proportion of functional substitutions was higher than in the nonverbal task, and in fact this error type occurred above chance level only in the verbal condition. A striking finding was that the patient could point to objects attached to different parts of her body even though she could not localize those body parts themselves. In addition, she could reliably point to the remembered position of all these objects. Nevertheless, the presence of objects did not improve the patient's performance when she was instructed verbally to point to the body parts where the objects were currently attached.

It must be stressed that the patient's localization deficit was specific to body parts. Her preserved ability to point to different parts of inanimate objects means that an interpretation of her deficit as a general incapacity to analyse *any* whole into its component parts is inadequate (De Renzi and Scotti, 1970; Poncet *et al.*, 1971). It can be argued that a human body is much more complex than other objects. Comparability of performances in pointing to parts of a body and of inanimate objects may also be limited because fewer parts were sampled in the latter than the former tasks. However, although our patient and the patients reported by De Renzi and Scotti (1970) and Poncet *et al.* (1971) had quantitatively similar impairments in localizing body parts, our patient, unlike theirs, did not show impaired localization of parts of objects. A verbal comprehension deficit for body part names or for task instructions cannot play a role in our interpretation of the results for several reasons: the patient could name body parts and could define, at least functionally, body part names; her performance was consistently worse in the nonverbal than in the verbal task, and she understood the instructions of the localization tasks insofar as she pointed correctly to parts of objects and to objects attached to her body. Thus our results confirm and extend those previously reported by Ogden (1985) and more recently by Semenza (1988), in that autotopagnosia can exist as a localization deficit *specific* to body parts.

A model of 'body knowledge' representation

The present study was an attempt to understand further the types of representations and processing necessary to perform localization of body parts tasks. Our results lead us to propose a general framework, shown in fig. 3, which attempts to delineate both the nature and levels of representations from which an 'image' of an individual's own body may emerge. We hypothesize that at least four kinds of representations contribute to body knowledge processing.

1. The first contains semantic and lexical information about body parts, such as names, the functional relations that exit between body parts, such as the wrist and the ankle (e.g., articulations), the functional purpose of the mouth or the ear, etc. These representations are in large part propositional and are likely to be more strongly linked to the verbal systems.

2. The second contains the category-specific visuospatial representations of an individual's own body but also of bodies in general. These representations define a structural description of the body and specify in a detailed manner the position of individual parts on the body surface (e.g., the nose is in the middle of the face), the proximity relationships that exist *between* body parts (e.g., the nose is next to the eyes; the leg is between the ankle and the knee, etc.) and most importantly the *boundaries* that define each body part. These representations are necessary for 'part/whole' analysis.

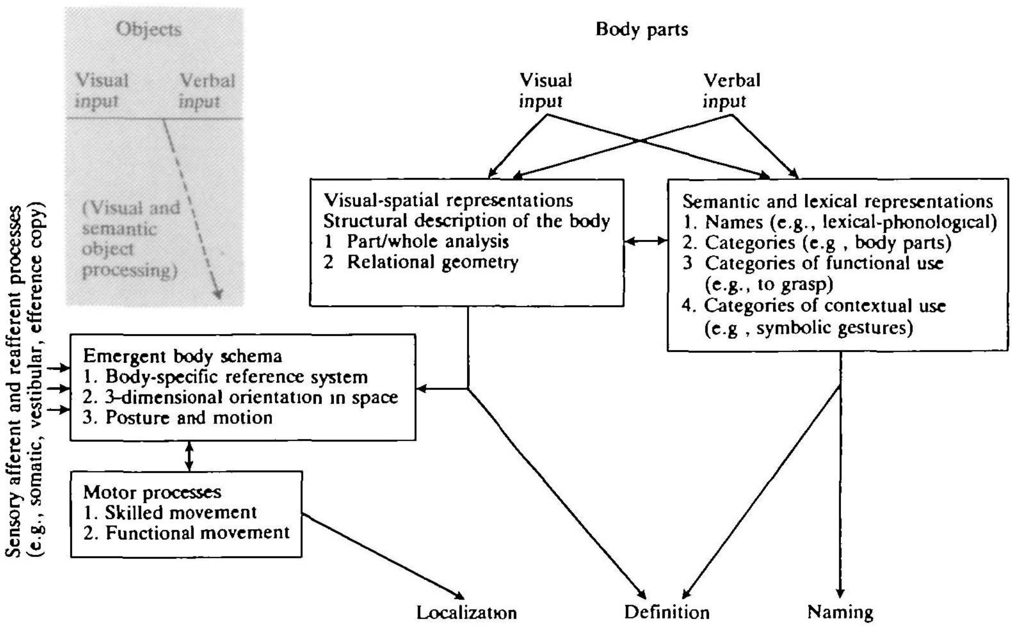

FIG. 3. Schematic diagram of postulated representations contributing to processing of body knowledge. Dashed box indicates postulated locus of the functional impairment in autotopagnosia. The shaded area on the left is added in order to account for the results in the objects pointing task.

They are likely to be more strongly linked to the nonverbal visual and somatic sensory systems.

3. The third level is the emergent body-reference system and is conceptualized as a dynamic, actual body image. It gives information about the position and the changes in position of an individual's own body parts relative to each other and in relation to the external space. It is a polymorphous 'system' that emerges from various sources of sensory information: the somatosensory homunculus, as well as vestibular and visual afferences.

4. Motor representations also contribute to the construction of a spatial representation of the body. Theories of sensorimotor organization typically assume that movements in space are coded with respect to some form of body-centred reference and in turn that movement execution generates information (by way of corollary discharge and/or polysensory reafference) for the coordination of body and external space representations (Paillard, 1971). It therefore appears reasonable to suggest that representations of motor programs contribute to the construction and maintenance of an emergent body-reference system as defined above, but also at a more symbolic level, to the establishment of categorical knowledge of functional and contextual use of body parts.

The components of a body representation system are hypothesized to be relatively independent but can also interact with one another. The degree of involvement of each component in body parts tasks may depend on particular task demands (fig. 3). For instance, naming or defining functionally a body part probably requires mostly the participation of the semantic and lexical representations. The localization of a specific body part, whether it is expressed by a pointing gesture or a verbal response, is postulated to be mediated principally by the visuospatial representations. The emergent body-reference system is a necessary step in body parts localization since only it can provide information about the *actual* location of the body segments.

The idea that body knowledge processing might involve different types of representations is not new. A 'body image' linked to the verbal (Selecki and Herron, 1965) or semantic systems (Dennis, 1976) has already been hypothesized. The 'conceptual knowledge' of the body evoked by Semenza (1988) probably refers to the same processes. The existence of a visual mental image in which the relations between body parts are defined has also been alluded to by Ogden (1985). Finally, the third level described here is very close to the postural schema hypothesized by Head and Holmes (1911). To our knowledge, however, the model we propose is the first synthetic description of body knowledge representations and we believe that it can account for both our results and those reported in other patients with autotopagnosia.

We propose that the deficit observed in our patient involves mostly the visuospatial representations while the semantic representations and the body-reference system appear intact.

Spatial and semantic body representations: two distinct types of knowledge

Several aspects of the present results support the distinction between these two categories of representations. First, there is the independence between naming and localization of body parts. Our patient, as for most patients with autotopagnosia, could name body parts that she could not localize. Interestingly, the reverse pattern of results was reported by Dennis (1976) in a patient who could localize body parts (with nonverbal instructions) but could not define or understand names of body parts. This suggests a double dissociation of the processing systems involved in these two tasks. Secondly, there is the dissociation between definition of functional (preserved) and spatial (impaired) attributes of body part names shown by our patient. Both Ogden (1985) and Semenza (1988) have reported similar results using analogous tasks. Thirdly, there is the prevalence of 'contiguity' errors in the localization of body parts in our patient, which suggests a 'fuzzy' knowledge of proximity relations and of boundaries between body parts. This type of error was much more frequent than functional substitutions which can be considered a more 'semantic' class of error.

All our findings point to a marked impairment of spatial knowledge while lexical and semantic knowledge about body parts is preserved (fig. 3). The overall greater impairment in nonverbal tasks suggests that spatial representations are normally activated mainly by visual inputs. The larger number of 'functional substitution' errors in the verbal tasks probably reflect the coactivation of semantic information. This activation presumably cannot provide a *location* for the target, but may contribute to reducing the range of choices to a set of functionally equivalent body parts. Alternatively it could be argued that the patient's deficit reflects a partial breakdown in lexical/semantic representation and that functional substitutions reflect a genuine semantic confusion. However, this is contradicted by the fact that such semantic confusions did not occur when she only had to name, or to define functionally, the same body parts. Thus her impairment is more likely to be located at a later stage, either in the visuospatial representations themselves or in accessing these representations (fig. 3).

Direct access to a body reference system

Evidence for a direct access to a body-reference system comes from the results on the object position memory task. The patient's performance on this task is a strong argument for an intact body-reference system that can be used to code object positions and retrieve them from long-term memory (fig. 3). It indicates that this system can be accessed directly in a task that does not require a prior analysis of the semantic and spatial characteristics of the body parts on which objects were placed.

We therefore propose that autotopagnosia is an impairment which can affect predominantly, if not exclusively, visuospatial representations relative to the body structure. An important implication of these results is that such visuospatial knowledge may be distinct from, and independent of, the semantic representations of the body and the body-reference system.

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APPENDIX 1

Patient's general neuropsychological assessment

Global Deterioration Scale	4 (moderate)	
MATTIS Dementia scale		
Global score	108 (max = 144)	
Attention	30 (max = 37)	
Initiation and perseveration	25 (max = 37)	
Construction	2 (max = 6)	
Conceptualization	31 (max = 39)	
Memory	20 (max = 25)	
Memory		
Wechsler Memory Scale		
Information	3	
Orientation	4	
Mental Control	3	
Memory Passages	1	
Digits Total	5	
Visual Reproduction	0	
Associate Learning	1.5	
MQ	59	
Buschke Selective Reminding Test	Patient	Controls (n = 37)
Recall	4.50	8.37 (1.38 ST)
Consistency	0.24	0.67 (0.18 ST)
Language		
Verbal Fluency (90 s)	Patient	Controls
Word Association (health)	6.5	19 (6.77 STD) (n = 40)
Letter (S)	4	23 (5.82 STD) (n = 40)
Category (animals)	7	25 (6.29 STD) (n = 19)
Sentence Completion	41/42 (correct)	
Reading	Impaired	
Writing	Impaired	
Visual perception		
Naming (pictures)	14/15 (correct)	
Drawing	Severely impaired	
Object assembly	Unable to perform	
Block design	Unable to perform	
Stereognosia		
Naming		
Left hand	15/15 (correct)	
Right hand	15/15 (correct)	
Apraxia		
Ideomotor	Normal	
Ideational	Impaired	

APPENDIX 2

Body parts stimuli used in the verbal and nonverbal localization tasks and in the Naming task

1. Nose	6. Lips	11. Forearm	16. Waist	21. Cheek
2. Wrist	7. Eye	12. Chest	17. Eyebrow	22. Forehead
3. Knee	8. Hair	13. Neck	18. Hips	23. Upper arm
4. Hand	9. Foot	14. Ear	19. Chin	24. Ankle
5. Shoulder	10. Calf	15. Thigh	20. Toe	25. Elbow

APPENDIX 3

Number of instances (in brackets) in which the pointing responses were directed to body parts other than the target, across all replications of the verbal *(own body) and* nonverbal *tasks. Error type: C = contiguous, FS = functional substitutions, O = other.*

Verbal

Target	*Response*
Wrist	Elbow (4 FS), ankle (1 FS)
Hand	Forearm (3 C), knee (2 O)
Shoulder	Upper arm (1 C), neck (2 C)
Lips	Chin (1 C)
Eye	Forehead (2 C)
Calf	Thigh (4 C), leg (1 C)
Forearm	Elbow (1 C), thigh (4 FS)
Ear	Cheek (1 C)
Thigh	Hip (5 C)
Eyebrow	Forehead (1 C)
Hip	Waist (3 C)
Upper arm	Shoulder (4 C), elbow (1 C)
Ankle	Wrist (1 FS)
Elbow	Ankle (2 FS), wrist (2 FS), knee (1 FS)

Nonverbal

Target	*Response*
Wrist	Forearm (1C), elbow (2 FS), ankle (1 FS), neck (1 O)
Knee	Thigh (3 C), waist (1 O)
Hand	Wrist (1 C), nose (1 O), chest (1 O), shoulder (1 O)
Shoulder	Upper arm (2 C)
Lips	Chin (2 C)
Eye	Cheek (1 C), eyebrow (2 C), ear (1 FS)
Hair	Forehead (1 C)
Foot	Ankle (1 C)
Calf	Leg (3 C), forehead (1 O)
Forearm	Elbow (2 C), upper arm (1 FS), chin (1 O)
Neck	Chin (3 C), forehead (1 O)
Ear	Cheek (1 C), eye (1 FS)
Thigh	Hip (1 C), hand (1 O)
Waist	Chest (2 C)
Eyebrow	Forehead (1 C), eye (1 C)
Hips	Waist (3 C)
Chin	Neck (2 C), cheek (1 C)
Cheek	Neck (2 C), chin (1 C)
Upper arm	Shoulder (1 C), (cheek O)
Ankle	Foot (1 C), elbow (1 FS)
Elbow	Upper arm (3 C), forearm (1 C), wrist (1 FS)