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VISUAL REPRESENTATIONS IN LEXICAL LEARNING ENVIRONMENTS: APPLICATION TO THE ALEXIA SYSTEM

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Abstract: *Cognition-based arguments in support of using multimedia aids for the learning of vocabulary have so far offered only an imprecise, general framework. CALL experimentalists have also tried to establish the effectiveness of multimedia for vocabulary learning, but their attempts reveal that the underlying representations have not been clearly defined. After reviewing these points, we propose criteria for evaluating the quality of a visual representation in a lexical environment. These criteria are then used to discuss visual representations in paper and electronic dictionaries and in CALL environments. A kind of confusion has been made between multimedia and nonverbal knowledge. Hence visual representations are scarce and limited to concrete words. One way to extend multimedia in lexical learning is to rely on linguistic knowledge and build lexical networks. We present the ALEXIA system, a lexical learning environment for French as a second/foreign language. We detail its network module which can automatically build graphs of some lexical semantic relations. It is a first step for offering learners representations they can easily interpret. Visual representations which can cover a significant part of the lexicon are computable, extendable and interactive.*

Key-words: *vocabulary, learner dictionary, cognitive issues, visual representations, lexical graphs*.

1. WRITTEN TASKS, VOCABULARY AND MULTIMEDIA

If we only consider written tasks in second or foreign language learning, vocabulary knowledge is a key factor in reading comprehension and written production. Vocabulary instruction is also often practised as a stand alone activity in order to deepen the knowledge of a lexical unit, to broaden the vocabulary, to strengthen the relationships among lexical units. A growing amount of research studies the effects of multimedia support for these L2 learning tasks and tries to relate them to cognitive models. In this section we examine two representative cognitive-based approaches and discuss whether they can provide rationales for integrating multimedia in lexically-oriented CALL.

In the second section we review some experiments undertaken with multimedia CALL environments which had the aim of being conclusive with respect to the efficiency of adding multimedia resources to support lexical learning. In section 3 we define criteria for evaluating the quality of a representation and argue that these criteria should serve as a preliminary step for examining visual representations, before thinking of setting up experiments with learners. We use the criteria in section 4 to review multimedia representations in paper and electronic dictionaries and in CALL lexical environments. Although often referred to, visual representations in CALL are scarce, non-interactive and cover a very limited part of the lexicon.

In the following sections (5 to 8), we present the ALEXIA system, a lexical learning environment for French as a second/foreign language. We show how some of the mentioned limitations can be bypassed by processing linguistic information in order to automatically produce visual representations, namely lexical networks.

1.1. Multimedia and text comprehension

In a comprehensive paper Chun & Plass (1997) present the "dual coding theory" (originated with Paivio’s work (1971)) which postulates the existence of two different storage systems for information - a verbal and a nonverbal system. Information in a symbolic representation is stored in the verbal system, information in a nonverbal, analog representation is stored in the nonverbal system. They also present an extension of this theory to multimedia learning and point out the advantages of contiguous presentation of visual and verbal material. Storing information in two different systems represents:

a) a more elaborate encoding, resulting in more retrieval routes to the material,

b) the possibility of storing more information in these two systems,

c) the opportunity to store information in the optimal system for the specific type of information and for the learner’s individual characteristics (verbal and spatial abilities, visualizer/verbalizer preferences).

They also postulate (as is frequently done) that different cognitive processes are involved in micro level processing and macro level processing of multimedia information. On a macro level (overall text comprehension), visual information serves as an aid for text comprehension and functions as supplemental information that is added to the mental model of the text by mapping analog visual representation onto the analog mental model. This type of model elaborated by the learner when reading texts has been the focus of intensive psycholinguistic investigations.

On a micro level (vocabulary acquisition), the presentation of visual information contiguously with verbal information results in the construction of referential connections between the verbal and the visual representation of the material, and the storage of information in two different systems.

Besides this dual coding system, there may be another cognitive-based argument to support the use of some multimedia aids (like graphics) for vocabulary learning, i.e. the structure of the mental lexicon.

1.2. The structure of the mental lexicon

Most of the theory about the mental lexicon presents it as a web of words (see Aitchison (1987) for a comprehensive review). The relations between lexical entries are of two kinds: *intrinsic* and *associative* (Levelt, 1989). The intrinsic relations derive from the linguistic features included in every unit: semantic (synonym, hyponym, antonym), morphological, phonological, and also graphemic. Associative relations are often described as being less directly based on information included in lexical units, but on the fact that words frequently co-occurred in language use (War - death and truth - beauty for example). Many experiments have shown that the most important relations are the semantic ones. Among the intrinsic semantic relations, hyponyms (which can also be considered as a specific case of synonyms), and co-hyponyms (like red, white, blue, etc. which are co-hyponyms of colour) induce tight relations among units.

Associative relations also are semantically based, relying on world and encyclopaedic knowledge. But associative relations are not exclusively extra-linguistic. Firstly, for many words co-occurrence can be linguistically described as in the Meaning-Text theory (Mel'cuk & Polguère, 1987) and in the corresponding Dictionnaire Explicatif et Combinatoire (Mel'cuk, 1992). For example the collocation narrow escape is described as a Magn lexical function (meaning 'very', 'intense', 'intensely'): Magn(escape) = narrow. Secondly, there is another sort of collocation where simple units are so tightly linked that they behave as a single unit and are stored in the mental lexicon as such, as proved by psycholinguistic experiments; e.g., cost of living, prime minister, etc. We will see further on why we should make these distinctions between linguistic and extra-linguistic with respect to visual aids.

The idea that it can be useful support of learning to build graphics that "reflect" the structure of the mental lexicon is a common assumption which CALL researchers have already started to put into practice, as we will see. However this apparently "natural" argument can be seriously challenged from cognitive standpoints. Indeed the true mental lexicon is an impressively flexible structure which can operate very differently depending on the discourse context. The fact that a word's association can be changed so quickly by the context made Aitchison doubt that "we could ever lay down fixed and detailed pathways linking words in this mental lexicon" (ibid., p. 73). Moreover the learner's mental lexicon is constantly moving, some relations being strengthened depending on his/her private exposure to language, new relations being added when encountering new words. Consequently its structure appears to be more of an idiosyncratic than of a standard nature. Lastly we should also take into account the time scale. On one hand, vocabulary acquisition being a very slow process (Bogaards, 1994), we can imagine that significant changes and growth in the learner's mental lexicon network take time. On the other hand in CALL, practice of any particular piece of software is always occasional and very limited in time. Besides, as we will see, experiments designed for evaluating CALL environments are set up with restricted access times to a computer scheduled for the learners.

Asserting that electronic networks and graphics can mimic the mental lexicon and support learning is not a straightforward process. More research needs to be designed if we want to move onto firm ground.

1.3. Research issues

We summarize this section by extracting statements and setting research questions on the conditions under which multimedia instruction is effective with respect to vocabulary:

- Visual material to support vocabulary acquisition has to be designed differently from visual material to aid text comprehension, depending on the distinctive types of related cognitive processes (Chun & Plass, 1997). Then, how should these two kinds of support be co-ordinated?
- Multimedia support for vocabulary instruction reflecting explicit knowledge about words stemming from linguistic and knowledge representation studies has to be different from multimedia support for the building of private dictionary/lexicon.
- For the former type of support should we distinguish multimedia structures that can represent linguistic knowledge from multimedia structures for extra-linguistic knowledge?
- How should the multimedia information be designed in order to aid the process of vocabulary acquisition? What types of verbal information and what types of visual information are helpful? What kinds of visual information for various word categories (e.g., nouns, verbs, adjectives) are helpful? What is the effect of presenting both verbal and visual information? Should they be presented contiguously, simultaneously (e.g., audio plus textual, audio plus visual, etc.)?
- Which specific individual differences have an effect on vocabulary acquisition in multimedia environments? How can an environment be designed to support the highest possible number of these differences? Which collaborative and competitive effects does multimedia information have on learners with different abilities and learning styles?
- How can vocabulary learning in multimedia environments be assessed? How can we take into account the time constraint on multimedia environments which support the building of the private lexicon?

We distinguished multimedia supports for *text comprehension* from those for *vocabulary acquisition*. Although it is beyond the scope of this paper to detail more aspects related to text comprehension, it is important to note that research issues from these two domains share common interests. One example concerns the studies about the deleterious versus the constructive effects of learning with multimedia (Chun & Plass, 1997, p 66). Information in different presentation modes that are perceived through the same channel can compete for perceptual resources and then impede learning: when viewing a film in a foreign language, a learner may not have enough executive resources to comprehend the foreign language and all the visual information given. On the contrary, Mayer & Anderson (1991) found that when the text information is presented as voice over (hence using a perceptual channel different from the visual one), learning and transfer can be improved. A second example of research findings that could be common to text comprehension and vocabulary acquisition relates to the study of individual differences (spatial, verbal abilities, visual/verbal preferences, etc.).

Let us now turn our attention to the way researchers tried to assess multimedia support on vocabulary instructions and on their findings.

2. EXPERIMENTS WITH MULTIMEDIA AIDS AND SEMANTIC MAPPING IN VOCABULARY INSTRUCTION

One still frequently reads papers in which people are eager to know whether the use of hypermedia is an effective learning tool and claim that we still lack empirical evidence on its efficiency. But setting experiments to answer such a vague question is not interesting. We know in advance, from studies and models cited in the previous section, that a pedagogically and linguistically sound software which can extensively use hypermedia facilities (nonlinearness, flexibility, associativity, multimedia support) will be efficient. If people need to be reassured they can read, for example, Liu & Reed (1995). These researchers carefully designed a hypermedia system to support vocabulary learning around the videodisk *Citizen Kane*. All the media (video, audio, text) were carefully integrated, on-line contextual lexical helps were provided (including various types of linguistic knowledge, semantic networks), and indexing tools and map tools were added to help the learner navigate among the various parts of the system and the various kinds of information. Lastly instructional activities were also offered. A significant treatment (10 hours over a five weeks period) was administered. The sample (N = 63) and the design was appropriate to draw conclusions on the efficiency of vocabulary acquisition (over 80 words). But the authors had other aims in mind when designing the experiment. They studied two learning styles (field dependent and field independent) and showed that, provided that there were no statistically significant difference in the learning achievement of the groups, learners did make very different use of the resources provided by the system (Liu & Reed, 1994).

In fact what is at stake in the most interesting experiments is the study of individual differences and their role in or their effect on multimedia learning. For example, Chun & Plass (1996) when studying the visualizer/verbalizer preference on vocabulary acquisition present results that suggest that visualizers are more effective in using visual cues for remembering vocabulary information whereas verbalizers are more effective in using verbal cues.

It is a common issue to design experiments that try to discriminate between various media supports in lexical learning activities. It is interesting to comment on some of them which have been recently published and referred to on several occasions. Tripp & Roby (1994) sought to measure the effects of visual and auditory cues (metaphorical graphics, audio resources, illustrative graphics, etc.) on vocabulary recall in a hypermedia environment. Their results show that the audio factor (which consisted of the word being pronounced when a card was opened) did not contribute to learning. They then concluded that audio is not necessary in such learning situations. But the 120 vocabulary items were presented in isolation, with no context, with nothing but translations. Moreover, the authors did not control any subject factors.

In another study Svenconis (Svenconis & Kerst, 1995; Svenconis, 1994) carried out an experiment to evaluate the respective or combined influence on learning of lexical presentation of words in lists, in semantic maps and with or without sounds. Three independent variables were measured: the Semantic Structure, the Instructional Method, and the Sound Component. Semantic structure, the way in which the 3 groups of 24 words were associated was divided into Tightly Related (able to be defined by other terms in the same group, cf. figure 1), Moderately related, and Loosely Related (unable to be defined by other terms in the same group).

Instructional methods, the way the subjects were presented with the words, was divided into Semantic Mapping and Word Listing.

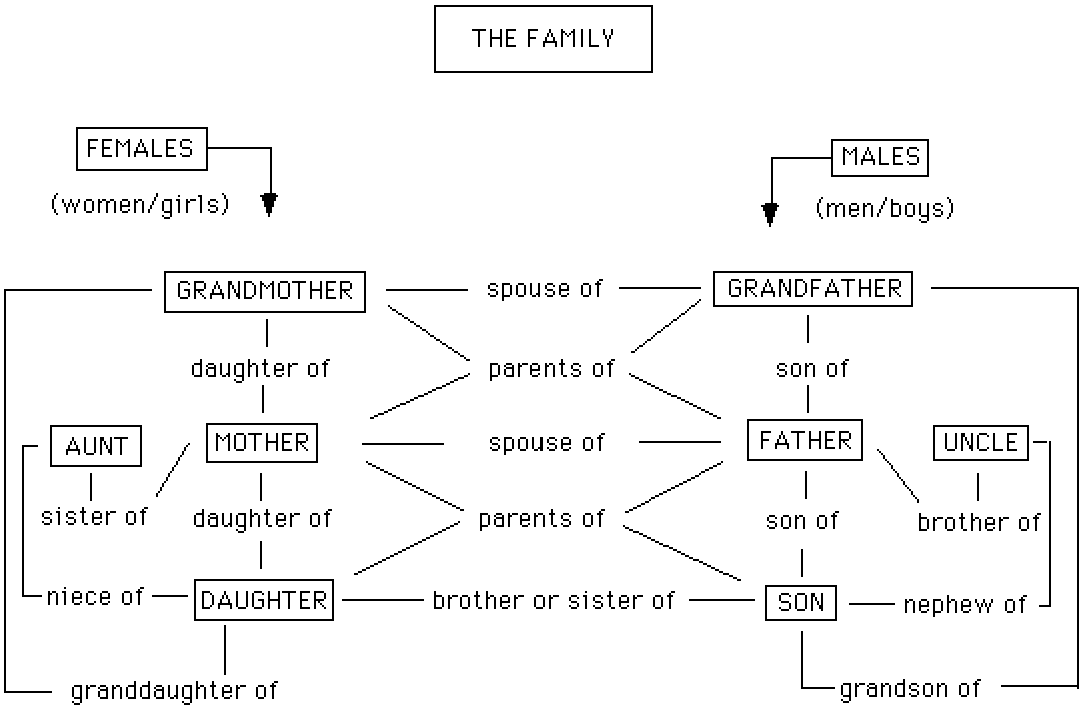

Figure 1: Semantic Map of "Tightly Related" Words in Svenconis' system

In the listing condition, each group of 24 words was presented alphabetically on the screen. In the mapping condition, the words were presented in the form of semantic maps that visually display the relationships among the words. The semantic map for the Tightly related words presented the graph of a family with nodes being words and links labelled with family relationships. The semantic map for the Loosely Related words presented another grouping of words involved in a family outing. Groups of words were arranged around one event and links between groups indicated the ordered events of the outing.

Learners (12 per group) were absolute beginners in the second language and were computer illiterate. After 15 minutes of mouse instruction, they had 22 minutes to "learn" the 24 words. Results of the tests completed in a follow-up session revealed that there was no significant main effect for methods. The highest scores were those of the method SemanticMappingWithSound, closely followed by WordListingWithoutSound! A rapid conclusion (which the author did not make) could be that assembling every kind of resource gives the best results, but that it is not worth doing it because the boring list of words are statistically as effective!

There are several problems in this experiment: firstly, details of the procedure (type of learners, of learning materials) show that it is pedagogically unsound, which means that, as in the previous experiment, learning cannot be really studied; secondly, individual factors have not been considered, thus preventing, even under better conditions, a determination of relative efficiency of the media for certain learners; thirdly, too many factors were being measured at the same time. For example, in order to answer the interesting question, initially set by the author, about the kind of proper model of semantic map that should be built to improve learning, it would have been interesting to set up an experiment based only on the Semantic Structure variable.

In other domains than language learning, external representations are also extensively studied. Cox & Brna (1995), for example, have developed a learning environment which offers several kinds of representations to help learners in reasoning. Their experiment showed that problem solving based on standard representation (versus representations drawn by the learner) is more efficient, but learners should have the choice of the representation depending on their individual differences (among which we again find the verbalizer/visualizer distinction).

Whereas it is possible in scientific domains to use standard representations and draw upon experiments, in language learning we cannot yet rely on such standard formats. In the next section, we will discuss criteria for evaluating the quality of a representation in vocabulary instruction.

3. CRITERIA FOR EVALUATING THE QUALITY OF A REPRESENTATION

Let us now focus our attention on visual information used in computer-assisted vocabulary tasks such as comprehending the meaning of a lexeme or finding the appropriate lexeme in production, or memorising a lexeme among a set of other already known lexemes. In all these tasks motion video is not interesting since the visual information has to relate several lexemes at a glance and display the graphemic form of lexemes. So we are looking for visual supports that are still images whether it is a photo, a drawing, or a diagram (a graphic being a special case of diagram).

In order to compare existing visual representations and compare them to textual representation, we need to define criteria:

- informationality: as Larkin & Simon (1987) put it, two representations are informationally equivalent if all the information in the one is also inferable from the other, and vice versa. In order to evaluate a representation one has to consider, for example, what kinds of relations it stresses among lexemes. The amount of information (including relations) is not the only criteria to consider: a representation which is discriminative (for example among meanings) may be much more informational than another which accumulates information and consequently prevents easy readability. In fact, informationality has to be related to computationality.
- computationality: the learner has to compute the information laid out in a representation in order to extract it. Processes such as search, recognition and inference have to be considered in comprehension and production tasks. Indirect processes leading to memorization have also to be taken into account when considering learning per se. Hence in order to appreciate the computationality of a representation one has to evaluate to what extent it supports the learner in processing easily, quickly and correctly. We can presume that easiness will facilitate learning. Quickness is an important factor stressed in research on dictionary usage: a learner rapidly gives up when the search is too long. Correctness should not be forgotten, because we will see that some representation may induce wrong inferences.
- extendibility: fluency is tightly related to the size of lexicons that a learner is able to handle: as regards the mental lexicon, it varies approximately from 2 000 words for low-level fluency to 20 000 for high level; and a usual learner dictionary covers more than 50 000 entries. Consequently a representation should be easily extendable. A straightforward way to fulfil this criteria when building a representation from a dictionary (or a lexical database) is to be able to automate the process.
- interactivity: conversely to the large size of the lexicons, the representation should offer appropriate restricted views on lexical information and interactive devices that let the learner circulate from one piece of representation to another and, if needed, to modify it.
- versatility: we call versatility the extent to which it is easy from one form of representation to access another form. For example, depending on the learner's preference, s/he may want to switch from a verbal to a visual representation, or vice versa. Or one kind of representation may be interactively completed by another type of information (such as textual information appearing in visual representations) in order to play on the positive effect of presenting both types of information.

After having defined criteria for evaluating representations, we will next consider existing representations.

4. EXISTING REPRESENTATIONS

The most widely used information systems where visual information lies beside textual are dictionaries (whether electronic or paper-based). We will consider them before CALL programs.

4.1. Paper and electronic dictionaries

Many books may be considered as the first hypermedia systems that ever existed: multimedia information (textual, still images), hypertextual organisation (notes, table of contents, references, index, cross-index, etc.). It is even more the case for paper dictionaries where a linear reading is not at all expected and where the variety of access paths to lexical units represents one of the key features of a dictionary. British lexicographers have, over the past few years, made outstanding achievements and invented new kinds of learner dictionaries, such as Collins Cobuild, Cambridge Word routes, Longman Activator, etc. (Bogaards, 1996). Besides improving the quality of the description of each lexical entry, they invented new ways of outlining the relationships between lexical entries. It is particularly striking when one looks at the new dictionary oriented towards production (such as the Longman Activator), where the reader can at a glance have all the various lexemes arranged around one concept. But these improvements only relate to textual information. Visual ones are still very traditional.

In paper dictionaries we mainly find three types of traditional visual information:

- Picture of one object: drawings of specific objects such as tools, animals, or plants, are often more comprehensible than a long definition. So a drawing is more informational than text, computationally efficient (it speeds up the comprehension and the recognition process), but very limited. It still only concerns concrete nouns.
- Encyclopaedic layout: such as the presentation of the various pieces of furniture in a bedroom. It may seem informational, because it is the only way to access the most frequent concrete nouns of one specific world knowledge domain, but the objects presented are prototypical. Thus you will only find hypernyms. If you are looking for the more specific name of an object belonging to class displayed, you will have to look somewhere else. But no access will be provided from where you are, except if there is another picture close to the first one displaying coordinates. If it is computationally limited, it is hardly extendable to other things than some concrete nouns. Versatility is often very limited: not many dictionaries index the lexical entry of a word and its display in an encyclopaedic picture.
- Semantic links in encyclopaedic pictures: the most common semantic relations are the co-hyponymy (such as a drawing with various kinds of beds) and the "part-of" (the display of the various parts of a body). The same comments can be made on this sort of representation as on the preceding one.

It is striking to realize that no progress has been made in this area of lexicography. There is a sort of covert assumption in this linguistic area to consider visual information as being only representation of the real world, hence restricted to a very small part of the lexicon, non linguistic, consequently not very interesting. We rarely find a visual representation of predicative nouns, like displaying in a table the relations and the words belonging to the human family . All the emphasis has been put on the quality of the layout of the textual information for synonyms, antonyms, hyponyms, troponyms, etc. Could the nature of the material support, here paper and ink, explain this limitation?

The same statement can be applied to electronic dictionaries. Relying on electronic hypertext facilities, they have mainly used hyperlinks. They have added natural language processing tools such as lemmatizers. From the multimedia standpoint they focus on the integration of oral information such as adding oral pronunciation of words or accessing words by typing phonetic transcriptions. This new type of verbal information is certainly useful for the learner, but no progress has been made on visual representation, although the electronic support offer many new possibilities.

The reason for that may be that we are not advanced enough in linguistic and psycholinguistic research. In electronic dictionaries, the textual information of lexical semantic relations is very limited: all kinds of synonyms are presented at the same time for nouns, and the presentation of intersective meanings between verbs is poor. The electronic dictionary WordNet (Miller & Fellbaum, 1992), for which the design started in the eighties, is still far in advance of the other ones, especially for their work on troponyms and the entailment relations for verbs.

4.2. CALL lexical environments

We have recalled the limited (but still necessary) part of the lexicon that can visualized when using pictures of the real world. So we will now focus our attention on semantic maps, where only words and relationships between words are represented.

A preliminary question is to wonder what kinds of semantic relationships are the most interesting. Comments expressed by learners in the Svenconis' system (Svenconis & Kerst, 1995) may help us find cues to the answer, even if they were extracted from a limited number of subjects (24 in this case). We mention the three kinds of semantic maps drawn: the tightly related, the moderately and the loosely related group of words. The percentages expressing the learner's preferences were 53 % for the tight group, 17% for the moderate one and 10% for the loose one. The first one (displaying the map of family) was based on predicative nouns, i.e. on linguistic relationships, and was consequently straightforward to design. However the last one (displaying events around an outing) was based on nonlinguistic world knowledge, representing the personal mental image of the designer. This non-standard presentation (and also non-extendable) may have come into conflict with the private learner's representation. We must here recall that the mental lexicon has a very idiosyncratic organisation. This form of representation may be of interest when linked to a text describing the family outing (which was not the case here) for supporting text comprehension, but it seems inappropriate in vocabulary learning per se. In fact linguistic relationships may be much more worth considering than other forms of ad hoc representations.

Bui (1989) presented several new types of representations of linguistic relations in what she called her Hyperlexicon environment:

- Analogical: the author stressed the need to help the user learn by analogy. For example in order to answer such questions as "Foot is to man as ___ to horse", the system could display two graphs based on part_of relations, one for man, another for horse and when the learner click on *foot* the system highlighted *hoof*.
- Applies_to links: in order to stress what she called "semantic nearness" she designed graphs to help the learner answer questions such as "What terms related to *eat* apply to horse?". Two is_a based graphs displayed hyponyms of *ingest* and LivingThing. When clicking on the nodes *eat* and *horse*, the system could compute the relationship and display the verb *graze*, also represented on the first network (by using a specialization link plus semantic constraints). One problem with this representation is its computationality: the learner may easily infer wrong things such as the fact that every time a horse ingests something it grazes (in a stable for example).
- Parametrized semantic views: here attention was paid to the usage relationship (from crude to formal and specialized) and to positive versus negative connotations. For example adjectives relating to death could be ordered on a linear scale starting from *croaked* (crude register) to *terminated* (specialized register). A two dimensional graph (one scale for usage, another for antonymy) located verbs expressing the various ways of hating or loving.

The first two representations are informationally interesting and rely on new kinds of interactivity. But they are computionally problematic (what is the formal meaning of "semantic nearness"?) and hardly extendable. The third one is also interesting because it is a way to display related meaning of adjectives and verbs. But its extendability supposes that we can rely on detailed linguistic scales. Bui said she was computing its representations from lexical databases, including the WordNet base. But no details were given on the coverage of its system (could her system automatically draw other representations out of her demo ones?) and she told nothing about the hypermedia editor which managed the drawing. The author may have been too ambitious in trying to tackle too many research issues at the same time. Bui did not tell whether she experimented these representations with learners.

CAMILLE is a hypermedia courseware for intermediate and advanced learners of French for specific purposes (Chanier, 1996a). The user can access, from the activities, lexical resources: a dictionary and a set of networks. From the scripts and the focus of activities in the software, we have selected the most important lexical fields, fields where many words occur and have closely related meanings. Our intention was to break down the linear description of words found in most dictionaries, i.e. we wanted to present a word:

- as a set of elements extracted from various sets which belongs to different contexts (a word may be an element of a derivational family of the dictionary, an element appearing in several networks, and an item of information in the culture book of the software). Thanks to hypertextual links, we gave easy access from one type of presentation of one word to another, i.e. from graphs to entries presented as text in the dictionary or to encyclopeadic-like entries in the culture book, and vice-versa.
- as having a meaning that can mainly be defined differentially, that is, relative to other words.

We have designed by hand networks of nouns, verbs or adjectives with the following principles in mind (see figure 2):

- Each network has a central concept (such as tenacity, dismissal, persuasion, job, etc.).
- Every edge is labelled and the number of labels (which symbolize semantic relations) is very limited. We used: antonymy, hyponymy (and its converse, the hypernymy), quasi-synonymy and a specific kind of magnifying function which relates words which have various degrees of intensity. The last three ones are represented in figure 2 (see section 5 for more details on the relations).
- Graphically gather words which are quasi-synonyms in order to reduce the number of links, nodes, and help the learner make inferences: ellipses which circumscribe words that have the same meaning; other words may be linked to a set of words (in an ellipse) or to isolated words.
- Outline word usage so as to prevent overgeneralisations: colours (displayed as grey-scaled in figure 2) divide the network into three areas according to the formal, informal, or colloquial registers.
- Link visual and textual information: from one node the user can access a corresponding lexical entry in the lexicon and vice-versa; when the user crosses over an icon which labels an edge, a pop-up window appears and explains the difference of meaning between the two nodes of the edge (see the pop-up window in the top right side of the main window in figure 2).

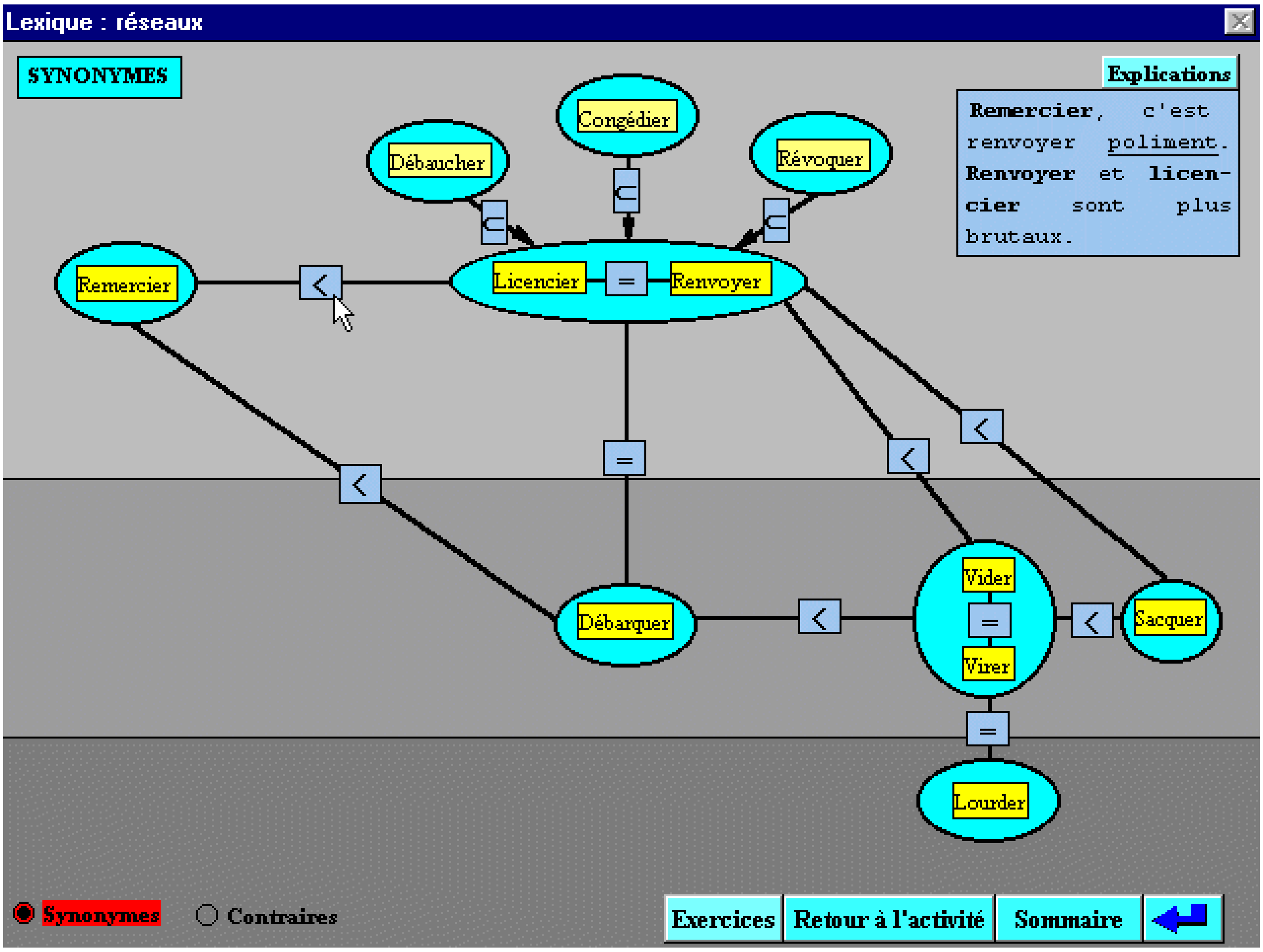

Figure 2: A partitioned lexical network built around the semantic field of Dismissal in the CAMILLE system.

From all the experiments we set up (formative, summative evaluations with learners extensively using every software - more than 20 hours per CD-ROM (Chanier, 1996b)) we always have had very positive comments and did not notice problems when interpreting networks. But it should be said that in our experiments lexical issues were secondary and we have not made detailed measures. We paid attention to the informational, computational and versatility criteria, but our design principles were not formal enough to let us automate the drawing. We still have had to narrow the linguistic field of investigation to get extendable representation as we will see in the ALEXIA system.

4.3. Private learner's representations

Instead of presenting to learners networks and graphics based on standard linguistic relations, one may wonder whether it is worth letting them freely draw on computers their own representations in the same way teachers invite learners to build private dictionaries by taking hand notes.

It is a difficult issue because not much research has been done on this subject. Goodfellow (1994) was one of the first CALL researchers to offer in his lexical learning environment the possibility to design a private dictionary by grouping words together. His idea was that when asking learners to group words, one comes close to their mental lexicon, which has an idiosyncratic structure. The interface was very simple, only offering the possibility to put words into lists and labelling every list with a head word. No graphic facilities were implemented. Experiments drawn on a limited number of subjects showed that this method could help in remembering words. But more extensive evaluations should be set up before drawing conclusions.

Another interesting approach has been taken by Buzan (1993) with Mindmap. He designed a procedure (which idea originated in the 70s) for taking notes by writing concepts and relating them in graphs. The Mindmap method can be used for hand note taking, but a computer program has also been implemented. It offers the advantage of letting the user separate his/her notes in several graphs, index one part of a graph to another, and reorganize every piece of the network easily at will. Experience proved that, even if the process appears at a first glance straightforward, users need to be extensively trained for composing such graphs. The author argues that several experiments proved that Mindmap is an efficient way of note taking; we are not aware of any application to CALL lexical learning.

A graphical approach such as Mindmap is worth considering because its formalism is flexible enough and it does not let the user invent from scratch his/her own format. The latter option seems to lead to nowhere as we mentioned in section 2 when referring to Cox & Brna's work (1995). A balance has to be discovered between presenting the learner a predefined format with reliable linguistic links and a flexible, easily manageable format that could let him/her represent an historical view of his/her private learning, which may be different from standard linguistic relations. Lacking more conclusive elements, we decided in the ALEXIA system to implement a private dictionary as Goodfellow did with no graphics, and to define visual lexical representations relying on linguistic grounds.

5. THE ALEXIA SYSTEM

Firstly, we will present the ALEXIA system and we will discuss the processed semantic relations. Then, we will show the features of the graphs and the possible interactions. We will finish with the presentation of the method of graph generation we have developed. In this section, an overview of the system will be given before detailing the lexical data of the general dictionary.

5.1. Presentation of the system

ALEXIA is a computer assisted lexical learning environment of French as a foreign language. It is composed of several units: a corpus of texts, a general dictionary, a personal dictionary and a lexical activities unit. It also comprises a learner's model which indicates how the learner uses the system so as to be able to follow the learner and to assess his/her learning (Chanier *et al*, 1995, Selva & Issac, 1996).

ALEXIA contains a corpus of approximately 400 texts available, all related to the field of work, employment and unemployment. We chose this field because most of the words belong to everyday vocabulary, they are not specialized and are mastered by every native. This corpus is only available for reading and is used for every piece of written comprehension work. We have also used it for the extraction of the most representative words and phrases of the field, that is, the most common words and phrases. In this paper, we will not develop the whole system but we will focus on the general dictionary. Firstly, we present the data from a lexicographic viewpoint, then the dictionary as it appears to learners and finally we develop the graphic representation.

5.2. Levels of description of the lexical units

In a text, the groups of letters enclosed by two blanks that we usually name *word* refer to a canonical form. Whenever the canonical form is unique (it may not be so, such as suis, first person present of être, *to be* and of suivre, *to follow*), this form, or label, can be described on three lexical levels.

Firstly, for instance in the metalanguage of the dictionaries, the canonical form labels all the homonyms of a word. For instance, "voler" actually refers to two words, one has dérober (*to steal*) as synonym, the other means être dans les airs (in this sense, voler can be translated by *to fly*). Secondly, also in the dictionaries, the canonical form labels a lexical item, that is, the polysemic word which can be considered as the sum of its meanings. This is the classical entry of a dictionary. A homonym is an entry. Then, the canonical form (abstracted from a group of letters in a text) labels the meaning of an entry, the lexeme. This is the sense of a word in an context-related utterance.

The lexical database is a glossary of about 200 entries which represents about 400 lexemes given the polysemy of the words. As entry, or lexical item, we consider "simple words", i.e., words enclosed by two blanks (ex: travail, *work*) or compounds and collocations (ex: travail au noir, *moonlighting*). For more details, see Selva & Issac (1996).

5.2.1. Nature of the lexical data

Each entry is described in the most exhaustive way in the lexical database. As an example, figure 3 gives an abbreviated version of the lexical entry for the verb diriger. This information is not displayed as such to the learner, but under various formats, in an interactive way, as we will see in sections 5.3 and 6. We have two kinds of information. Firstly, generic information concerning all the lexemes for diriger: part of speech, gender, written form, short phrase to discriminate between the homonyms, if there are any, and frequency in the French language. Secondly, specific information for each lexeme: meaning number (1, 2, etc.) and sub-meaning number (1a, 1b, 1c, etc.) if necessary, abridged and normal definition (written as a sentence), syntactical behaviour (mostly for verbs), semantic constraints on the arguments (human, non human, abstract, concrete, etc.), register, pointer (the number of the sentence) to a file of examples extracted from the corpus.

In addition, for every lexeme, we list the different semantic relations which link it to other lexemes: quasi-synonymy, hypernymy, hyponymy, intersective synonymy, antonymy, actancy (with the part of speech and the number of the argument of the actant), derivation (with the part of speech and the number of the argument of the derivative), lexical functions (see Mel'cuk, 1992).

```
% DIRIGER
part of speech: verb
gender: no
written form: "diriger"
homonym: no
frequency in French: 138

Meaning 1a: (to manage, to lead)
abridged definition: "contrôler une entreprise, une organisation, une opération"
definition: "lorsqu'on dirige une entreprise, une organisation ou une opération, on en est responsable, on la contrôle, on donne des ordres et on prend des décisions pour que le travail soit fait correctement"
syntax: n1,V,n2
constraints: n1 human
register: current
example:172
hyponym: être responsable de, être à la tête de, mener, gouverner, régir, administrer
intersective synonym: gérer
actant: (dirigeant,noun,1),(dirigeant,adjective,1)

Meaning 1b: (to be in charge of)
abridged definition: "contrôler un groupe de personne"
definition: "lorsqu'on dirige une personne ou un groupe de personne, on les commande, on leur dit ce qu'il faut faire"
syntax: n1,V,n2
constraints: n1 human, n2 human
register: current
example: 173
hyponym: commander, être responsable de, être à la tête de, mener
actant: (employé,noun,2),(ouvrier,noun,2)

Meaning 2: (to steer)
abridged definition: "conduire un véhicule"
...
quasi-synonym: conduire

...

Meaning 4b: (to direct against)
abridged definition: "orienter de manière hostile"
definition: "lorsqu'on dirige quelque chose contre quelqu'un, on l'oriente vers lui de manière hostile et agressive"
syntax: n1,V,n2,contre,n3
constraints: n1 human, n2 not human, n3 human
register: current
exemple: 177
```

Figure 3: abbreviated entry for diriger extracted from the lexical database

As the synonymy relations are the most developed ones in the database, and in order to dispel ambiguity, we detail properties of the following relations: quasi-synonymy, hypernymy and hyponymy, and intersective synonymy.

5.2.2. Quasi-synonymy

By quasi-synonymy, we mean the similarity of meanings of two lexemes. Two lexemes are quasi-synonyms if the substitution of one by the other in a sentence never changes its truth value. We use quasi-synonymy instead of true synonymy because there are always small differences between two lexemes: subtle differences of meaning, of use, of occurrence with other words, of syntactical behaviour, of connotation, etc.

Quasi-synonymic relations between entries are always dependent on a linguistic context. Indeed, two entries are never true synonyms in the absolute, i. e. in all contexts, but they are in specific ones. To take the example of the introduction to WordNet (Miller *et al*, 1993), plank and board are almost always substitutable in carpentry contexts, but in other contexts of board, such a substitution would be totally inappropriate. The context is generally given by the sentence. This constraint does not exist anymore when describing relations between lexemes, for the context is bound to be included in the meaning. However, when the context disappears as it is the case in the dictionaries, it has to be reintroduced by explicitly specifying which lexemes are quasi-synonyms. This rarely happens with French dictionaries (except the DEC, Mel'cuk, 1992). One of the specifications of ALEXIA is to systematically describe the semantic relations between lexemes instead of words as is done in other French dictionaries. From our point of view, this feature is particularly important for learners. Setting up quasi-synonymy between words instead of lexemes does nothing but lead to confusion.

5.2.3. Hypernymy and hyponymy

Hypernymy and hyponymy are two semantic relations which result from the hierarchical organization of the lexicon. A lexeme A is an hyponym of a lexeme B (or a lexeme B is an hypernym of a lexeme A) if the meaning of A is more specific than that of B, if all the features of B belong to A. Lexemes are linked by a "kind of" relation. For instance, carpenter is an hyponym of work and work is an hyponym of activity.

The hyper/hyponymy relation is quite obvious for nouns designing concrete objects. But as one considers more abstract lexemes than nouns, the relation is more difficult to make out. As to verbs, hyper/hyponymy appears to be more complex than for nouns. Indeed, verbs and nouns do not have the same features (Fellbaum, 1993) and, whereas the main relation of hyper/hyponymy is a "kind of" relation for nouns, it is entailment for verbs. Fellbaum shows that the entailment relation actually groups four lexical entailments. In ALEXIA, we mainly consider the troponymy relation: a verb A is a troponym of a verb B if you can say: "To A is to B in some particular manner". For instance, to discharge is to dismiss in some particular manner. Here "manner" has to be interpreted in a loose way which allows us many semantic interpretations.

Troponymy is a special case of entailment which involves temporal inclusion and co-extensiveness. This means that A entailing B, first, A occurs whenever B does (temporal inclusion), and in particular for troponymy, A and B share the same stretch of time, that is to say that the activities of A occur during those of B and vice versa (co-extensivity).

5.2.4. Intersective synonymy

Intersective synonymy is a relation between two lexemes which share only some of their features. Although there is an intersection of meaning, they cannot be considered as quasi-synonyms. For instance, profession (meaning *occupation*) and job (meaning *work*) are two intersective synonyms.

5.3. Lexical access and textual display

After this lexicographic presentation of the database, we now consider the way the system helps the learner to use the dictionary.

Firstly, the system takes the lexical access strategies into account by helping the learner to find the lexeme s/he is looking for in the dictionary. It guides the learner to the entry by considering homonymy and collocation problems. Then it presents all information of the entry in various textual displays and in different windows: abridged, selective (figure 4) and normal definitions, synonyms, antonyms, actancy, derivation, lexical functions, etc. For more details, see Selva & Chanier (1998).

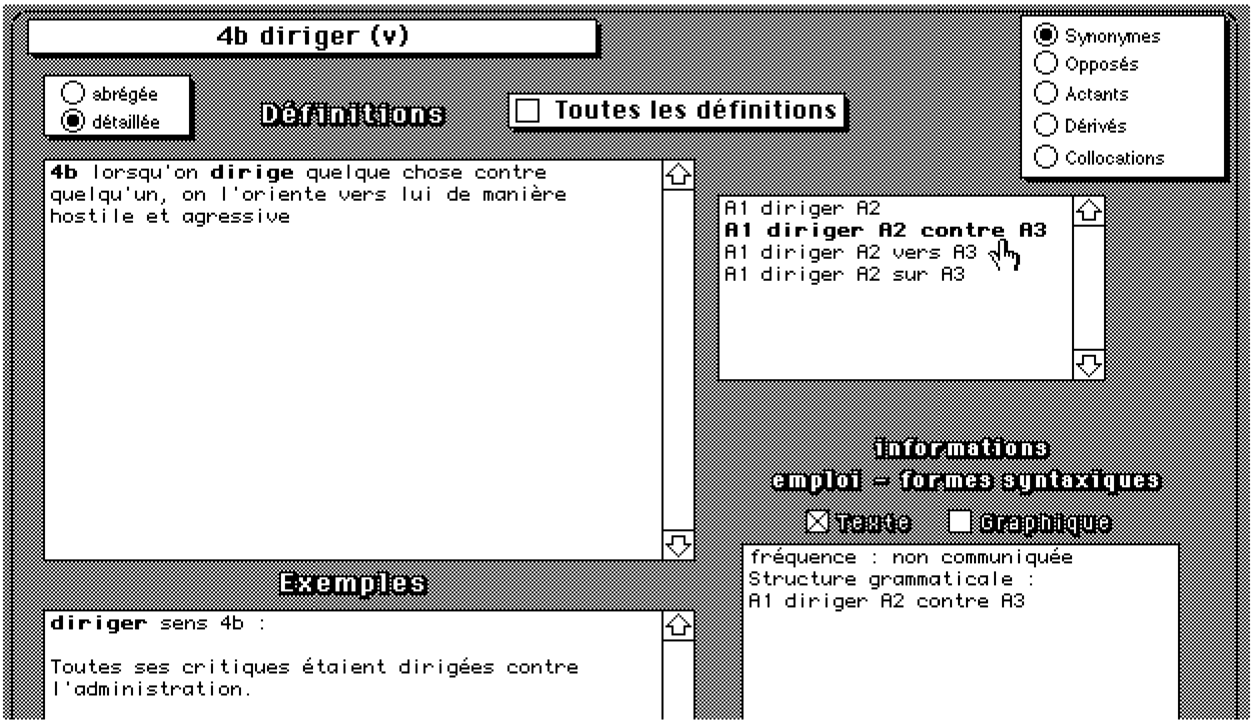

Figure 4: selective definition for the meaning 4b of diriger (*to direct against*) as it appears to the learner.

Beside a textual display, the system also allows the learner to see part of the information, such as synonyms, in a graphic way. We now discuss this point.

6. LEXICAL GRAPHS IN ALEXIA

We specify which semantic relations are processed by the graphs, then detail the properties of the lexical networks, and eventually see the constraints and limits of the display of these networks.

6.1. Grouping of the semantic relations processed by the graph

Although the semantic relations can be displayed separately, the semantic mapping of a lexeme will be made richer and more global by grouping the relations during the display according to their nature. Indeed, actors and derivatives of a lexeme can be displayed simultaneously, for the intersection between the set of actors and the set of derivatives is not empty (an actor may be a derivative).

Similarly, we can group the different kinds of synonymies together. Hypernymy, which is a broader synonymy, can be displayed with other synonymies. For instance, if one wants the synonyms for director, it seems quite natural to read chief somewhere. Indeed, I can replace director by chief in the sentence:

This morning the director explained his projects to us

Thus, we can present quasi-synonyms, hypernyms, hyponyms and intersective synonyms at the same time. We have four groups of relations: the group of synonymies, antonymy, actors-derivatives and lexical functions. In the textual interface of the ALEXIA general dictionary, all these relations are displayed. But at the present time, only the synonymies are processed by the graphs. They are the most developed relations in the database. Moreover, because of certain properties such as transitivity or equality, the presentation of the different synonyms of a lexeme is more convenient and more natural in the form of networks.

6.2. Properties of graphs

From a selected lexeme in the database, the system is able to automatically generate a graph showing all the lexemes linked to the first one by a kind of synonymy. The nodes of the network are the canonical written form of the lexeme plus its meaning number in the database. We put an ellipse around them in order to make them stand out better. Actually, every ellipse represents a semantic concept. The links are arrows with a symbol indicating the semantic relation (figure 5).

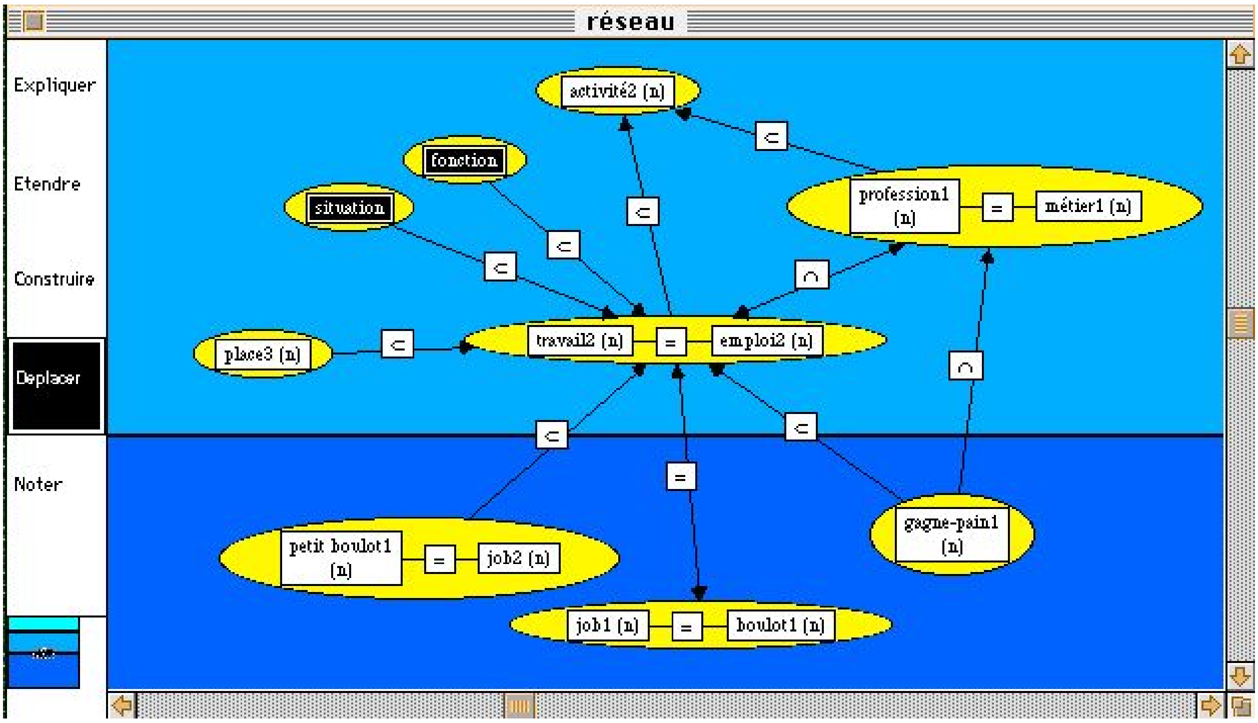

Figure 5: graph for emploi (*job*)

For quasi-synonymy (symbol =) and intersective synonymy (symbol ↔), the link is a double-arrow, for they are symmetric relations. Hypernymy and hyponymy, as they are asymmetrical and in opposition, share the same symbol (℘), for we just need to reverse the direction of the arrow to express either one or the other relation. By looking at figure 5, we can see that:

- travail and emploi are quasi-synonyms as well as profession and métier
- emploi is a kind of activité, i. e. activité is an hypernym of emploi
- profession is also a kind of activité
- emploi and profession are intersective synonyms. They share some features (related to the concept of work) but cannot be considered as quasi-synonyms[1].).
- situation and fonction, hyponyms of emploi, are in black, for they are only cited in the database and not described.

It is necessary to use symbols as regards the relations in order to keep the graph clear and to save space. There are few symbols and tests have shown that the learners have no trouble interpreting the graph in the right way. In terms of efficiency, a symbol is faster to interpret than a name or a paraphrase. It is important for the learner to know the register of a lexeme easily. For synonymy the context is essential and some lexemes, even if the sentence is semantically correct, may be too familiar in one context, or too formal for another. We decided to set up a gradation in the graph by grouping the lexemes according to their register. Thus, the most formal lexemes

[1] Indeed, in French, profession and métier are determined and defined activities whereas emploi and travail are not (un emploi de facteur but *un métier de facteur or le métier de facteur but *l'emploi de facteur. Depending on whether the first noun is determined or not, the correct phrase will include the definite or undefinite article.

will be at the top of the graph, and the most informal ones will be at the bottom. We created three zones (roughly *formal, current* and *informal*) and use colour to make the difference easier to see. Very quickly, the learner knows if he or she can or cannot use this word in a defined context.

In the graph of figure 5, we can see that:

- petit boulot, job (meaning 1 and 2 in the database), boulot and gagne-pain are informal

- job and boulot are quasi-synonyms

- boulot and travail are quasi-synonyms but in different registers (normally marked with different shades of blue and not in a grey scale).

6.3. Size and limits in the display of the networks

Due to the size of the network, we cannot display it totally and we have to display a local part of it around the selected lexeme. But where should we stop the display? Because of the transitivity of the synonymy the network around a lexeme may be very large and ideally the borders are those of the network itself. In practice, the display of level 2 of the synonyms of a lexeme (i. e. the synonyms of the synonyms of a lexeme) appeared in certain cases to provide too much information, which is detrimental to comprehension. Moreover the computation of all the lexemes takes too much time. The display of order 2 needs studies of disposition and optimization of the calculations. At the present time, the system only displays the direct synonyms of a lexeme. However, we can make a special treatment with quasi-synonymy. Indeed, when two lexemes are quasi-synonyms, they express (roughly) the same meaning and can be grouped in the same ellipse. This grouping allows us to decrease the complexity of the graph while displaying more information. By convention, grouping is not possible when the lexemes do not share the same register.

A computational representation need not be frozen. With computers, we can act precisely on the information and on the presentation mode (interactivity and computationality criteria). We will now detail the possible interaction of the learner with the system.

7. INTERACTIVITY

The main possibilities are, at the present time: giving explanations on every part of the graph (lexemes, relations, zones); moving around on the network; moving arrows and ellipses if the graph is not clear.

The third possibility is fairly obvious. When there are a lot of lexemes or relations on a graph, there may be intersection of arrows or superimposing of several nodes. Indeed, the complexity of a graph grows with the number of the graphical items and a clear presentation requires sophisticated algorithms and a long time for calculations. For the time being the user can get a clear presentation by a simple drag and drop on the nodes of the network.

We now detail the first and second possibility.

7.1. Explanations

The most obvious interaction is the possibility to have both the definition and an example of a lexeme by clicking on it. This is an important feature, for, whereas definitions and examples are necessary for comprehension, it is useless to display them permanently on the graph (instead of having it on request). This relates to the informationality criteria (information and clarity). A future step will be the connection of the graph with the whole dictionary. This will allow the learner to choose between a graphic and a textual representation of the lexical data of the dictionary (versatility criteria) and to pick up all the information on the lexeme or on the corresponding entry he or she selected.

When studying synonymic relations between close words, it is interesting to be able to compare the definitions of both lexemes in order to make out the nuances of their meaning and use. This information can be obtained by clicking on the symbol of a relation. The explanations given can help the user to understand the differences between two lexemes. The system also gives explanations on a register when clicking on its zone. This feature is mostly for new users who are not accustomed to the system.

7.2. Moving around on the network

One can go all over the network by rebuilding the graph on another lexeme. Suppose you want to know how to name a person at the head of a company. You can begin by displaying the graph for chef (*chief*) (figure 6)

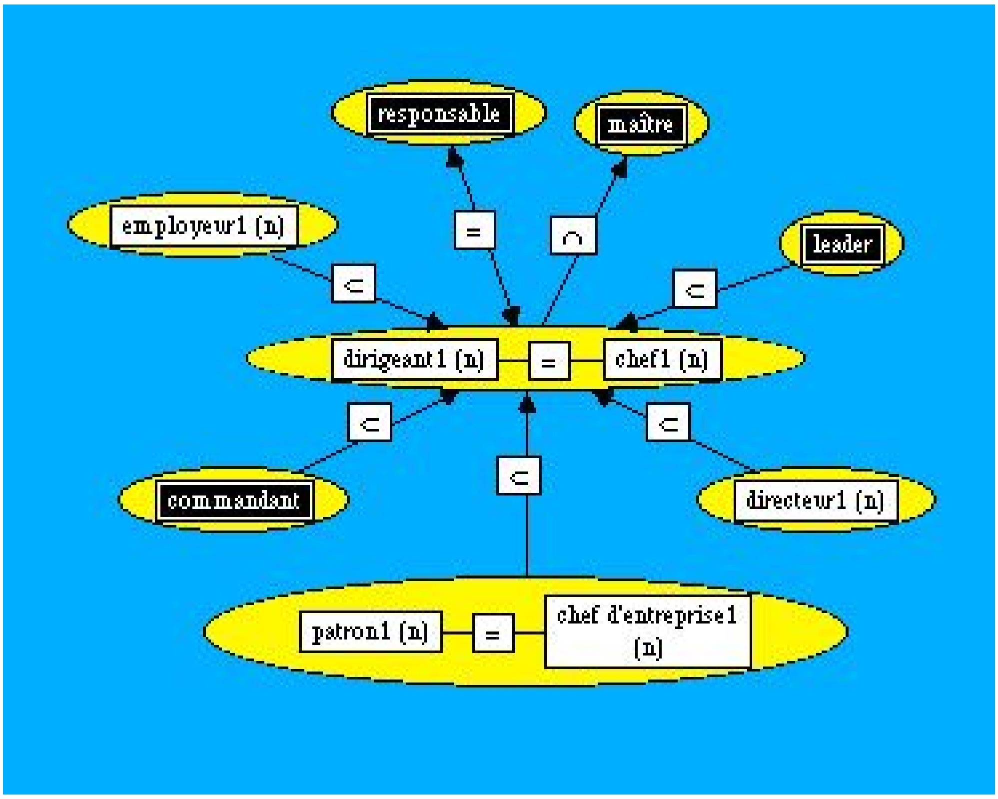

Figure 6: graph for chef (*chief*)

As hyponym of chef, you read patron (*manager*) (or chef d'entreprise, *chief of company*) which is what you want. But if you want more details (for instance, are there other words for patron, are there kinds of patron?), you can rebuild the net around patron (figure 7). Then boss appears (informal word for patron), which is maybe closer to what you were looking for. You also discover there are kinds of patron, for instance industriel *(industrialist).*

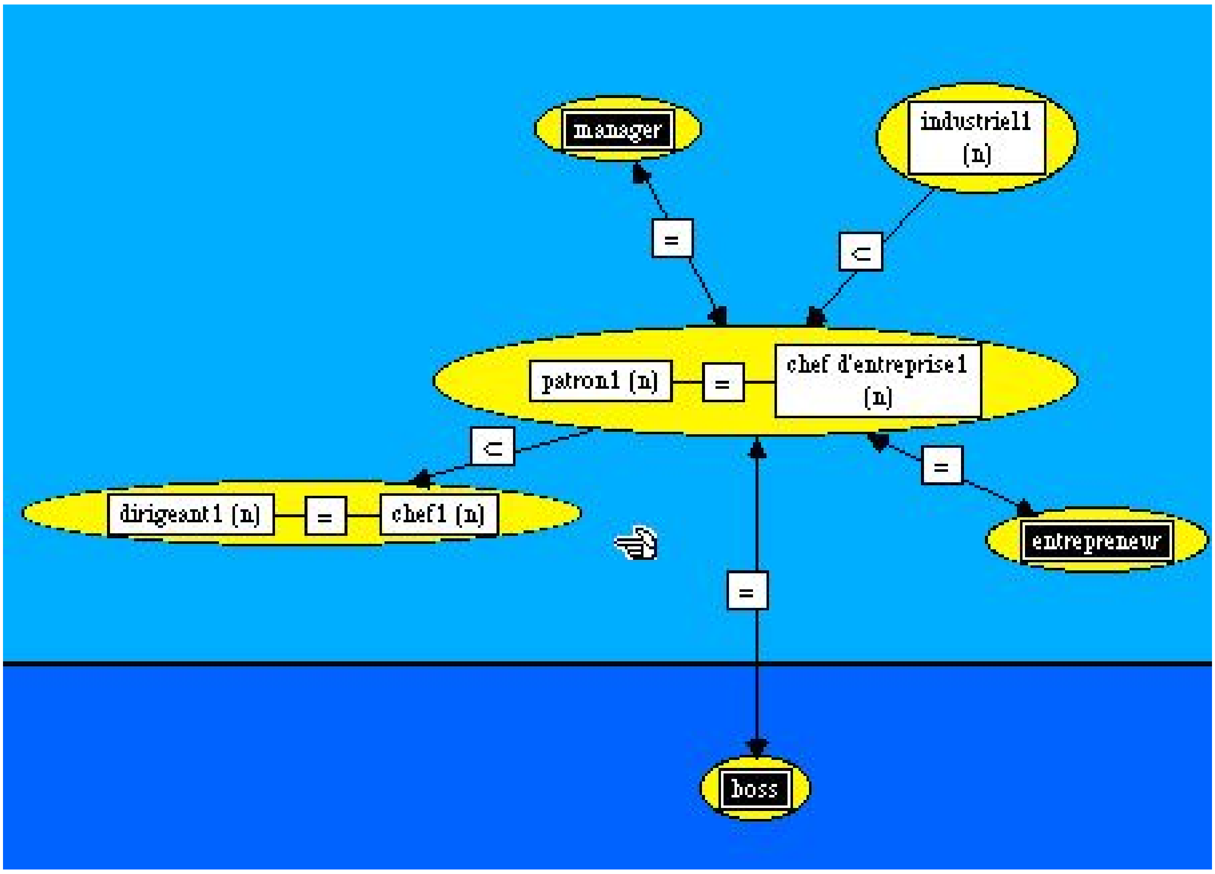

Figure 7: graph for patron (*manager*)

In a production stage, it is very convenient to come and go from one lexeme to another one following the meaning you want to express. For each lexeme, the user can easily and quickly see what the nearest meanings are. In a textual display, as the words are followed by their definition, more attention is needed to separate them from the text than a direct look at a graph. This graphic way of moving from one concept to another one can be regarded as another way of using a dictionary. It allows the user to have a good understanding of the meaning of a lexeme and is more intuitive than a glance through an alphabetical list in which only chance and convention determined word order. Indeed, as Miller (Miller *et al*, 1993) outlines it, this way of graphic moving is much closer to the mental lexicon because of the semantic associations between concepts.

8. COMPUTER IMPLEMENTATION

The method for automatically generating graphs was developed from scratch (Pichon, 1996), since no existing algorithm for computing graphs could generate a network with the above features. The construction of the graph is preceded by an extraction stage. Indeed, we need first to determine the synonyms of the selected lexeme to display. The program goes over the database and calculates synonyms by reflexivity and transitivity. The display of the graph follows a five stage algorithm which calculates the coordinates for every lexeme. The goal consists in displaying a lexeme L and its synonyms, its neighbours N_i. By convention, L is at the middle of the graph and the N_i are placed around it.

1) The program classifies the N_i in three groups, according to their register. Some groups may be empty.
2) According to the number of neighbours in each register, the program calculates the angular sector to reserve for every register. The more neighbours a register contains, the larger the reserved sector is.

3) For every register, the program calculates the weight of every lexeme and allocates a sector to it. Then, it calculates each tendency and orders the lexemes in a list according to their tendency. It is a recursive function but, since we just need synonyms of synonyms, recursivity stops at Level = 2. Definitions of weight and tendency are given in appendix 1.

4) The program distributes the neighbours group by group around L, by giving them an angular position. The first neighbour is placed below L (angle - $\pi/2$). Then, we go back to the top on the left or on the right of L, and give an angular position for every neighbour according to the space left, the calculated weights and tendencies and the links between neighbours (which have to be considered before the tendencies). The program has to place neighbours alternatively on the left and on the right of L so that the graph is well-balanced and the nodes are harmoniously arranged around L (figure 8).

5) The program calculates a radius for every neighbour, depending on the number of registers which separate them. This fixed value is modified if necessary so that the nodes do not overlap.

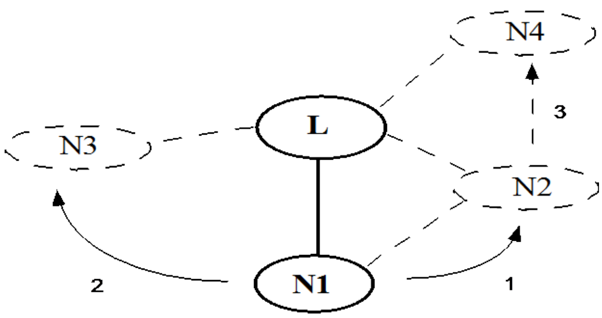

Figure 8: Order of arrangement of the nodes around L

9. CONCLUSIONS

When presenting cognitive-based arguments which could support the use of multimedia aids for vocabulary learning we referred to two different approaches: the first one postulates the existence of two separate information systems, verbal and nonverbal, which are simultaneously called upon when processing vocabulary data, and the second one stresses the network structure of the mental lexicon. These approaches only offer a general framework but no direct way of applying multimedia in lexical learning. We recalled the various research issues which are currently investigated, or at least stressed.

We then examined to what extent CALL experiments provide answers to any of these issues. Giving evidence of the efficiency of hypermedia as an effective learning tool is not a problem. Several experiments which tried to measure more detailed things, such as the use of various media or graphic representations are not reliable. In fact people tried to give a definite answer either pro or con multimedia in lexical CALL by setting experiments with learners without having clearly defined the kinds of representation they were looking at.

In order to approach the question in a more useful way, we have proposed criteria for evaluating the quality of a visual representation in a lexical environment. These criteria can be used in a preliminary step when considering existing representations and before thinking of setting up any experiment with learners. We then examined visual representations in paper and electronic dictionaries and in CALL environments. On these supports a kind of confusion has been made between multimedia and nonverbal knowledge. Hence visual representations are scarce and limited to concrete words. One way to extend multimedia in lexical learning is to rely on linguistic knowledge and build lexical networks. The design of such networks is of particular interest if we want to build representations which can easily be interpretable by learners. In order to cover a significant part of the lexicon they also need to be computational and extendable. Developing such representations and algorithms is still a research issue.

The network module in the ALEXIA system offers partial answers to this problem. We showed the main features of the graphic display by describing the possible interactions and explained the method of graph generation by outlining the linguistic and computational difficulties. As we have seen, the program only displays the direct synonyms of a lexeme. In certain cases, it could be interesting to display more lexemes such as synonyms of order 2. But the complexity of the graph increases and constraints such as avoiding intersection of the arcs become difficult to respect. These constraints certainly require new algorithms of placement of the lexemes. Another possible development is the display of other semantic relations than synonymies such as antonymy, actancy or derivation. This has to be done but the complexity of relations such as antonymy (for instance antonyms can be exclusive, can follow a gradation, etc.) demands more linguistic and computional works.

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APPENDIX 1 (cf. section 8)

The <u>weight</u> of a node N (compared to another one L) is its bulk. It depends on the size of the label (length of the written form of the lexeme) and on the number of quasi-synonyms to display in the same ellipse. The formule is given by the recursive function *Weight*. Given N, a neighbour, L, the lexeme, Lev, the level of transitivity (Level 1 mean synonyms of the lexeme, Level 2 means synonym of synonyms, etc.) and M_1, M_2,..., M_i,..., M_n the neighbours of N:

$$\text{Weight(N,L,Lev)} = \text{Area(N)} * n^2 + \frac{\sum \text{Weight}(M_i, N, Lev+1)}{5^{Lev}}$$

$$\text{Weight}(N_0, L_0) = \frac{\text{Weight}(N_0, L_0, 1)}{1000} + 10$$

The <u>tendency</u> of a node N (compared to another one L) is a heuristic value determining what could be a good direction for N so that its arc with L does not intersect with another one when N is linked with a node in another register (figure 9). If the arc has rather to be drawn towards the bottom, the tendency will be rather negative. The tendency is given by the recursive function *Tend*.

$$\mathrm{Tend(N,L,Lev)} = \mathrm{TendL(N,L)} + \frac{\sum \mathrm{Tend}(M_i, \mathrm{N,Lev}+1)}{5^{\mathrm{Lev}}}$$

$$\mathrm{Tend}(N_0,L_0) = \mathrm{Tend}(N_0,L_0,1)$$

where *TendL* is a value depending on the register of N and L. For instance, TendL(N,L) = 0 if N and L have the same register but TendL(N,L) = +50 if N is in the high zone register and L in the low zone register.

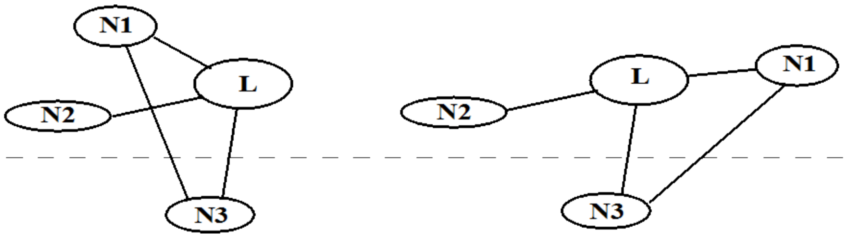

Figure 9: Incorrect value for tendency of N1 on the left, correct on the right