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Encapsulation and prospection in written scientific English

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ABSTRACT

The aim of this article is to present a study of the textual organisation of scientific discourse in English. In order to carry out this study, several articles from the journal "Scientific American" were analysed. The main unit of analysis was the sentence and the purpose of the analysis was to discover the linguistic means for creating text out of sentences, i.e. how textual unity is reached. The analysis carried out revealed that the sequential organisation of the text, one sentence after the other is created by mentioning previous entities, but the hierarchical organisation of the text is achieved by means of "encapsulation" and "prospection". The purpose of this article is to present the different linguistic realizations of encapsulation and prospection in the scientific texts analysed. Textual nouns, nominalizations, pronouns and devices known as "metadiscourse" function in the text by integrating "content" into "discourse as interaction".

1. INTRODUCTION

The purpose of this article is to present a study of the organisation of written scientific discourse based on Sinclair's model of text structure and his notions of encapsulation and prospection (Sinclair, 1993; 1994). This study will attempt to show how encapsulation and prospection help to organise scientific written discourse and create the hierarchical organisation of the text. Encapsulation is the means of recovering what has been previously said in order to add what is new. Prospection refers to the anticipation by the writer of what he or she is going to say next.

Apart from Sinclair's notions of encapsulation and prospection, this study follows his idea of the condition of the text as composed of two planes, the autonomous plane and the interactive plane (Sinclair, 1985: 20-21). The autonomous plane concerns the information included in the text, what is being said in the text. The interactive plane refers to the act of communicating, to the fact that the utterer is always implicit in the text telling something to the receiver. In some cases, for example, when reporting, the utterer appears explicitly. Some expressions, such as "obviously" or "I understand", are a signal that indicates the presence of the utterer. The written texts analysed show that encapsulation and prospection are the means of integrating the autonomous plane into the interactive plane.

2. SINCLAIR'S APPROACH TO WRITTEN DISCOURSE STRUCTURE

According to Sinclair (1993: 7) the structure of written text is created by each new sentence: "There is support in the details of text organisation for the view that each new sentence takes over the status of "state of the text", and therefore that the previous sentence relinquishes that role". In fact, Sinclair (1993, 8) states that "our hypothesis is that there is an underlying structure to discourse where each new sentence makes reference to the previous one, and encapsulates the previous sentence in an act of reference". Later on, Sinclair (1994:18) develops this theory and makes the hypothesis that the text contains everything a reader needs in order to understand. Therefore, it encapsulates what has been previously said converting it into shared knowledge and prepares the reader for what goes next. Sinclair explains that encapsulation "reclassifies a previous sentence by "demoting" it into an element of the structure of the new sentence" (Sinclair, 1993: 8). Prospection (Sinclair, 1993: 12), on the contrary, "...occurs where the phrasing of a sentence leads the addressee to expect something specific in the next sentence".

Sinclair (1993) claims that these "global acts of reference" are the ones that create the cohesion of the text and actually lead to the perception of coherence. Sinclair (1993:8) also states that this kind of relation between sentences is different from Halliday and Hasan's notion of "cohesion", which he calls "point-to-point cohesion", since it only establishes relations between the words in the text. For example, a pronoun can be related back to a noun phrase earlier in the text. By contrast, there is a second type of cohesion which deals only with sentences as a whole and is responsible for the organization of the text[1]. This second process of cohesion is the one that is created by means of encapsulation and prospection. These two mechanisms connect each new sentence in the text by either relating it to previous sentences or to following ones.

3. SCOPE OF THE STUDY AND METHOD OF ANALYSIS OF THE DATA

This study of encapsulation and prospection in scientific discourse in English is part of a wider study of cohesion and coherence in scientific discourse which involved the analysis of six articles from the journal *Scientific American* with a total of 22,800 words. In order to carry out this analysis, a total of 1,030 sentences were numbered and classified according to the cohesion mechanism present in each one. In the examples given the first number before the sentence signals the number of the text and the second number refers to the specific sentence in that text. By classifying all the sentences in the texts analysed, it was possible for me to develop a typology of the linguistic realization of encapsulation and prospection in scientific articles.

4. ENCAPSULATION IN SCIENTIFIC DISCOURSE

The study carried out reveals that in the scientific texts analysed encapsulation is used to retrieve what has already been said, but does not necessarily involve only the previous sentence. It is frequent for an encapsulation to cover more than one sentence as in the following example where "this idea" in sentence 99 encapsulates both sentences 97 and 98. The idea implemented by the team of scientists mentioned in sentence 99 is that of eliminating "jamming" by means of an arrangement of tunnel junctions:

(1) (6.97) **One of the simplest ways to eliminate the jamming is to connect several tunnel junctions in series (end to end).** (6.98) **In such an arrangement the junctions defend one another from the fluctuations.** (6.99) THIS IDEA was implemented in 1989 by a team of Swedish and Soviet scientists.

However, in the next example, the word "reactivity" in sentence 13 only recovers the last part of sentence 12:

(2) (1.12) Other properties stem from clusters' unfilled electronic bonding capability, which leaves them "naked" and **hence extremely reactive**. (1.13) THIS REACTIVITY makes them effective tools for the study of the solid state and, potentially, for such industrial processes as the growing of crystals, selective chemical catalysis and the creation of entirely new materials with made-to-order electronic, magnetic and optical properties.

Therefore the extent of an encapsulation may vary from a previous clause to several sentences or even a paragraph as in the following example where the noun in sentence 4, "dream" encapsulates the whole previous paragraph.

(3) (5.1) Investigators have long dreamed of building an optical computer.

(5.2) Electronic switches and circuits would be replaced by a network of light through which individual impulses carry and process information.

(5.3) The idea is not only aesthetically appealing but also offers the promise of a machine that would be even faster and more versatile than the most powerful computer in use today.

(5.4) The realization of THE DREAM, however, has been thwarted by the lack of sufficiently tiny optical-signal processing devices. (5.5) Like its electronic counterpart, the transistor, the basic building block of any optical processing or communications system must operate at low power and at high speed, and to do so it must be small. (5.6) In the microelectronics industry, transistors having dimensions smaller than a micron (a millionth of a meter) are now routinely fabricated in numbers approaching tens of millions on a single semiconductor chip. (5.7) Compared with this astonishing feat, the miniaturization of optical devices has lagged considerably.

The "dream" mentioned in sentence 4 is "building an optical computer", information given in sentence 1 and explained in both sentences 2 and 3. Sentence 2 is an explanation of what an optical computer is and sentence 3 encapsulates both sentences 1 and 2 as "the idea" mentioned is that of building an optical computer.

Encapsulation in texts does not only vary in scope. The linguistic realization may also be different. In these previous examples, the encapsulation was realized by means of a noun, although example 2 would be classified as an instance of a nominalization. Apart from nouns, there are several other means of encapsulating previous text. These other means are a) nominalizations; b) pronouns; c) adverbs; and d) implicit encapsulation. Let us see how they work in the texts analysed.

4.1. Encapsulation by means of nouns

The kind of nouns that are used for encapsulating previous text have been studied by several authors and have received different names. Francis (1986) called them "anaphoric nouns" because they look backwards to retrieve what

has been said previously in the text. Later (Francis, 1994) referred to them by using the expression "discourse labels" because they can be described as "metalinguistic" nouns. In this study she classifies these nouns into two categories: “advance” and “retrospective” labels, which clearly correspond to “prospection” and “encapsulation” (1994: 83). She studies the kind of “metalinguistic” nouns that can operate as such and classifies them into “illocutionary” nouns, “language activity” nouns, “mental process” nouns and “text” nouns[2]. Other authors who have dealt with these types of nouns are Tadros (1994) and Goutsos (1996).

Among the nouns that can be included here we find words such as "problem", "difference", "phenomenon", "task", "case", "concept" and “principle”. What makes these types of nouns special is that their meaning is not an entity in the real world, but something that has been mentioned previously as in the next example where the principle in sentence 48 is that expressed in sentence 45:

(4) (3.45) **One might stop scattering altogether by shortening the critical pathways to less than the average distance between electron collisions.**

(3.46) That would ensure that most electrons hurtle through the critical switching area on ballistic paths (3.47) [see "ballistic electrons in semiconductors," by Mordehai Heiblum and Lester F. Eastman; Scientific American, February, 1987]. (3.48) But practical application of THIS PRINCIPLE is not expected until years after the more conventional Gallium Arsenide transistors have found their place on the technological menu.

The nouns used for encapsulation found in the texts analysed are the following:

achievement - adjustment - advantage - approach - architecture - arrangement - attribute - breakthrough - case - concept - conclusion - configuration - constraint - curve - degree - description - development - difference - discovery - distinction - effect - effort - end - experiment - feat - figure - focus - function - idea - issue - limit - logic - margin - mechanism - organisation - phenomenon - prediction - principle - problem - procedure - process - property - quality - range - rate - reason - requirement - result - scale - speed - stage - strategy - structure - study - task - technique - technology - venture - way - work.

Due to their nature and way of functioning in texts, I prefer to call these nouns “textual nouns” since they are used to encapsulate previous text or, as we shall see later on, also to prospect. But there is another important role for many of these nouns and this is their evaluative function[3]. Many of the encapsulating nouns are evaluators themselves, but more often than not they are also accompanied by an adjective which intensifies this evaluative function.

(5) (5.6) **In the microelectronics industry, transistors having dimensions smaller than a micron (a millionth of a meter) are now routinely fabricated in numbers approaching tens of millions on a single semiconductor chip.** (5.7) Compared with THIS ASTONISHING FEAT, the miniaturization of optical devices has lagged considerably.

But this is not the only way to show its evaluating function. In the following example it is possible to see how encapsulation allows the evaluation by means of an attributive construction.

(6) (24) Because gallium arsenide consumes less power, **it produces less waste heat that must be drawn from the circuit.** (25) THIS QUALITY is particularly valuable because there is a trade-off between a semiconductor's speed and power.

4.2. Encapsulation by means of nominalization

Nominalization is a phenomenon that has already been studied by systemicists and its role has been mainly linked to the distinction between theme and rheme. Halliday has mentioned its importance in the creation of scientific text (Halliday, 1988:168-169). Downing (1997) has studied its role in encapsulating discourse topics in journalism. Martin (1993:227) has stressed its importance in the creation of technical terms.

By means of an encapsulating nominalization, a verbal process, an attribute or a circumstance is turned into an entity participating in another process as in the following example:

(7) (2.29) It sweeps the clusters along into an evacuated chamber, where the pressure differential causes **the spray to expand supersonically.** (2.30) Collisions that take place during THE EXPANSION cool the clusters to a temperature near absolute zero, stabilizing them for further study."

In this example, "the expansion" in sentence 30 encapsulates the clause signalled in bold and so the participant and the circumstance involved in the process which were explicit in sentence 29 are now implicit and "the expansion" in sentence 30 must be interpreted as "the supersonic expansion of the spray".

The texts analysed reveal that an encapsulating nominalization works differently to an encapsulating non-derived nominal. In fact, nominalizations encapsulate shorter stretches of text and only immediately previous information as the following example shows:

(8) (2.76) These metals show cluster frequency peaks at **the sizes that are predicted by a quantum model for a spherically symmetrical body with shared electrons.** (2.77) THE PREDICTIONS closely resemble magic numbers derived from the quantum model of atomic nuclei and are similar in some respects to the electron shells calculated for the hydrogen atom.

For this reason, nominalization is considered to be another type of encapsulating device, different from textual nouns. The instances of nominalization found in *Scientific American* reveal that it is closer to the surface of the text than encapsulating textual nouns. A nominalization usually corresponds to the verbal process mentioned in the previous sentence as in the following example in which the subject of each sentence recovers the information given in the previous sentence:

(9) (5.92) Hence, **the intensity of the reflected beam oscillates in time** as successive layers are grown. (5.93) Accurate measurement of THE FREQUENCY OF THE OSCILLATION **can precisely determine the time to deposit a single layer of atoms.** (5.94) THE RESULTING EXACT KNOWLEDGE OF THE DEPOSITION RATE can then be used to strictly control the layer's thickness.

Even when the sentence is a complex one, nominalization recovers just the previous clause, as in this other example:

(10) (1.73) Hence when a layer of AlGaAs thinner than 200 angstroms is sandwiched between two pieces of doped GaAs, **the electrons tunnel through it to the GaAs on the other side.** (1.74) THIS TUNNELING is one kind of quantum effect.

It is important to note that not every nominalization found in a text has an encapsulating function. In the texts analysed, there are many cases of nominalizations that do not encapsulate previous text. They refer to scientific phenomena or processes that are expressed by means of a nominalization (Wignell *et al.* 1993: 146) as in the following examples:

(11) (1.75) When barriers confine electrons within a space comparable to an electron wavelength, the electrons are subject to two other, interrelated quantum effects: SIZE QUANTIZATION AND RESONANCE. (1.76) SIZE QUANTIZATION causes the continuum of energy levels that usually exists in the conduction band of a solid to become articulated into discrete energy quanta, or states.

(12) (4.15) The retina, in contrast, contains five layers of cells, through which information flows both vertically from one layer to the next, and horizon-

tally (among neighboring cells in the same layer). (4.16) The SENSING of photons and the PROCESSING of the information they contain are inextricably combined.

"Size quantization" and "resonance" are the words used to refer to those effects and "sensing" and "processing" are two actions affecting the photons and the information mentioned in sentence 16. These nominalizations do not encapsulate previous text. In fact, in example 11, they are the topics being introduced.

4.3. Encapsulating pronouns

Halliday and Hasan (1976: 52) referred to this way of encapsulating pronouns in text as either "extended reference" or "text reference". Later studies of the encapsulating role of pronouns attempted to make a tentative hypothesis as to the different function of "it", "this" and "that" (McCarthy, 1994). The study undertaken reveals that for this scientific genre it is possible to reach some conclusions concerning the use of pronouns in the text.

The only pronouns that have an encapsulating function are singular demonstrative pronouns and the instances found in these texts always encapsulate just the preceding sentence. The most frequent pronoun is "this" which is generally placed in the theme of the sentence and acts as a subject, as in the following example:

(13) (7.21) But **the metals with the higher transition temperatures could usually be made in clusters of only three to five atoms.** (7.22) THIS made it impossible to determine how many atoms were required for the emergence of properties more like a solid and less like a cluster.

However, "this" does not always appear in the theme of the sentence:

(14) (2.97) **At some voltage the Fermi level of the emitter will attain the same energy as one of the energy levels in the dot, and electrons will move into and resonate within the dot.** (2.98) There is a single voltage at which THIS occurs;

"This" is not the only encapsulating demonstrative. It is also possible to find the pronoun "that" as in the following example, but the following and another case are the only instances in all the texts analysed where it occurs:

(15) (3.203) My colleagues in the advanced gallium arsenide technology laboratory and other IBM facilities, working at three centers in New York

> State and one in Switzerland, recently built and packaged a trio of chips that transmit one billion bits per second. (3.204) None of this speed will go to waste: (3.205) **transmission links must be about 10 times faster than the computers they connect.** (3.206) THAT is because the links transmit data in series, whereas computers process data in eight-bit batches, or bytes (with two bits added to check for errors in transmission)".

The analysis undertaken reveals that the pronoun "it" never encapsulates previous text. The uses of this pronoun in the texts analysed can be of two types. It retrieves entities mentioned previously or it forms part of an extraposition.

4.4. Encapsulation by means of adverbs

The use of adverbs to encapsulate previous text has already been mentioned by other authors. Halliday & Hasan (1976:74-75) signal the encapsulating power of "then". Concerning the Spanish language, Bello mentions the use of the Spanish adverb "así" to encapsulate previous questions (Bello, 1981: 303).

In the sample texts analysed, the adverbs acting as encapsulators are "here", "thus" and "so". These adverbs can encapsulate stretches of text of different length, but they are generally used to refer to information that has appeared in the previous sentence as in the following example where the adverb "here" in sentence 82 encapsulates a circumstance of the immediately preceding sentence:

(16) (2.81) Bonds seem to be more localized in **clusters of main-group metals such as lead and antimony.** (2.82) HERE the outermost electrons occupy the p orbitals, which are spatially more constricted.

(17) (2.110) Catalysis begins when the surface of a catalyst adsorbs, say, molecules of carbon monoxide and nitrogen oxide. (2.111) **These molecules then drift to «active sites» where bonds are broken and reformed, say to nitrogen and carbon dioxide.** (2.112) The molecules THUS produced are desorbed, and the catalyst is freed to repeat the process.

It is interesting to see that some of the most usual "discourse markers" can also function as encapsulating adverbs of circumstances as is the case of "then" in the following example:

(18) (3.238) The companies can be expected to market fully validated circuit designs **within a year or two.** (3.239) Perhaps THEN, when computers, computer links, televisions and compact disks all contain gallium arsenide, we will be able to say that the technology of the future has finally arrived.

Several authors have mentioned this plurifunctionality of "then". Tadros (1994, 76) talks about "inference then" and previously Schiffrin (1987, 246-247) mentioned the difficulty of distinguishing between "then" functioning as an adverb and "then" as a discourse marker. Schiffrin claims that in conversation "then" is an adverb when it signals a temporal relation and a marker when it establishes a consequence relation between two sentences. In the texts analysed it is possible to find examples of both uses. When it signals a temporal relation it can be paraphrased as "after that"; however when it is a discourse marker it can be paraphrased as "as a consequence of that".

4.5. Implicit encapsulation

Implicit encapsulation is linked to the presence of certain vocabulary items that "imply" the existence of previous information in the text as in the following example where the word "answer" presupposes a question, which is of course the question appearing in the previous sentence:

(19) (6.1) "What is the smallest amount of electric charge that can sit on the head of a pin? (6.2) THE ANSWER may surprise".

Together with "answer", we can mention some other words such as "example" in sentence 121 which implies the information given in sentence 120 in an elliptic complement.

(20) (4.120) But **many parts of the central nervous system are in fact thin sheets that carry two-dimensional representations of computationally relevant information.** (4.121) The retina is merely THE MOST OBVIOUS EXAMPLE.

Another clear signal of implicit encapsulation is the presence of a comparative expression. In fact, it is one of the most frequent cases of implicit encapsulations in the texts analysed. For instance, the comparative expression in sentence 23, "a more generally effective procedure" encapsulates implicitly the procedure previously mentioned in sentence 18:

(21) (2.17) Because of their microscopic size and extreme chemical reactivity, clusters could not be investigated with the techniques of traditional surface

chemistry or even synthesized in the laboratory, until the 1950's. (2.18) **In these early efforts, an oven was used to vaporize a metal, which was then precipitated as clusters on a substrate.** (2.19) Alkali metals such as sodium and potassium were tried first, at about 1,000 degrees Celsius; (2.20) metals with higher melting and vaporizing points were studied later. (2.21) But the metals with the higher transition temperatures could usually be made in clusters of only three to five atoms. (2.22) This made it impossible to determine how many atoms were required for the emergence of properties more like a solid and less like a cluster.

(2.23) A MORE GENERALLY EFFECTIVE PROCEDURE, in which a solid metal is vaporized with a laser, was devised in 1981 by two groups, one led by Richard E. Smalley of Rice University, the other by Vladimir E. Bondybey of AT&T Bell Laboratories.

In other cases, the encapsulation is performed by means of an implicit qualifier as in the following example where "equally important" must be understood as "as important as the previous advantage of gallium arsenide mentioned in the text".

(22) (3.121) **EQUALLY IMPORTANT is the capacity of gallium arsenide and its alloys to detect light by reversing the reaction underlying LED's and laser diodes.**

This use of implicit encapsulation reveals that the writer relies on the reader's memory and expects him or her to remember the previous advantage which has been mentioned not in the previous sentence or paragraph, but in sentence 103.

(23) (3.103) In addition to electron mobility and band-gap flexibility, gallium arsenide's third and most dramatic advantage over silicon **is its capacity to radiate and detect near-infrared radiation.** (3.104) In gallium arsenide the potential energy of an electron moving from the conduction to the valence band can easily be given up as a quantum of electromagnetic radiation, or photon. (3.105) The same reaction in silicon generally requires a nonradiative reaction, such as a collision, in order to conserve momentum. (3.106) This difference in band-gap properties explains why gallium arsenide can support optoelectronic functions and silicon cannot.

5. PROSPECTION IN SCIENTIFIC ENGLISH

The second procedure for linking sentences in the interactive plane is prospection. This concept of prospection which, as we have already seen, has

been dealt with by Sinclair (1993; 1994) has been also taken into account by other authors such as Tadros and Francis. However, neither of them undertakes the development of a complete taxonomy of prospecting devices. Tadros (1994) talks about "prediction", which she defines as a "prospective rhetorical device which commits the writer at one point in the text to a future discourse act" (Tadros, 1994: 70) and distinguishes six categories: enumeration, advance labelling, reporting, recapitulation, hypotheticality and question. In her study of lexical cohesion, Francis (1994) deals with "discourse labels" which function as "advance labels". She considers "metalinguistic" nouns as the most important group of nouns which function as advance labels, but she also mentions the importance of these nouns as retrospective labels. The results of our study concerning textual nouns confirm these two functions since those nouns functioning in prospection are the same as those functioning in encapsulation.

(24) (3.125) Such integration is a major goal for economic and functional REASONS. (3.126) **FIRST, like all miniaturization, it would greatly reduce the unit costs of the device (allowing a single wafer to produce scores of chips, each containing thousands of circuits).** (3.127) **SECOND, by placing a photodetector extremely close to the circuit that first amplifies it (the «front-end» circuit), one can design the connection between the two elements so as to minimize the antennalike pickup of unwanted signals from neighboring circuits, called cross talk -a major problem in circuits connected to nonintegrated detectors by conventional wire links.**

The main function of prospection is to signal the communicative value of what is going to appear next, but also to interrupt the present flow of information and for that reason they are usually connected to the signalling of a new paragraph.

The linguistic devices that act as prospection in the texts analysed are a) textual nouns, i.e. the same kind of nouns that act as encapsulation, but now they behave in the other direction; b) nominalization, but now it is adjectives and relative clauses instead of verbal processes; c) imperatives and extrapositions; d) sentence adverbs; e) questions and finally, f) discourse markers. It is important to note that discourse markers are a special type of prospecting device since they simultaneously encapsulate previous information.

The linguistic devices that signal prospection make clear their contribution to the creation of the interactive plane in the text since they signal a call to the reader. The study carried out here discovers that the prospective devices found in the scientific texts analysed happen to be the same devices that some authors classify as metadiscourse signals (Vande Kopple, 1986; Williams, 1990).

5.1. Prospection by means of a textual noun

The kind of nouns that are used for prospection are the same as those found in encapsulation. However, there are two clear differences when they are compared to nouns in encapsulation. First, nouns in prospection are less frequent. The following enumeration of the nouns found in prospection in *Scientific American* makes it clear that they are fewer than those used for encapsulation.

Nouns used for prospection

advance - case - challenge - characteristic - conclusion - information -issue - path - problem- question - reason - situation - success - technique - way.

Secondly, the prospective function of these nouns is also signalled by the presence of a linguistic device such as a cardinal number or a determiner. For instance, in the texts analysed there are many examples of these kinds of nouns accompanied by a cardinal number and the prospected sentences are then signalled by means of discourse markers. Several authors (Tadros,1994:71; Goutsos,1996: 511) have mentioned this condition and the examples found in the texts confirm this:

(25) (6.174) Conceivably, single-electron circuits could be made even more dense, but such attempts will encounter TWO PROBLEMS. (6.175) **FIRST, researchers need to pioneer techniques to fabricate complex structures whose smallest dimension is less than 10 nanometers.** (6.176) **SECOND, they must determine how single-electron effects change as the dimensions of the device decrease to the atomic scale.**

As in examples 25 and 26, the amount of text prospected is signalled by means of discourse markers. Sequence words such as "first" and "second" in sentences 175 and 176 in example 25, or sentences 12 and 15 in example 26, are obviously related to the presence of the number "two" before the nouns "problems" and "ways".

(26) (1.11) Since the invention of the transistor in 1948 by John Bardeen, Walter H. Brattain and William B. Shockley of Bell Telephone Laboratories, researchers have tried to improve semiconductors IN TWO WAYS. (1.12) **FIRST, physicists and electrical engineers seek materials that can switch on and off more quickly and perhaps perform other tasks, such as the detection and generation of light.** (1.13) **INDEED, it was toward these ends that Gallium Arsenide, which does not occur in nature, was formulated in the 1950's by Heinrich Welker of Siemens Laboratories.** (1.14) **He ALSO investigated closely from elements in**

the columns of the periodic table adjacent to silicon and germanium, the constituents of the earliest transistors.

(1.15) **SECOND, engineers refine the techniques by which semiconductors are manufactured.**

In example 26, it is also possible to see that the amount of text prospected can be longer than one sentence and again that it is closely related to signalling devices such as discourse markers. The use of "indeed" and "also" in sentences 13 and 14 signal that the information in those sentences relates to that expressed in sentence 12. Discourse markers are a special kind of prospective device since they also act as implicit encapsulators.

As in the case of encapsulating nouns, prospecting nouns can also have an evaluative function as in the next example where the adjective "formidable" intensifies the already "positive value" of the word "challenge":

(27) (1.15) Because they can be about 100 times smaller than the devices in present-day integrated circuits, however, designing and fabricating a viable device presents A FORMIDABLE CHALLENGE. (1.16) **Manufacturing processes will have to become considerably more sophisticated, and new strategies for interconnection and architecture will have to be devised to cope with the special problems of size reduction.**

The next example shows how encapsulation and prospection combine in texts. In sentence 187, it is possible to find prospection by means of a textual noun "issues". The amount prospected is signalled with the expression "for one" in sentence 188 and again, by means of a nominal group in sentence 191, "another unresolved issue". In sentence 190, there is an encapsulation by means of another noun. "This prediction" encapsulates the information given in the previous sentence since the prediction is what "the preliminary analysis shows": "that in such structures an electron can behave simultaneously as a wave and as a particle":

(49) (6.187) SEVERAL FUNDAMENTAL ISSUES are still to be solved. (6.188) **FOR ONE, investigators have not yet tackled the issue of how energy quantization influences single-electron charging effects in circuits that consist of many quantum dots or quantum wells.** (6.189) **A preliminary analysis shows that in such structures an electron can behave simultaneously as a wave and as a particle.** (6.190) **If THIS PREDICTION turns out to be true, it will be very important for fundamental physics.**

(6.191) **ANOTHER UNRESOLVED ISSUE is whether the correlated transfer of electrons requires tunneling.**

5.2. Nominalization in prospection

Prospective nominalization is realized by means of nominal relative clauses. Several authors stress their value as a mechanism for connecting text. Quirk *et al.* (1985: 1069) consider that the nominal relative clause functions as a reinforcing conjunct. Downing & Locke (1992: 250-251) mention wh-clefts as a means to refer retrospectively to a previous part of the discourse and to correct a previous statement. The examples found in the texts analysed reveal that these nominal relative clauses signal the importance of the information that is appearing now in the new sentence comparing it to what has been previously said as in the following examples:

(28) (6.41) Hence, the important quantity is not the charge in any given volume but rather how much charge has been carried through the wire. (6.42) This quantity is designated as the "transferred" charge. (6.43) WHAT IS MOST SURPRISING, **this charge can have practically any value, even a fraction of the charge of a single electron.**

(29) (1.88) As it happens, that distinction is not crucial for transistor operation. (1.89) WHAT DOES MATTER IS THAT in a quantum-effect device two slightly different voltages can evoke profoundly different responses.

These examples illustrate the difference between prospective and encapsulating nominalisation. In encapsulation, a previous verbal process is nominalized and becomes a participant of the new clause. In prospection, however, a nominal relative clause is the subject of a relational attributive clause that evaluates the information coming next.

5.3. Imperative and extraposition

In the texts analysed there are several cases of imperatives which signal the presence of new information. These imperatives are usually mental and behavioural verbs, as in the following example:

(30) (6.72) For convenience, ASSUME THAT the deposited charge rate is positive rather than negative.

The textual function of imperatives has also been signalled by other authors. Lamiroy and Swiggers (1991) have studied the use of *tiens* in French while Swales *et al.* (1998) devote a whole article to these imperatives, although they consider its use in scholarly writing a marginal phenomenon. Nevertheless, they (Swales *et al.* 1998:97) stress the important role these imperatives

have: "Results show that main text imperatives tend to congregate in sections where the principal argumentation occurs". The imperative in *Scientific American*, although not very frequent compared to other devices, is a mechanism with a definite function. It can be said that it is the typical construction to introduce further references to a research topic as in the following example:

(31) (2.113) The efficacy of a catalyst depends on its ability to attract reactants strongly enough for adsorption yet hold their end products weakly enough for desorption. (2.114) **[SEE «Bimetallic Catalysts», by John H. Sinfelt; *Scientific American,* September, 1985].**

Mental and behavioural verbs are used for prospection not only in imperatives. In *Scientific American*, they also appear in extraposed clauses as in the following example:

(32) (4.117) We have taken the first step in simulating the computations done by the brain to process a visual image. (4.118) How readily can this strategy be extended to other types of brain computations? (4.119) **IT MAY SEEM THAT the essentially two-dimensional nature of today's integrated circuits would severely limit efforts to model neural tissue.** (4.120) **But many parts of the central nervous system are in fact thin sheets that carry two-dimensional representations of computationally relevant information.**

I have already explained that in the texts analysed the pronoun "it" is mainly used to retrieve a previous entity, although there are several cases of an "anticipatory it". The analysis carried out reveals that these extrapositions signal the presence of new information relating it to what has been previously said since they are generally accompanied by an encapsulating discourse marker.

(33) (5.131) IT TURNS OUT, HOWEVER, THAT when the cavity containing the amplifying medium is short and has a small diameter, the walls of the cavity itself, through reflections, can modify the direction in which the light is initially emitted. (5.132) In a small cavity the light can be emitted only in certain allowed directions and at certain wavelengths. (5.133) In an extremely small cavity the light is emitted only along the direction of the desired laser beam.

(5.134) IT WOULD THEREFORE APPEAR THAT microlasers having a diameter of approximately one third of a micron may form the ultimate optoelectronic information-processing device: a small, fast and highly efficient laser requiring low power.

5.4. Questions

In example 33, it was possible to see that the extraposed clause was preceded by a question. The prospective value of questions has already been signalled by several authors. Hoey (1983) commented on their contribution to the organisation of written discourse and Tadros (1994) included them in her list of predicting mechanisms. In *Scientific American*, questions are frequently used as a prospective device and they are often placed at the beginning of a paragraph as in the following example:

(34) (2.106) The conclusion to be drawn from these studies is that different physical characteristics of clusters converge with those of solids at different scales. (2.107) The solid does not emerge all at once, but like the Cheshire cat it fades into view slowly, with the smile appearing first.

(2.108) HOW MIGHT THE SURFACE CHEMISTRY OF CLUSTERS BE EXPLOITED? (2.109) **One promising application is in industrial catalysis, which is central in petroleum refining (to recover gasoline fractions from heavier distillates), in pollution control (to oxidize or reduce noxious emissions) and in the synthesis of pharmaceuticals.**

5.6. Sentence adverbs

Sentence adverbs are also used for prospection. They function very similarly to the extraposed clauses mentioned previously as they tell the reader how he or she must interpret the sentence they introduce; therefore Quirk *et al.* (1985: 615) state that these adverbs could belong to a clause with a verb of speaking the subject of which could be "I". Of course, that "I" would be interpreted as the writer, making the role of these adverbs evident in the creation of the interactive plane.

(35) (6.94) To apply current and voltage to a tunnel junction, one must attach metallic wires to it. (6.95) UNFORTUNATELY, the wires pick up quantum fluctuations of the electromagnetic fields that exist everywhere.

5.6. Discourse markers

The last of the prospective mechanisms I include has special characteristics. As I have already mentioned, discourse markers are a special kind of prospective device because they also act as implicit encapsulators. These

retrospective properties explain why they are never placed at the beginning of a text.

It is important to note that they frequently combine with other mechanisms as in the following example where the marker "however" is accompanied by an extraposed clause:

(36) (2.78) As Walter D. Knight, Marvin L. Cohen and their co-workers at the University of California at Berkeley have discovered, abundance peaks coincide with sodium clusters of 8, 20, 40, 58 and 92 atoms. (2.79) The pattern constitutes compelling evidence that the electrons in these particular cluster systems are delocalized in the same general way as electrons in the corresponding solids. (2.80) **It should be noted, HOWEVER, that the quantum model that predicts these abundance peaks cannot be translated to the solid state, which, unlike the cluster, is not a spherically symmetrical system.**

Discourse markers have a clear function in the construction of the argumentation in the text and as Mosegaard (1998: 199) states "...fulfil an important function as linguistic "road signs" guiding the hearer towards the interpretation of the discourse that the speaker intends". In the following example, the simultaneous encapsulating and prospective function of discourse markers is clear.

(37) (6.69) **FOR EXAMPLE, what happens if the junction is connected to a source of constant current?** (6.70) **If the surface charge Q is zero initially, THEN the system is within the Coulomb blockade limits, and tunneling is suppressed.** (6.71) **THEREFORE, the current flowing from the source through wires will start to change the charge Q continuously.** (6.72) **For convenience, assume that the deposited charge rate is positive rather than negative.** (6.73) **If the charge reaches and slightly exceeds +e/2, tunneling becomes possible.** (6.74) **One electron will THEN cross the junction, making its charge slightly greater than -e/2.** (6.75) **HENCE, the system is within the Coulomb blockade range again, and tunneling is not possible.** (6.76) The current continues to add positive charge to the junction at a constant rate, and Q, grows until it exceeds +e/2 again. (6.77) The repetition of this process produces the single-electron tunneling (SET) oscillations: (6.78) the voltage changes periodically with a frequency equal to the current divided by the fundamental unit of charge, e.

"For example" in sentence 69 states that the new paragraph is going to explain previous information by means of an example. "Therefore" in sentence 71 signals the information given in that sentence is a consequence of the process mentioned in the previous sentence. Similarly, "then" in sentence 74

emphasizes that the "crossing of the junction by the electron" takes place once "tunneling has become possible", but that electron will cause the charge to increase and consequently "tunneling will not be possible" as sentence 75 signals by means of "hence".

6. CONCLUSIONS

To conclude, I want to stress the importance of encapsulation and prospection in the organisation of scientific texts. They act as a an organisational technique which the writer employs in order to arrange the information given and achieve a total effect of unity and clarity. The study undertaken reveals that encapsulation and prospection can explain how the linear organisation of sentences can lead to a hierarchical organisation of the information. Scientific texts are constructed one sentence after another, but that linear organisation is interrupted and changed by means of encapsulation and prospection. Encapsulation and prospection are therefore essential for the construction of scientific written discourse as they create the hierarchical organisation of the text and contribute to the perception of coherence. They also act as the means of contextualising new information relating it to what has already been said.

It is important to note that, although they have been reviewed in this paper separately, in the scientific texts analysed they work together to guide the reader through the information provided. The recognition of encapsulation and prospection and the links they establish between the sentences in the text are essential for the perception of coherence in scientific texts. Encapsulation and prospection reveal the writer's manner of organising sentences and combining them into paragraphs to make up the entire text

The study also confirms Sinclair's idea of a text having two planes: the interactive plane and the content plane. Encapsulation and prospection integrate the content plane into the interactive plane.

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NOTES

[1] It is important to note, however, that Sinclair does not want to disregard "point-to-point cohesion completely.

[2] According to Francis (1994), "textual nouns" operate both in encapsulation and prospection.

[3] The evaluative function of lexical signalling in texts is emphasized by Hoey (1993:34).

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APPENDIX 1

TEXTS ANALYSED

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