

Semantic links between single words in schizophrenia

An artificial intelligence approach

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Abstract

The aim of this study is to explore the semantic associations in schizophrenia through a computational semantic network. We analyzed the data from two tasks, continuous association task without single stimulus word and phonological verbal fluency (formal lexical evocation with a letter stimulus) through a artificial semantic network (LISP language). This network defined and computed the semantic inter-words links and made queries about the different semantic levels of the responses performed by 22 schizophrenics and 17 normal controls. Results show a cluster constriction in continuous association task and more irrelevant responses (already said words) in the schizophrenics in the two tasks. In the continuous association task, the semantic links using an mental imagery evocation, and consequently a more longer inter-words time, were significantly lower in schizophrenic patients than in control subjects. Finally we found some differences in the organization of semantic categories between the two groups in relation with stereotypic responses.

Introduction

Eugen Bleuler defined the association trouble in schizophrenia as a fundamental symptom. For him, the association disturbances were conceived as being a primary disorder from which derive the majority of secondary symptoms. Different classification schemes of word-associations types were proposed to describe these disturbances in clinical practice. For example, Kraepelin noted that fatigue tends to increase the verbal links (phonological) between the word associations (for example : 'polyp', 'polygon') in comparison with the meaning links (semantic) ('Cat', 'dog'). Most authors suggested later that the association disorders reflect a basic thought disorder in schizophrenia: loss of abstract attitude with overinclusiveness (Meadow, defect in categorization abilities as aphasia disorders (Goldstein). Milgram showed that schizophrenics tends to produce more irrelevant perseverations and more supraordinate categories than normals.

The controverse between Chaika (Chaika,74,77) and Fromkin (Fromkin) and Roch-recours (Lecours) dealt with the problem of the existence of rules governing the errors of speech production in schizophrenia. Fromkin noted that schizophrenics presents a defect in repression of errors but no difference in semantic organization of responses. More recently, most authors suggested a neuropsychological deficit in attention (Silverman).

Therefore the selective attention deficit hypothesis cannot be the mechanism whereby positive symptoms of schizophrenics are generated. In an Allen and Frith study (Allen83), schizophrenics

with positive symptoms tended to produce smaller clusters (set of word responses with lower inter-words duration times (Deese) resulting of two processes - search of conceptual dimensions and production of semantic instances of this dimension (Allen83) than the normals and the schizophrenics with positive symptoms.

Lack of inhibition of errors and irrelevant responses, attention disorders and retrieval constriction were in relationships with the results of frontal deficit in schizophrenia (Weinberger (Warkentin, Liddle91, Liddle92).

The aim of the study is to contribute on this discussion with a experimental study of single words production performed by schizophrenics during verbal fluency task and continuous association task. In verbal fluency task, subjects have to name as many words as possible beginning with a defined letter (formal lexical evocation). In continuous association task, subject have to name all words without semantic or formal constraint, except as many as possible, in a limited duration.

The normals characteristics, as proportions of correct answers and errors, and their relation with age classes, sex and level of education were well known since the first words-association works and also in French language (Cardebat). Verbal fluency was reputed to implicate neuropsychological functions of frontal lobes, especially attention and cognitive inhibition tasks (Warkentin). By contrast, continuous association task could be more easy for schizophrenics in reason of the lack of constraint and so the number of responses could be higher.

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The responses of continuous association and verbal fluency tasks will be analyzed with an artificial semantic network who use the conceptual links method (Sowa). The most important interest is the use of conceptual structures which can describe the semantic associations with a relative limited number of symbolic links (12). Also the inference rules generating these symbolic links limit the subjectivity of the human operator. Endly the semantic categories of the spoken words are linked between dynamic procedures as class inheritance and feature inheritance. Thus the semantic network build by the system can be consulted by the operator to know the numbers of occurrences of words in the different supra-categories.

1.Method

1.1 Subjects

The schizophrenics group contains 22 subjects. Recruited patients were chronic schizophrenics (DSM-III-R) hospitalized in two psychiatric departments near Paris. There were all French language native males, ages between 18 to 50. The patients who presented alcoholic or drug problems and those with thymic symptoms, neurologic antecedents or brain injury, were excluded of this study. Patients were treated with neuroleptics since at least 15 days so that their clinical state could be considered as stable, without marked desorganization, hallucinations or delisional speech. Four patients had anticholinergic drug medication and half on the group received benzodiazepines. The control group contains 17 subjects and was comparable for age and cultural level (number of study years). The normal subjects had no neurologic no psychiatric antecedents. Their verbal level (vocabulary subtest of WAIS-R) was assessed and matched to that of the patients. All of them had given their informed consent.

1.2 Procedure

In the continuous association task subjects were tested individually and were required to say as many as possible words during two minutes. In the verbal fluency the subjects had to say all the words beginning with the letter c (also during two minutes). No repetition and poprer names were recommended in two tasks. Presentation of the tasks to the subjects and recording of the performances were performed in a standardised way by the same psychiatrist (MJG).

Outputs words and interword paises were tape-recorded and digitized in a Powermac 7100 device, using a SIGNALIZE (3.OTM) software. Interword times were measured in milliseconds using this software, in order to define the clusters of words. Clusters of words were defined by setting an interword time threshold in each subject according to the following procedure. For each task, the inter-word times were classed in a decreasing manner, and the

linear regression line was computed. Curves of the residuals were fitted afterwards, with the adjusted values (computed forme the equation of the regression line) on the y axis and the residuals (i.e. the differences between the measured times and the adjusted values) on the x axis. From these curves, the inflexion point corresponding to the point of the curve where the difference between the adjusted value and the measured time diverged from the main distribution was taken as the cluster threshold time. Any interword time equal or superior to this threshold was considered as an inter-cluster time, so that the clusters were definite as groups of words flanked by two inter-cluster times.

List of words were further analyzed with a semantic interpreter software written in the list processing symbolic language: LISP. In this computer language very used in AI, a list is represented externally to the computer in terms of characters, and internally in terms of memory cells. It can compute all the words and their conceptual links and supra semantics categories definite in a semantic knowledge base build with primitive categories.

The links between the words are grouped in four macro-links according to their type (See the table (LINKS and the figure (RESEAU0.PCL)). The primitive superordinate categories were hand-made by a operator in blindness of the type of subjects (patient or control). These links are governed by a set of inferences rules (See Appendix). These links and rules were inspired by Sowa (Sowa and the primitive categories by Schank (Schank). The innocence of words, links and categories were calculated by the computer. Statistical analysis was performed using SYS-STAT software through ANOVA and post hoc t-test.

Results

Table 1 presents the quantitative results of the two tasks. The mean number of words was not significantly different between the two groups and for the two tasks ($p > 0.1$). Yet in verbal fluency the schizophrenics tended to produce less responses ($p = 0.08$). But when only the means of correct responses are considered, i.e. without the repeated words, the difference was significant between the two groups in verbal fluency ($p < 0.02$). Also the difference of repetitions differed in the two tasks ($p = 0.02$ in continuous association task and $p = 0.001$ in verbal fluency).

The number of clusters did not significantly differ between the two groups. A trend towards cluster constriction in schizophrenics was found in the continuous association task ($p = 0.058$) but not in the verbal fluency task ($p > 0.1$). Finally the number of different categories did not differ between the two groups.

Table LINK presents the results of the analysis of the semantic links in the continuous association task. The mean number of macrolinks produced in the continuous association task differed between the groups (ANOVA $F = 2.73$ d.f. = 5.33 $p < 0.03$).

The macro-link M-SCEN differed significantly between the normals and the schizophrenics ($t = 6.82$ $p < 0.01$). The sublink in the difference between our two groups of subjects was probably the link FONC (functional relationship: nail /hammer) which tended to differ (t -test $p < 0.06$) and be less used in the group of schizophrenics.

Table CATEGORY presents the analysis of the semantic categories. The size of the categories definite from the knowledge base in the network differed between the two groups ($F = 2.20$, d.f. = 13,25 $p < 0.05$).

The score of living beings category was significantly higher in the schizophrenic group ($p = 0.04$). The subcategory implicated was the animal category. With the modality verbal fluency this result did not appear. The other types of categories did not show any differences.

Discussion

Therefore the results of this half group in the fluency and evocation tasks did not significantly differ from the half group without benzodiazepin (U test from Mann Whitney). The irrelevant errors, and especially the repetitions of already said words, are very significantly more frequency in the schizophrenic group supporting the frontal deficit hypothesis in schizophrenia by lack of inhibition of mistakes regarding the initial instructions of test ('as many as possible', 'no repetition...'). We found also, with a different method of cluster's bounds definition, the same significantly cluster's constriction observed by Allen and Frith (1983) in free emission task with categorical stimulus (Allen83). In terms of artificial semantic network theory, this constriction could be described as a "pruning" effect on several branches of the tree representing the semantic space.

The use of conceptual links can be help to known the nature of these branches. The semantic analysis of the free emission responses showed that the schizophrenics cannot used with the same efficacy the SCEN strategy and especially the functional links. Moreover the duration of inter-words times is significantly different between the M-CLAS links and M-SCEN links for the normal control subjects. Also the cognitive task to use these links need more time for the M-SCEN links than the M-CLAS links.

This is a good argument to validate the hypothesis that M-SCEN links reflect a mental visual image description (verbal report from visual memory (Roland) which is used to inspect the image and its

relevant parts (FIND operator on Kosslyn's theory (Kosslyn). Yet the result don't appear with the schizophrenic group because there is a increase of duration of CLAS link in this group.

The times inter-words of the links (SCEN) are also significantly longer as the other links. It is possible that the task to take a mental imagery in the mind during a certain time is maybe harder from the schizophrenics because they have a frontal deficit whose limited the attention focus on visual imagery or the functional correlation between cortical areas. Goldenberg and al. found the imagery system to be composed of regions of the medial occipital and inferior temporal lobe (Goldenberg and Roland).

Concerning the type of semantic categories, some clinical observations in neuropsychology tend to demonstrate the existence of impairment specific. For example, a neurological patient had more difficulty to identifying inanimate objects than identifying living things (Nielsen 1946) but another patient from Hécaen and Ajuriaguerra showed a reverse dissociation (Hécaen). A Yamadori and Albert 's subject had a specific difficulty in understanding the meaning of common objects (Yamadori). The psychiatric literature suggest that there is also a lot of specific semantic features in the schizophrenia. From Jones (1988) the concrete words are easier represented in semantic memory in long term because they are associated with a mental imagery (Jones). With negative transformation task Irigaray (Irigaray) found more lived entities categories in schizophrenics.

More recently Damasio works suggest a correlation between degree of generality of semantic categories and location of lesion in the temporal lobe (Damasio). Patients, with brain damages, whose lesions are more anterior in the temporal lobe are more likely to have lost highly specific taxonomy (Churchland). Our results tends to show that the schizophrenics don't use especially semantic category even for abstract, body, actions, substances whose are tested because these categories were suspected to be different on account of the phenomenology of the inner world of schizophrenia. All these categories differ not significantly between the two groups even the abstract category. Yet we can see that the lived entities category is more frequent in the schizophrenic group, according with Irigaray. But the multivariate analysis showed that there is only the subcategory animal inside the lived entities category who were in fact more represented in the schizophrenic responses only in the continuous association word task.

This result is in harmonize with the data issued from projective tests in schizophrenia. Front of ambiguous stimuli of the Rorschach's figure, schizophrenics answer more animal category as normals [p.37](Rorschach). In projective study about schizophrenia the animal category is considered as a stereotypic response (Rorschach

).Therefore it's known that the number of responses in the animal category was often greater than the other categories in the fluency task and this also for normal subjects because this semantic field is well known since the childhood and contains more well delimited subcategories (Cardebat).

Our results with continuous association task are the same in this point as the result with ambiguous stimuli. Rorschach wrote also there is in his test a negative correlation between the percentage of animal category and the percentage of kinematics responses in the schizophrenic group. Now the FONC link, lower in schizophrenic responses, needs a kinematic mental representation (temporal and spatial interaction between physical or conceptual objects). So it seems that is more difficult for the schizophrenics to evoke an association between two concepts engaged in a functional and adaptive relation suggesting an effect of cognitive deficit resolving with a stereotypic strategy.

All these results suggest that the artificial computing semantic network method could provide a conceptual and practice tool to investigate the associations disorders in schizophrenia and simultaneously to contribute on the discussion about the biologic pertinence of different semantic models (meaning atoms and discriminate features for Katz and Fodor (Katz, network theories for Collins and Quillian (Quillian, theories derived from computational semantics (e.g. Miller Johnson-Laird, 1976 (Miller), or script and MOPs models (Memory Organisation Packets) (Schank as those used in Artificial Intelligence to natural language understanding.

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Table 1: Results

		CONT. WORDS		VERBAL FLUENCY	
		Normals n = 17	Schizophrenics n = 22	Normals n = 17	Schizophrenics n = 22
All words	mean	45.88 ± 15.43	45.2 ± 16.18	25.76 ± 6.60	21.04 ± 10.21
	t		0.12		1.74
	p		0.90		0.08
Repeated words	mean	0.52 ± 1.70	1.86 ± 1.78	0.64 ± 1.11	2.22 ± 1.66
	t		2.38		3.54
	p		0.02		0.001
Clusters	mean	7.52 ± 3.32	9.68 ± 5.81	5.05 ± 2.65	4.04 ± 2.91
	t		1.44		1.13
	p		0.15		0.26
Cluster size	p		0.06		0.45
Categories	mean	14.05 ± 3.91	13.13 ± 4.07	10.82 ± 2.53	9.86 ± 3.57
	t		0.71		0.91
	p		0.47		0.33

Table 2: Correlation between numbers of words and cluster size

		CONT. WORDS		VERBAL FLUENCY	
		Normals	Schizophrenics	Normals	Schizophrenics
words /clusters	Correlation r	0.57	0.69	0.66	0.85

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Table 1: Semantic categories: $F = 2.20$ $p = 0.05$

	CONT. WORDS		VERBAL FLUENCY		
	Normals	Schizophrenics	Normals	Schizophrenics	
CURIOUS	mean	0.64 ± 1.24	4.86 ± 6.31	3.52 ± 3.73	16.01 ± 21.01
	<i>t</i>		3.06		2.72
	<i>p</i>		0.006		0.012
LIV. THINGS	mean	8.24 ± 6.35	15.21 ± 13.93		
	<i>t</i>		2.08		
	<i>p</i>		0.04		
ANIMALS	mean	0.88 ± 1.45	3.13 ± 3.96	2.91 ± 3.11	1.40 ± 1.37
	<i>t</i>		2.46		1.82
	<i>p</i>		0.02		0.08
ABSTRACT	mean	12.96 ± 16.31	10.87 ± 17.27		
	<i>t</i>		0.38		
	<i>p</i>		0.37		
ACTIONS	mean	4.44 ± 5.44	8.48 ± 13.95		
	<i>t</i>		1.24		
	<i>p</i>		0.22		
BODY	mean	1.69 ± 2.74	3.80 ± 6.34		
	<i>t</i>		1.4		
	<i>p</i>		0.17		
SUBSTANCE	mean	1.38 ± 2.43	2.17 ± 3.57		
	<i>t</i>		0.77		
	<i>p</i>		0.41		

Table 2: 'Deep pruning hypothesis' words = supraordinate categories

	mean	SD	<i>t</i>	<i>p</i>
control subjects	1.38	2.43		
schizophrenics	2.17	3.87	0.77	0.44

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MACRO-LINKS	F	P
M-PHO	2.27	0.14
M-SCEN	6.82	0.01
M-CLAS	3.42	0.07
M-SYNTA	0.26	0.60
UNKWOWN	1.25	0.27

Table 1: F Analysis of Macro-links (Continuous words association) (Link FONC with t-test post hoc =0.018)

Table 2: Results with t-test analysis

	CONT. WORDS		VERBAL FLUENCY		
	Normals	Schizophrenics	Normals	Schizophrenics	
LINK (CLAS)	mean	12.29±9.64	15.40±10.37	0.05± 0.06	0.07 ± 0.10
	t		0.96		0.80
	p		0.34		0.42
LINK (SCEN)	mean	7.00 ±5.61	3.18 ±2.80	0.11± 0.33	0.09 ± 0.42
	t		2.78		0.21
	p		0.008		0.83
LINK /k/	mean			36 ± 16	33 ± 22
	t				0.55
	p				0.58
LINK /ch/	mean			5.40 ± 7.00	6.90 ± 18.00
	t				0.38
	p				0.70
LINK /s/	mean			1.30 ± 2.80	7.80 ± 11.9
	t				2.49
	p				0.002

Table 3: Duration of interwords times regarding with the semantic links (in msec) in continuous words association.

	NORMALS		SCHIZOPHRENICS		
	CLAS	SCEN	CLAS	SCEN	
DURATION OF LINKS	mean	727 ±1050	1010 ±1235	1146 ± 1743	1010 ± 1300
	t		2.20		0.74
	p		0.02		0.45

APPENDIX

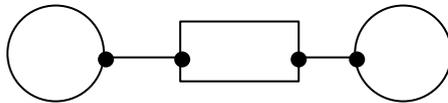
Rules of link's attribution

Following are showed the inferences rules controlling the establishment of links between a word A and the next word B in the list of responses :

Rule PART : It is a link PART between A and B if and only if all these conditions are true:

- A is a physical object
- B is a physical object
- A is connected with B or B is connected with A.

for example in the notation of conceptual structure from Sowa.



and in the notation of LISP language:

(putprop 'LOAF 'TREE 'PART) with 'loaf 'tree as symbolic atoms and 'part in the p-list of the symbol.

Rule FONC : It is a link FONC between A and B if and only if all these conditions are true:

- A is a physical object
- B is a physical object
- A serves B or B serves A

CIGARETTE \Rightarrow (FONC) \Rightarrow LIGHTER

Rule PHO : It is a link PHO between A and B if and only if one of these conditions is true:

- A and B begin by the same syllabic. (In french a syllabic needs one consonant or two consonant and one vowel).
- A and B end with the same syllabic rhyme.

CAMEL \Rightarrow (PHO) \Rightarrow CAMERA

Rule PHOCLAS : It is a link PHOCLAS between A and B if and only if all these conditions are true:

- A begins by the same syllabic than B (or opposite)
- A and B belong at the same semantic category and are linked by a link AKO (A-Kind-Of) on a semantic class efinite.

POSE \Rightarrow (PHOCLAS) \Rightarrow POSITION

Rule CLAS : It is a link CLAS between A and B if and only if these conditions are true :

- A and B belong to the same semantic class predefinite and linked together by a link AKO (A-kind-of) with one of upraordinate classes.

CAT \Rightarrow (CLAS) \Rightarrow DOG

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This is the most general type. It is used to put together words that are more specific names of same generic object (IS-A-SORT-OF), for instance to represent the classification of animals and vegetable in biology-related fields.

Rule CONT. The link CONT means the opposite between two concepts complementarily between two concepts linked in a conceptual pair.

GOOD \Rightarrow (CONT) \Rightarrow BAD

Rule SUCC. The link SUCC describes an enumeration of concepts in an ordinary class or short class.

MONDAY \Rightarrow (SUCC) \Rightarrow TUESDAY

Rule ATTR : It is a link ATTR between A and B if and only if all these conditions are true:

- A is an object physical or abstract, or a class in the network
- B is an object physical or abstract, or a class in the network
- A is cosubstantially with B in physical or abstract universe, or A et B are linked together in idiomatic.

SKY \Rightarrow (ATTR) \Rightarrow BLUE

Rule TYPI : It is a link TYPI between A and B if and only if all these conditions are true:

- A is a physical object or a semantic class
- B is a instance of A.

DOG \Rightarrow (TYPI) \Rightarrow SNOOPY

Rule SYNO : It is a link SYNO between A and B if and only if all these conditions are true:

- A and B can be used one for this another in a sentence without change the meaning.

HABIT \Rightarrow (SYNO) \Rightarrow VETEMENT

Rule SPAT : it is a link SPAT between A and B if and only if all these conditions are true:

- No precedents rules can be used
- A and B are physical objects.
- A et B are coexisting in a script or in a realistic scene.

BOAT \Rightarrow (SPAT) \Rightarrow SEE

Rule LING. We use the link LIN if and only if it's a linguistic variation between A and B. This declinaison don't change the semantic class.

LION \Rightarrow (LING) \Rightarrow LIONNE

Rule ?k : (only with verbal fluency task): If no precedent rules can be applied and if A and B are beginning both with the consonant /k/ and the letter c .

CAR \Rightarrow (?k) \Rightarrow CARDS

Rule ?s : (only with the verbal fluency task): if no precedents rules can be applied and if A and B are beginning both with the consonant /s/ and the letter c .

SEND \Rightarrow (?s) \Rightarrow SOMETHING

Rule ?ch: (only with the verbal fluency task): if no precedents rules can be applied and if A and B are beginning both with the consonant /ch/ and the letter s .

SHOW \Rightarrow (?ch) \Rightarrow SHOWER

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Rule ? : if no precedents rules can be applied then this link is unknown.

TABLE \Rightarrow (?) \Rightarrow BREATH

If there are more than one between A and B then we specify only one in the network. The choice of this link follows these META-RULES:

In all cases where PHO coexists with another link we use only this link (PHO).

In the cases where there is another combinaison of links, we use the following hierarchy to select the most superior link:

CLAS \Rightarrow PART \Rightarrow FONC \Rightarrow ATTR \Rightarrow SPAT

At last some links are grouped in four MACRO-LINKS:

MACRO-LINK (M-CLAS) is the amount of the occurrences of (CLAS) and (TYPI). These links describe the mental operation consisting in the selection of items inside the same semantic category.

MACRO-LINK (M-SYNTAGM) is the amount of the link (SYNO) (SUCC) (CONT). These links describe syntactic operation by comparison with the paradigmatic selection as the CLAS link.

MACRO-LINK (M-PHO) is the amount of (PHO) (LING) and (PHOCLAS). These links consist in the selection of items with phonological strategies.

MACRO-LINK (M-SCEN) is the amount of (PART) (FONC) (SPAT) (ATTR). These links describe complex relationships between concepts belonging different semantic category (See the table LINKS).

Semantic links used. See also in appendix for example and formalization.

MACRO-LINK	
LINK	designation
CLAS	semantic class
M-CLAS	
TYPI	typication
SYNO	synonym
M-SYNTAGM	
SUCC	series in an ordinary class (days...)
CONT	contrary
ATTR	attribution
M-SCEN	
SPAT	spatial coexistence
FONC	fonctional relationship
LING	linguistic association (genus, plural...)
M-PHO	
PHO	phonological similarity
PHOCLAS	phonological similarity and semantic class
UNKNOWN	
?	unknown

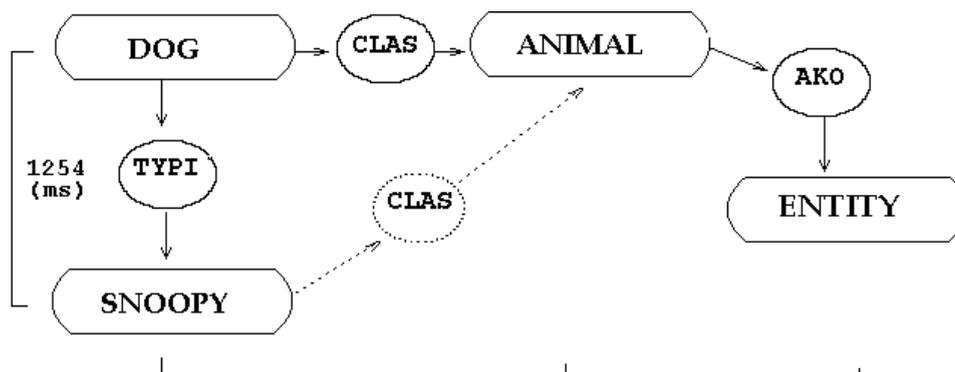


Fig. 1

Example of links between two words (DOG and SNOOPY) separated by a inter-words time (in ms). The link CLAS between DOG and the category ANIMAL was hand-made by the operator, as the link TYPI between SNOOPY and DOG, but the link AKO between ANIMAL and the supra category ENTITIE was known by the system. The link CLAS between SNOOPY and ANIMAL (dotted line) is build artificially by the system alone (inheritance relationship). So the category ANIMAL contains two instances. When we ask the system: Is SNOOPY an animal? The system could answer alone: YES.