Semantic links between single words in schizophrenia

An artificial intelligence approach

Benoît Virole

1995-2021

The aim of this study was to explore the semantic associations in schizophrenia through a computational semantic network. We analysed 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 definited 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 organisation of semantic categories between the two groups in relation with stereotypic responses

Keywords

Schizophrenia Artificial Intelligence

Introduction

Eugen Bleuler [3] definited 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 pratice. For example, Kraepelin [24] 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 [28], defect in categorization abilities as aphasia disorders [16]. Milgram showed that schizophrenics tends to produce more irrelevant perseverations and more supraordinate categories than normals. The controverse between Chaika [7] [8], Fromkin[13] and Roch-Lecours [25] dealed 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 [37]. Therefore the selective attention deficit hypothesis cannot be the mechanism whereby positive symptoms of schizophrenics are generated. In an Allen and Frith study [2], schizophrenics with positive symptoms tended to produce smaller clusters (set of word responses with lower inter-words duration times [11] resulting of two processes - search of conceptual dimensions and production of semantic instances of this dimension [2]) 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 [42] [40] [26] [27]. The aim of the study is to contribute on this discussion with a experimental study of single words production perfomed 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 continous association task, subject have to name all words without semantic ou formal constraint, except as many as possible, in a limited duration. The normals caracteristics, 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 [5]. Verbal fluency was reputed to implicate neuropsychological functions of frontal lobes, especially attention and cognitive inhibition tasks [40]. 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. The responses of continuous association and verbal fluency tasks will be analysed with an artificial semantic network who use the conceptual links method [38]. 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 occurences of words in the differents supra-categories.

Method

The schizophrenics group contains 22 subjects. Recruted patients were chronic schizophrenics (DSM-III-R) hospitalised in two psychiatric departements 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, hallunications 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.

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 be 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 digitalized 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 limear regression line was computed. Curves of the residuals were fitted afterwords, withe 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 forme 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 definited 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 fetween the words are grouped in four macro-links according to their type (See the table). 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 [38] and the primitive categories by Schank [35]. The inoccurence 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. For example a 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 (dooted 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.

Results

Table 2 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 differents categories did not differ between the two groupe. Table **??** 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 differd 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 shizophrenics ($t = 6.82$ $p < 0.01$). The sublink in the difference between our two groups of subjects was probably the link FONC (fonctional relationship: nail, hammer) which tended to differ (t-test $p < 0.06$) and be less used in the group of schizophrenics. Table presents the analysis of the semantic categories. The size of the categories definited from the kwnowledge 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 form 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 [2]. 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 emision responses showed that the schizophrenics cannot used with the same efficacity the SCEN strategy and especially the functionnal links. Moreever 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 in good argument to validate the hypothesis that M-SCEN links reflect a mental visual image description (verbal report from visual memory [33] which is used to inspect the image anf its relevant parts (FIND operator on Kosslyn's theory [23]). 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 functionnal correlation between cortical areas. Goldenberg and al. found the imagery system to be composed of regions of the medial occipital and inferior temporal lobe [15] and [33].

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 diffculty to identifying inanimate objects than identifying livings things (Nielsen 1946) [31] but an another patient from Hcaen and Ajuriaguerra showed a reverse dissociation [17]. A Yamadori and Albert 's subject had a specific difficulty in understanding the meaning of common objects [39]. The psychiatric literature suggest that there is also a lot of specific semantic features in the schizophrenia. From Jones (1988) the concret words are easier represented in semantic memory in long term because they are associated with a mental imagery [21]. With negative transformation task Irigaray[19] 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 [10]. Patients, with brain damages, whose lesions are more anterior in the temporal lobe are more likely to have lost higly specific taxonomy [9].

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 phenomelogy of the innere world of schizophrenia. All these categories differ not significantly between the two groups even the abtract 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 [34, p.37]. In projective study about schizophrenia the animal category is considered as a stereotypic response [34] 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 fiedl is well known since the childhood and contains more well delimited subcategories [5]. Our results with continuous association task are the same in this point as the result with ambigous 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's seems that is more difficult for the schizophrenics to evocate a association between two concepts engaged in a functionnal and adaptive relation suggesting an effect of cognitive planification 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 simultany to contribute on the discussion about the biologic pertinence of different semantic models (meaning atoms and discriminant features for Katz and Fodor [22], network theories for Collins and Quillian [32], theories derived from computational semantics (e.g. Miller & Johnson-Laird, 1976 [30]), or script and MOPs models (Memory Organisation Packets) [35] as those used in Artificial Intelligence to natural language understanding.

References

[1] Allen A. H., Liddle P.F, Frith C.D. Negative features retrieval processes and verbal fluency *British Journal of Psychiatry,* 163, pp. 769-775.

[2] Allen H. A., Frith C.D., selective retrieval and free emission of category exemplars in schizophrenia. *British Journal of Psychology,* **74,** 481-490, 1983.

[3] Bleuler E. *Daementia praecox,* or the group of schizophrenias, International Universities Press, New York, 1966, (first edition 1911).

[4] Caramazza A. & Hillis A.E *Where do semantic errors come from? Cortex* 26, pp.95-122.

[5] Cardebat D., Doyon B., Puel M., Goulet P., Joanette Y. Evocation lexicale formelle et smantique chez des sujets normaux. Performances et dynamiques de production en fonction du sexe, de l'ge et du niveau d'tude. *Acta neurol. belg.* **90,** 207-217, 1990.

[6] Chapman L. J. Confusion of figurative and litteral usages of words by shizophrenics and brain damaged patients, *J. abnorm. soc. Psychol.,* 60, 412, 1960.

[7] Chaika E. O. A linguist looks at "shizophrenic" language *Brain and language* 1, 257, 1974.

[8] Chaika E.O. Schizophrenic speech, slips of the tongue and jargononaphasia : a remply to Fromkin and to Lecours et Vanier-Clment, *Brain and language,* 4 464, 1977.

[9] Churchland P., Sejnowski T. J., *The computational brain* MIT Press, 1992.

[10] Damasio H., Damasio A. *Lesion Analysis in Neuropsychology* Oxford, Oxford University Press, 1989.

[11] Deese J. Serial Organization in the recall of disconnected items *Psychol. Rep.* 3, pp. 577-582, 1957.

[12] Deese J. On the structure of associate meaning in *Psychol. Rev.* , 69, 3, pp. 161-175, 1962.

[13] Fromkin V.A., A linguist looks at 'A linguist looks at schizophrenic language', *Brain and language,* 2, 498, 1975.

[14] Goodglass H., Klein P., Carey P., Jones K. Specific semantic word categories in aphasia, *Cortex,* 2, pp. 74-89, 1966.

[15] Goldenberg G. patterns of regional blood flow related to memorizing of high and low imagery words - An emission computer tomography study *Neuropsychology,* 25, pp. 473-485.

[16] Goldstein K. *Language and language disturbances*, Grune et Stratton, New York, 1948.

[17] Hcaen H. & Ajuriaguerra J. de Agnosie visuelle pour les objets inanims par lsion unilatrale gauche. *Revue Neurologique,* 94, 222-233, 1956.

[18] Hinton G.E, Shallice T. Lesioning an Attractor Network: Investigations of Acquired Dyslexia in *Psychological Review,* vol. 98, 1 pp. 74-95, 1991.

[19] Irigaray L. Approche psycho-linguistique du langage des dments, *Neuropsychologia,* 5, 25, 1967.

[20] Johnson M.H., Magaor P.A., Effects of mood and severity on memory processes in depression and mania *Psychological Bulletin* , 101, pp. 28-40, 1987.

[21] Jones G.V. Images, predicates and retrieval cues in M. Denis, J. Engelkamp & J.T.E Richardson (Eds). *Cognitive and neuropsychological approaches to mental imagery* pp. 89-98, Dordrecht: Martinus Nijhoff, 1988.

[22] Katz J.J., & Fodor J.A. The structure of a semantic theory, *Language, 39, 170-210, 1963.*

[23] Kosslyn S.M Image and mind, Cambridge, Mass.: Harvard University Press, 1980.

[24] Kraepelin E. Dementia Praecox, Churchill Livingstone Inc., New York: 1919.

[25] Lecours A.R., Vanier-Clment M., Schizophasia and jargonophasia. A comparative description with comments on Chaika's and Fromkin's respective looks at 'schizophrenic' language Brain and language, 3, 516, 1976.

[26] Liddle P.F. and Morris D.L. Schizophrenic syndromes and frontal lobe performance. *British J. Psychiatry,* 158, 340-345, 1991.

[27] Liddle P.F., Friston K.J., Frith C.D., Hirsch S.R., Jones T. & Frackowiak R.S.J. Patterns of cerbral blood flow in schizophrenia. *British J Psychiatry* 160, 179-186, 1992.

[28] Meaddow A., Greenblatt M., & Solomon H. C., Looseness of association and impairment in abstraction in schizophrenia *Journal of Nervous and Mental Disease, 1953,* **118,** 27-35.

[29] Milgram N. A. Microgenetic analysis of word associations in schizophrenic and braindamaged patients *Journal of Abnormal and Social Psychology* 1961, **62,** 364-366.

[30] Miller G.A & Johnson-Laird P.N. *Language and perception*, Cambridge, Mass.: Harvard University Press, 1976.

[31] Nielsen J.M. *Agnosia, apraxia, aphasia: their value in cerebral localisazation* 2nd ed. New York: Hoeber, 1946.

[32] Quillian R. Word concepts: A theory and simulation of some semantic capabilities in *Behevorial Science* , 12, pp. 410-430, 1967, publi en franais dans *Textes pour une psycholinguistique* sous la direction de Jacques Melher et Georges Noizet, Mouton, 1974.

[33] Roland P.E. & Firberg L. Localization of cortical areas activated by thinking *Journal of Neurophysiology,* 53, 1219-1243.

[34] Rorschach H. *Psychodiagnostic* Berne, 1947, Paris, Puf, 1976.

[35] Schank R. Reminding and memory organisation: an introduction to MOPs, in *Strategies for natural language processing,* Lehnert & Ringke, Lawrence Erlbaum, Hillsdale, N.J.

[36] Shallice T. *From Neuropsychology to Mental Structure*, Cambridge University Press, 1988.

[37] Silverman J. The problem of attention in research and theory in schizophrenia, *Psychol. Rev.* 71, 352-379, 1964.

[38] Sowa J.F. *Conceptual Structures*, Addison Wesley, 1984.

[39] Yamadori A., & Albert M.L. Word category aphasia, *Cortex,* 9, 112-125, 1973.

[40] Warkentin S., Nilson A., Risberg J. & Carlson S. Absence of frontal lobe activation in schizophrenia, *J. Cereb. Blood Flow Metab.* suppl. 1, **9.** S354, 1989.

[41] Warrington E.K, Shallice T. Category specific semantic impairments , *Brain,* 107, pp. 829-854, 1984.

[42] Weinberger D. R., Berman K.F. & Zee R.F Physiological dysfunction of the dorsolateral prefrontal cortrex in schizophrenia. I. Regional cerbral blood flow rCBF. evidence. *Arch. of gen. Psychiat.* **43.** 114-125, 1993.

[43] Weingartner H., Cohen R.M., Murphy D.L., Martello J., Gerdt C. Cognitive processes in depression *Archives of General Psychiatry,* 38, pp. 42-47, 1981.

ACKWOWLEDGEMENT

Pr. Manus (C.H. Chenevier de Créteil) Dr. De Praingy (C.H.G Corentin Celton). M. François (CHU Robert-Debré).

Rules of link's attribution

Following are showed the inferences rules controling the establishement of links between a word A and the next word in the list of responses :

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

   (a) A is a physical object

   (b) B is a physical object

   (c) A is connected with B or B is connected with A.

   for example in the notation of conceptual structure from Sowa [38]:

   [LOAF]→ (PART) → [TREE]

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

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

   (a) A is a physical object

   (b) B is a physical object

   (c) A serves B or B serves A

   [CIGARETTE]→ (FONC) → [LIGHTER]

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

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

   (b) A and B end with the same syllabic rhyme.

   [CAMEL]→ (PHO) → [CAMERA]

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

   (a) A begins by the same syllabic than B (or opposite)

   (b) A and B belong at the same semantic category and are linked by a link AKO (A-Kind-Of) on a semantic class definited.

   [POSE]→ (PHOCLAS) → [POSITION]

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

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

[CAT]→ (CLAS) → [DOG]

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.

6. **Rule CONT.** The link CONT means the opposite between two concepts or the complementarity between two concepts linked in a conceptual pair.

   [GOOD]→ (CONT) → [BAD]

7. **Rule SUCC.** The link SUCC describes an enumeration of concepts in an ordonnary class or short class.

   [MONDAY]→ (SUCC) → [TUESDAY]

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

   (a) *A* is an object physical or abstract, or a class in the network

   (b) *B* is an object physical or abstract, or a class in the network

   (c) *A* is cosubstiantaly with *B* in physical or abstract univers, or *A* et *B* are linked together in idiomatics.

   [SKY]→ (ATTR) → [BLUE]

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

   (a) *A* is a physical object or a semantic class

   (b) *B* is a instance of *A*.

   [DOG]→ (TYPI) → [SNOOPY]

10. **Rule SYNO :** Il is a link SYNO between *A* and *B* if and only if all these conditions are true:

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

    [HABIT]→ (SYNO) → [VETEMENT]

11. **Rule SPAT :** iIl is a link SPAT between *A* and *B* if and only if all these conditions are true:

    (a) No precedents rules can be applicated.

    (b) *A* and *B* are physical objects.

    (c) *A* et *B* are coexisting in a script or in a realistic scene.

    [BOAT]→ (SPAT) → [SEE]

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

    [LION]→ (LING) → [LIONNE RBRACK

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

    [CAR]→ (?K) → [CARDS]

14. **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 consonnantic /s/ and the letter *c*.

    [SEND]→ (?s) → [SOMETHING]

15. **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 consonnantic /ch/ and the letter *s*.

    [SHOW]→ (?ch) → [SHOWER]

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

    [TABLE]→ (?) → [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:

1. In all cases where PHO coexists with another link we use only this link (PHO).
2. In the cases where there is another combinaison of links, we use the following hierarchy to select the most superior link:

$$\text{CLAS} \succ \text{PART} \succ \text{FONC} \succ \text{ATTR} \succ \text{SPAT}$$

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

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

2. MACRO-LINK (M-SYNTAGM) is the amount of the link (SYNO) (SUCC) (CONT). These links describe syntagmatic operation by comparaison with the paradigmatic selection as the CLAS link.
3. MACRO-LINK (M-PHO) is the amount of (PHO) (LING) and (PHOCLAS). These links consist in the selection of items with phonological strategies.
4. MACRO-LINK (M-SCEN) is the amount of (PART) (FONC) (SPAT) (ATTR). These links describe complex relationships between concepts belonging differents semantic category (See the table).

Table 1: *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

Table 2: *Mean numbers of words for two tasks*

		CONTINUOUS ASSOCIATION		**VERBAL FLUENCY**	
		Normals	**Schizophrenics**	**Normals**	**Schizophrenics**
		$n = 17$	$n = 22$	$n = 17$	$n = 22$
	mean	45.88 ±15.43	45.2 ±16.18	25.76 ±6.60	21.04 ±10.21
All words	t	0.12		1.74	
	p	0.90		0.08	
	mean	0.52 ± 1.70	1.86 ± 1.78	0.64 ± 1.11	2.22 ± 1.66
Repetitions	t	2.38		3.54	
	p	**0.02**		**0.001**	
	mean	7.52 ± 3.32	9.68 ±5.81	5.05± 2.65	4.04 ± 2.91
Clusters	t	1.44		1.13	
	p	0.15		0.26	
	mean	14,05 ± 3.91	13.13 ± 4.07	10.82 ± 2.53	9.86 ± 3.57
Categories	t	0.71		0.91	
	p	0.47		0.33	

VARIABLE	SS	DF	MS	t	p
M-PHO	194.19	1	194.19	2.27	0.14
error	3155.50	37	85.28		
M-SCEN	384.11	1	384.11	6.82	0.01
error	2082.65	37	56.28		
M-CLAS	1160.92	1	1160.92	3.42	0.07
error	12561.43	37	339.49		
M-SYNTA	4.18	1	4.18	0.26	0.60
error	574.48	37	15.52		
UNKWOWN	537.11	1	537.11	1.25	0.27
error	15845.19	37	428.24		

Table 3: Comparaison (ANOVA) of the macrolinks between normal controls and schizophrenics.

		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	

Table 4: Duration of interwords times regarding with the semantic links (in ms) in continuous association task.

		FREE EMISSION TASK		VERBAL FLUENCY	
		Normals	**Schizophrenics**	**Normals**	**Schizophrenics**
LIVING BEINGS	mean	8.24 ±6.35	15.21±13.93		
	t	2.08			
	p	**0.04**			
ANIMALS	mean	0.88± 1.45	3.13 ±3.96	2.91±3.11	1.40 ± 1.37
	t	2.46		1.82	
	p	**0.02**		0.08	
NO ANIMALS	mean	7.18 ±4.90	8.61 ±10.52	3.65±3.63	4.16 ± 5.13
	t	0.56		0.34	
	p	0.57		0.71	
ABSTRACT	mean	12.96±16.31	10.87±17.27		
	t	0.38			
	p	0.37			
ACTIONS	mean	4.44 ±5.44	8.48 ±13.95		
	t	1.24			
	p	0.22			
BODY	mean	1.69 ±2.74	3.80 ± 6.34		
	t	1.4			
	p	0.17			
SUBSTANCE	mean	1.38 ± 2.43	2.17 ±3.57		
	t	0.77			
	p	0.41			

Table 5: Semantic categories