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Category-specific Semantic Deficits: A Case Study*

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Abstract Brain - damaged patients with selective impairment to specific semantic categories of knowledge, like living things and nonliving things, have been reported repeatedly in the literature on various languages. These deficits have helped reveal how semantic knowledge is organized in the brain. In this study we present a Chinese patient, WJX, who has a selective deficit to living things compared to non - living things. His non - lexical processes (e.g. digit memory span, visual and phonetic discrimination, bucco - facial apraxia) are spared to a great extent. However, he often makes semantic errors in lexical tasks, including auditory/visual picture recognition, and oral picture naming. Furthermore, WJX makes a significantly larger percentage of errors on living things rather than non - living things. These results add further evidence from Chinese language to support the theory that brain damage can selectively affect semantic knowledge in the brain. We interpret these results as consistent with the proposal that the semantic system is organized along categorical dimensions.

Key words Organization of semantic knowledge, Category - specific semantic deficit, Living things

1 Introduction

Patterns of semantic processing deficits in brain - damaged patients have provided us with an opportunity to understand the organization of conceptual knowledge in the brain. There have been cases reported of selective deficits to specific semantic categories. The most well documented instance is that of the selective loss of knowledge for living things compared to non - living things. Brain - damaged patients have been reported who have disproportionate difficulties with naming animals in the context of a relative spearing of their capacity to name exemplars of other catogories[1~6].

Although on the surface these cases suggest that semantic category is one of the dimensions along which semantic memory is organized, the interpretation of these selective deficits to living things has been controversial. One of the schools of thought is that these selective deficits to living things do not reflect the actual organization of semantic concepts, but are only byproducts of some factors other than semantic categories, such as familiarity, visual complexity, and name frequency. In other words, these patients are worse at naming or recognizing living things because these are less familiar, the picture is more complex visually, and/or the words are less frequent. In fact, the disappearance of such categorical selectivity has been reported when these factors are controlled for[7]. However, this was not the case in other reports of selective deficits. For some patients, even when the confounding factors are controlled for, the difference in the degree of the deficit for living and non - living things still remains[3,8,9]. The most striking evidence supporting the existence of a real categorical deficit comes from cases with selective deficits to non - living things as opposed to living things[4]. In these cases, the account that categorical deficits are due to the intrinsic higher complexity of living things cannot hold as this is the category which is best preserved in these cases. This kind of data, along with cases with much finer categorical defi-

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cits (e. g., tools, body parts or musical instruments) has given us a way not only to understand whether semantic knowledge is organized along categorical dimension, but also how it may be organized. Although the literature on selective deficits with living things is rather rich and has a long history, the majority of the studies are with Indo – European language speaking patients, especially English. It would add value to the understanding of the human brain to look at other languages, given that the relationship between language – specific characteristics and semantic knowledge representation has been of great debate in various contexts.

In this article we report the case of a Chinese speaking patient, WJX, who performs significantly worse in recognizing and naming living things compared to non – living things, even when factors like familiarity or frequency of the items in each category are controlled. On a variety of tasks we obtained results consistent with the reported English – or Italian – speaking cases with similar selective deficits.

2 Methods and Results

2.1 Case background

WJX is a 75 year – old, right – handed man. He has a high – elementary education. Premorbidly, he worked as a secretary in a police bureau of Beijing. He came to the Beijing Friendship Hospital for assessment of memory deficits in 1997. His head CT scan showed a small low density region in the left posterior limb of the internal capsule. In December 2000, a SPECT scan SPECT revealed that amphicerebral cortex got gracile, rarefaction of radioactive distribution in right temporal lobe. Screenage diagnosis showed atrophy of amphicerebral cortex and ischemia in left temporal lobe. His MMSE score was 16 points out of 30 and consistent with a diagnosis of Alzheimer's Disease (AD).

At evaluation his speech was not fluent. His treating physician and his family members reported that he had comprehension and expression problems. He was initially administered a screening test, which included word copying, auditory discrimination, auditory/visual word matching, picture drawing, category fluency, oral reading, oral and written picture naming, and oral sentence generation. On this screening battery he was able to copy words and pictures, was able to repeat words, and was able to match an auditory presented word with its written rendition. However, he had difficult with comprehension and production of words. In these tasks, he often made semantic errors (e. g. apple for banana, dog for cat). On these tasks he seemed to have more difficulty with comprehension and production of names of living things relatively to nonliving things. Difficulty in object recognition or naming caused by brain damage could be due to at least two different sets of deficits. On the one hand, a patient may have a deficit affecting his semantic knowledge or his knowledge of other properties of the words he is trying to produce or comprehend. On the other hand, a patient may have a deficit affecting systems that are not directly related to the semantic system, such as working memory, perceptual processing, motor control, etc. In order to assess the integrity of these latter mechanisms, we administered to our patient a series of non – lexical tasks. These included: 1) a digit memory span test to assess his working memory; 2) visual discrimination, to test his visual perception; 3) bucco – facial apraxia and word repetition, revealing the integrity of the motor functions necessary for oral production. He was then administered a series of tests tapping into his semantic system. These included an auditory and visual picture verification task to test his semantic comprehension, and an oral picture naming task to test the oral production route from the semantic system. Written production could not be tested due to the patient's disability after the stroke.

2.2 Non – lexical processing

2.2.1 Tasks Digital memory span: In this test, the experimenter says a series of numbers aloud and the subject is asked to repeat the numbers in the right sequence. The test starts with a 3 – digit sequence (e. g. "2 – 7 – 1") and becomes progressively more complex as with each correct response to two trials at each length, an additional digit is added to the sequence (e. g. "3 – 8 – 4 – 2", etc.). The test ends when the subject fails both trials of a certain length.

Visual discrimination: Each trial includes 20 graphics, among which the first is the target picture,

and there are five pictures of the following 19 are exactly the same with the target picture, the other 14 are slightly different from the target in details. The subject needs to tell one by one whether the picture is the same with the target.

Bucco – facial apraxia test: On this test the subject is instructed to execute a series of 15 specific typed of movement with his mouth. For example, he may be asked to 'purse the lips, then relax', or bite the lower lip, then relax'. The subject has three chances to perform the action. If he fails on all three, the experimenter will perform the movement and asks the subject to imitate what he is doing.

Word repetition: The subject repeats aloud the words spoken by the experimenter one by one. The word list has 35 words, including nouns, verbs, adjectives, and adverbs.

2.2.2 Results Results for the four non – lexical tasks are listed in table one.

Table1 The correct performance (N, %) in non – lexical tasks*

Task	Results
Digital memory span	6
Visual discrimination	98% (561/570)
Bucco – facial apraxia	100% (15/15)
Word repetition	98% (39/40)

*: The value of digital memory span task is the correct number.

These results indicate that WJX's digital memory span is within the normal range (5 – 9); His performance in visual discrimination, bucco – facial apraxia and word repetition is also nearly perfect, which shows that the visual perception and oral motor control mechanisms are preserved.

2.3 Lexical processing

2.3.1 Tasks Auditory picture verification: All the pictures used in this task and the following two tasks (visual picture verification and oral picture naming) are taken from a standardized Chinese picture list[10] which was adapted from the Snodgrass and Vanderwart picture set[11] by having them normed with Chinese native speakers. In the auditory verification task, the subject is presented one picture a time, while a word is spoken by the experimenter. The subject needs to tell whether or not the word is the name of the object in the picture by saying 'yes' or 'no'. There are 162 pictures in this verification task, each picture (e. g., apple, /ping2guo3/) is presented on three different occasions, each time associated with a different word. Each picture is either matched with its correct name, a word that is semantically related to the target (e. g., banana, /xiang1jiao1/), or a phonologically related word (e. g., pan, /ping2guo1/).

Visual picture verification: The material and procedure of the task are identical as for the auditory picture verification task, except that the word is presented in written format, typed below the picture.

Oral picture naming: There are 232 line drawings of common objects used in this task. Seventy – two items are from living categories (animal, vegetables, fruits, insects, and birds), and 160 items from nonliving categories (tool, clothes, furniture, vehicle, musical instrument, household items, and other things). Each picture is presented individually and the patient is required to name aloud the object in the picture. There is no time constraint. The tester writes down each response. For each stimulus, the first complete response of the patient is regarded as the effective response.

2.3.2 Results WJX's performance on the lexical tasks is analyzed by percentage of correct responses and proportion of semantic errors (erroneous response semantically related to the target, e. g., 'cow' for horse) out of all errors.

Table 2 Results on three lexical tasks

	% (correct)	% (semantic errors/all errors)
Oral picture naming	46% (103/226)	58% (76/131)
Auditory picture verification	56% (91/162)	41% (35/86)
Visual picture verification	41% (67/162)	29% (32/110)

The results show that our patient makes semantic errors across all these modalities, suggesting that the processing shared by all these tasks, the semantic system, is impaired. We further looked at his performance on the three tasks for items in the living and non – living categories. The results are listed in table 3.

Table 3 Living things vs. non – living things

	Living	Nonliving
Oral picture naming	29% (21/72)	50% (80/160) *
Auditory picture verification	45% (29/64)	63% (62/98) *
Visual picture verification	38% (24/64)	43% (43/98)

The difference between percentage of correct responses for living and nonliving things is significant for the oral picture naming task ($\chi^2 = 8.767$, $p = 0.003$) and in auditory picture verification task ($\chi^2 = 5.069$, $p = 0.024$), but does not reach significance level in visual picture verification task. The finding of the same pattern in auditory input and output modality leads to the hypothesis that the knowledge for living things is damaged more severely than that for nonliving things. The lack of such effect in visual picture verification could be due to the fact that the task involves a recognition process for the written word as well, which is also impaired in this patient (as shown in the case background). The double deficit may overshadow the categorical pattern of semantic knowledge.

As discussed in the introduction familiarity, name frequency or visual complexity may be confounding factors. To disambiguate this possibility we did the following analyses.

2.3.3 Results for matched items From the 216 pictures named by WJX, we picked 45 living things and 45 nonliving things to make sure the two groups of items match on familiarity, name frequency, conceptual consistency, imaging consistency, and visual complexity. The performance on these 90 items is listed below in Table 4.

Table 4 Results for matched items

	N	Familiarity	Word Freq.	Conceptual Consist.	Imaging Consist.	Visual Complex.	% (correct)
Living	45	3.50	41.58	0.81	3.56	3.28	33% (15/45)
Nonliving	45	3.51	38.22	0.78	3.49	2.89	58% (26/45)

It is shown that even when the items are matched across all these factors carefully, the difference between these two groups remains significant: $\chi^2 = 5.421$, $p = 0.020$. This excludes the possibility that the dissociation between living and non-living patterns is an artifact. We interpret these findings as suggesting that the patient has a category-specific deficit.

3 Discussion

By administering a set of tasks to a brain – damaged patient, WJX, we have probed into different cognitive processes in ways that have revealed a clear pattern. To summarize our findings, we firstly demonstrated that his difficulty in recognizing and naming pictures is not due to impairment to low level processes like visual perception or motor control of the organs of phonation. After localizing his deficit to the lexical system, we administered tasks that tap into different modalities, including auditory picture verification (auditory input), visual picture verification (visual input) and oral picture naming (oral output). This allowed us to reach conclusions about the localization of the deficit in this patient. A robust finding is that he makes a significant proportion of semantic errors across all the modalities tested. This led us to conclude that the only shared processing component for all these tasks – the semantic system – must be impaired to some degree. Furthermore, he consistently made more errors for living rather than non – living things in auditory comprehension and production tasks. We ruled out the possibility of other confounding factors like frequency, imageability, etc., by comparising his performance on a subset of living and non – living items matched for all those variables. Even under these conditions his pattern of performance persisted. He continued to show more difficulty with living rather than non – living things. We interpreted these results as suggesting that the patient has a categorical selective deficit to the semantic system.

What can we learn from these findings about the human brain? We hasten to acknowledge that our data is far from enough to lead to the conclusion that knowledge of living and nonliving things is represented and processed separately in the brain, or that the semantic

system is organized along categorical dimension, or that it reveals how the semantic system is internally organized. There are at least three classes of theories that can account for our results, as well as for similar results from Indo – European language – speaking case. One such theory is the sensory/functional theory (SFT), which suggests that semantic knowledge is organized into perceptual and nonperceptual information, which are differentially important for different semantic categories. Selective impairment to a type of information would results in a deficit to those categories for which such information is most salient. To apply the idea to our case, it is the type of information (perceptual for example) shared by living things that is damaged, which results into poorer performance on this category of objects[6]. Correlational structure theories are similar to modality – specific theories in that they do not suggest that categories are a dimension along which the semantic system is organized. This class of theories proposes that the semantic system is organized by groups of features (properties). Damage to a certain property would lead to a deficit to the items possessing it. Living things tend to share more properties, hence it is more common to see them being impaired together as a group. A third class of theories, the domain – specific knowledge hypothesis, on the other hand, sustains that some categories which are evolutionarily important domains of knowledge (e. g., animals and plant life) may indeed exist as a natural way by which semantic knowledge is organized[7].

As stated in the introduction, although there have been quite a few cases with categorical selective deficits reported in the literature, we are pleased to discover a Chinese patient with this classical and elegant pattern. Of course the current issues under debate regarding the organization of semantic knowledge in the brain await further investigation. We hope that the present study is not simply a case report that adds further evidence to the existence of categorical selective deficits, but also a case that introduces the logic and methodology of neuropsychological investigations to the Chinese language and that will foster further investigations on this topic.

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语义范畴特异性损伤:一项个案研究

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摘 要 一些脑病患者对特定的语义范畴出现了选择性损伤,如有生命类和无生命类。他们的这种缺陷将有助于揭示人脑中语义知识的组织方式。本研究报道一例汉语患者,WJX,他选择性地损伤了有生命类知识,而对无生命类知识保存的相对较好。研究发现,他的非词典加工系统比较正常,如数字记忆广度,视觉及听觉辨认,嘴部肌肉运动等。但是,他在词典任务(如,听觉/视觉图形再认和图形命名)中却常常犯大量的语义错误。更重要的是,他对有生命类知识的正确率明显低于无生命类知识。该结果从汉语的角度为脑损伤能够选择地影响语义知识这一理论提供了新证据。本研究的调查结果也在一定程度上支持语义系统是按范畴组织起来的观点。

关键词 语义知识的组织,语义范畴特异性损伤,有生命类。

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