A FUNCTIONAL-SEMIOTIC ANALYSIS OF VISUAL AIDS IN SCIENTIFIC DISCOURSE

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1. INTRODUCTION

VISUAL aids constitute an explanatory technique often used in scientific discourse. I will consider visual aids all forms of non linear representation in which the display is in some way iconic. The purpose of this paper is to define the nature and properties of visual aids from a semiotic perspective. I will draw on Peirce's semiotic theory and on the contributions to the study of the iconic sign made by the French semiological tradition, and also by Eco.

Present-day researchers on EST that subscribe to a functional tradition provide us with guidelines for the interpretation of visual aids. For instance, Widdowson relates visual aids to his definition of the English used in science as "realization of universal sets of concepts and methods or procedures which define disciplines or areas of inquiry independently of any particular language" (1979: 24). He puts forward that there is a deep structure of communication in a particular discipline, which is the discourse consisting of its concepts and procedures and that is represented "in those universal features that appear overtly as intrinsic elements in the discourse itself; that is to say, the non-verbal modes of communication like formulae, tables, diagrams, etc." (Widdowson 1979: 24). These non-verbal representations can express both the conceptual aspects of the deep structure of a discipline and the procedural aspects.

Trimble (l985: l03) includes visual-verbal relationships in the set of rhetorical functions of EST. He claims that visual aids used in scientific discourse appear only in conjunction with other rhetorical techniques, that is, they always occur accompanied by linguistic signs. According to him, the function of an illustration is to add to the discourse some information, which is either difficult or impossible to convey accurately by words or requires a big effort to be processed in the text.

Illustrations have different functions in different scientific genres, this function varying also from article to textbook. In an article many of the visuals are part of the evidence for the experimental results displayed in it, so they serve a persuasive function. However, there are also visuals that help the reader to visualize and interpret the complex experiments and results. The visuals in a textbook are used mainly to picture rather than prove, for they try to present the concepts or the process itself without any attempt to demonstrate results.

2. THE SEMIOTICS OF VISUAL AIDS: THE IDEA OF ICONICITY.

Peirce's (1931-1958) theory of signs provides a basic framework for the analysis of the visual aids in science. The sign is the main element in the signifying process. Peirce's definition of the sign is based on three aspects of a triad: the sign-aspect, the object-aspect, the interpretant-aspect.[1] According to the relation of the sign to its object, Peirce divides signs into three types:

-The *index* keeps a physical relationship with its object.

-The *icon* refers to its object because of certain similarity with it.

-The *symbol* holds an arbitrary relationship with its object, a relationship determined by a law.

This distinction has been widely used, although Peirce does not regard these categories as clear-cut, since there is not any sign that can be regarded exclusively as an icon, index or symbol. Eco (l978) discards this distinction as vague and proposes a new classification of signs, in which the concepts icon, index and symbol are brushed aside. Although Peirce's typology of signs can be improved, I consider the concept of icon very useful for the study of visual aids. In an initial analysis it seems that the feature that distinguishes visual aids from other signs, especially from verbal discourse, is their iconicity, their analogical status, that is, the global perceptive resemblance to the represented object.

Peirce (1958) differentiates between three types of icons: *images, diagrams,* and *metaphors*. An image is an icon whose representamen only partakes of the quality of an object, representing it. Diagrams are indexic icons, the product of an analogical representation of the relations between the parts of the represented object: "those which represent the relations, mainly diadic, or so regarded, of the parts of one thing by analogous relations in their own parts are diagrams" (Peirce l958: 105). Finally, metaphor is, according to Pérez Carreño (l988: 67), the concept that allows for the possibility of verbal icons.

Peirce's definition of icon as a sign that represents its object mainly by its similarity poses some problems. This notion of similarity has been questioned by Eco, because of its imprecision. The definition of iconic sign was reformulated by Morris (l946), for whom a sign is iconic "to the extent to which it itself has the properties of its denotation." Eco (l970: 192) claims that this definition is a tautology, since we cannot state that the portrait of a person has the same properties as the person: the painted fabric has not got the texture of the skin, it cannot move, etc. Admitting that the portrait of a person is only iconic to a considerable extent, but not completely, Morris (1946: 7.2) states that "an iconic sign is a sign which is similar in some respect to what it denotes. Iconicity is a matter of degree." Now, the problem lies in the expression *in some respect.* Gombrich (l982: 107-108, in Peltzer, l991) also considers that the concept of degree should be taken into account for a definition of the iconic sign. For him an iconic sign must preserve the effective nature of the prototype. In order to achieve it the sign can consist in a rather basic schema to which more features can be added in order to make it conventionally (i.e. according to a code) resemble the real object.

Eco claims that there are some naive notions related to "icon" that should be rejected, among them the following: that the so-called "iconic sign" has the same properties as its object, that it is similar to its object, that it is analogous to its object, that it is motivated by its object.

Given that an iconic sign does not have the same properties as the represented object, the problem for semiotics is to find out how graphic or photographic signs, which do not share any material element with the things they represent, can seem similar to them in appearance or in their relations. According to Eco (1970: 14) the iconic sign reproduces some conditions of the perception and selects the stimuli (discarding the others) that enable the interpreter to build a perceptive structure with the same signification as the real experience denoted by the iconic sign. Eco illustrates this point by comparing the drawing of a horse to the real horse. When drawing the figure of a horse as a continuous line we do not reproduce the conditions of perception, because we perceive the horse according to a number of stimuli, none of which is similar to a line. Here is where "recognition codes" play an important role. The iconic sign reproduces conditions of the perception of the object, but these conditions must have been selected according to recognition codes and must have been reflected by graphic conventions that link an arbitrary sign to a condition of perception (for instance, lines are used to represent a zebra's hide). Therefore we select the main aspects of the perceived object following recognition codes.

> Presuming that they exist recognition codes (like any other) make provision for conveying pertinent features of the content. The recognizability of the iconic sign depends on the selection of these features. But the pertinent features must be expressed. Therefore there must exist an iconic code which establishes the equivalence between a certain graphic device and a pertinent feature of the recognition code. (Eco l979: 206)

The conclusion that can be drawn is that graphic signs are conventional, although they seem to be structured in a similar way to certain properties and relations of the represented object. The main point to understand iconic signs lies in the nature of these properties. Eco states that "the iconic object may possess: (a) optic (visible), (b) ontological (supposed), and (c) conventional properties of the object" (1979: 207). When drawing a car a child will represent only two wheels, because that is what he sees (visible properties), but before reaching this stage he will represent the car with four wheels because he knows that it has four wheels (ontological properties). A typical example of the third case is the representation of the sun as a circle with lines radiating from it. This iconic representation imitates some properties of another schematic representation, of a conventional image, like that of the sun as a fire sphere with lines of light. Thus "a graphic image reproduces the relational properties of a mental image" (Eco l970: 18).

The iconic code can establish two types of correlations: that between a perceptual unit and a pertinent unit of the graphic system; and that between a graphic sign vehicle and a global perceived object denoted by it. By choosing the pertinent features we carry out a reduction process that is specially manifest in cases such as stereotypes. For instance, a schoolboy is represented wearing a uniform in traffic signals, although we know that is not the normal case nowadays. Eco concludes that "the iconic sign builds a model of relations (between graphic phenomena) equivalent to the model of perceptual relations that we build by knowing and remembering the object" (1970: 21). Consequently the iconic sign does not share any property with the object, but with our perceptual model of the object. When we build an iconic sign we follow the same mental operations used to build the perceived object. That is why Eco claims that Morris' definition of iconic sign can be reformulated as "that which seems to reproduce certain properties of the represented object" (1970: 21). Eco regards the iconic sign as the result of a transformation process: "given a content-type that is in some way cognizable, its pertinent features must be projected into a given expression continuum by means of certain transformational rules" (1979: 189).

3. FUNCTIONAL AND FORMAL FEATURES OF VISUAL AIDS.

3.1. Functional features

As we said before, visual aids are an important part of the semiotic structure of scientific discourse, used to achieve a better and more precise understanding of the concepts displayed in it. They are non linear signs but they do not include everything we can consider "iconic sign" or we call "an image." In order to define visual aids and to fix their limits I will discuss their features.

They are visual signs, that is, perceived visually, which makes them spatial and timeless. These signs differ from linguistic systems, and especially from language, in their material. The signifier is a bidimensional one, characterised by three variables: the two dimensions of the plane and the variation of the ink "stains."

They are conventional signs. Segre (1990: 47) distinguishes between conventional and non-conventional signs taking the concept of code as a basis: conventional signs are coded. Conventional signs can be a personal creation or a collective creation, which has been transmitted (like the grammar and lexis of a language). They are characterised because they are closed sets, grouped into systems whose elements are related. These signs belong to a type of communication where there is always an adresser (the writer of the scientific discourse) and an adressee. There is also a possibility of response and the reader of this discourse may become the addresser. The sender tries to communicate something and the receiver for whom this message is intended has a knowledge of the code that allows him to interpret the message.

Visual aids are intentional signs and are therefore communicative, produced to be used as artificial tools. Expressive signs, by contrast, are emitted spontaneously, without any intention to communicate (Eco l976: 41). Thus visual aids reveal the intentionality to communicate something to a receiver, they are artificial signs created for the purpose of communication, opposed to natural signs. These signs are the product of a practical intentionality, as opposed to an aesthetic intentionality. A visual aid is a sign with a practical purpose: "a sign instrument serving an external aim" (Mukarovsky 1976: 236). The visual signs in scientific discourse serve the purpose of providing information when it cannot be depicted in words or it is too difficult or anti-economical to do it. It is this practical purpose that distinguishes an informative sign from the artistic sign, which is non-serving. In the visual aids the practical functions are foregrounded and the aesthetic function is backgrounded: the dominant function is the referential one.

Visual aids can be defined by their iconicity, but in order to make this claim it is necessary to define the notion of *iconicity* and to clarify its connection with *similarity, arbitrariness,* and *code*. Analogical has often been opposed to arbitrary, but in fact arbitrary is opposed to motivated. Taking Peirce's terminology the symbol would be arbitrary and the icon and index would be motivated, the first having a causal or contiguity link with the object, the second an imitative link. There is no opposition between analogical and arbitrary. Although an image can be analogical taken as a whole, it can contain different arbitrary relations.

If we take any visual we can think that the relationship between the signified and the signifier is one of similarity. But there is a part of what Veltrusky (1979: 250) calls "codified contiguity." In any visual sign there are graphic symbols such as the point, the circle, the triangle, the line, etc., which are combined to form crosses, spirals, etc. or to give rise to oppositions between straight line and curve, between horizontal and vertical. These symbols may convey different meanings in different contexts and in different visual signs. In some graphics we are even given the key to interpret them. So the visual sign, being as a whole iconic, contains relations that can be systematised. This leads us to reject the opposition between the analogical and the codified. The fact that the code used is not the same as that of the linguistic signs does not mean that it does not exist. Metz (1970: 3) observes that this belief would bring about two mistakes: to confuse "langue" and code, to conclude the absence of a code from the absence of "langue."

Eco remarks that the iconic codes are "weak codes." According to him "in an iconic syntagm . . . there are contextual relationships so complex that it seems difficult to distinguish among them the pertinent traits of the optional variants" (Eco 1970: 22). The signs in an iconic syntagm do not conform to the double articulation of language, they do not have positional and oppositional value because they do not have a meaning by the fact of occurring or not. They have contextual signifieds without having a signified per se. For instance, a point does not have a signified because of its opposition to a line in an established system. Their value depends on the context in which they appear.[2]

Finally, let us consider in what sense "analogical" should be understood when speaking of visual signs. Verón (1970: 58) remarks that similarity is a perceptual criterion. We regard a photograph as an analogical message because it "resembles" the represented object, but if the photograph is enlarged to a great extent the similarity disappears to give way to a series of discrete points of different intensity, which leads to the conclusion that the passing from similarity to non similarity is progressive. This statement still leaves the concepts of analogy and similarity undefined. Eco claims that analogy must not be understood as a mysterious relation between things and image, but from an operational point of view: "a procedure instituting the basic conditions for a transformation" (Eco l979: 201) which permits verification. The example of the analogical computer is very illustrative.[3]

3.2. Formal features of visual aids

As regards their structure and nature, visuals used in scientific discourse (hereafter SD) have some specific features already pointed out by Bertin (l970: 172) and Sager *et al.* (1980). Visuals lack the horizontal sequentiality of conventional linguistic representation. As they are not limited to one dimension, their layout can exploit the horizontal, vertical and diagonal dimensions of the page, presenting a simultaneous picture of the data.

The relationships between the information items in a visual are represented without syntactic links and signalled by non-linguistic conventions, pursuing the principles of economy and precision of expression. Owing to the absence of an order that follows established syntactic rules the understanding of visuals requires other types of ordering (e.g. numerical, alphabetical, in increasing or decreasing value, etc.) and prior knowledge of the conventions according to which these visuals operate.

The visual is built by means of three homogeneous dimensions: the two dimensions of the plane (x, y) and a variable z. The use of three dimensions facilitates the representation of highly complex relationships between the items of information and a multiple interpretation of the data provided. Since visuals are *ad hoc* systems, linguistic devices often have to be used so as to explain the meaning of the symbols, colour, grain and line differentiations (i.e. the variable z) employed.

The visual conveys a great quantity of information and it allows different levels of reading: we can read it as a whole, assessing the meaning of the whole visual, or we can pay attention just to a particular element. Between these two levels there are middle levels when we concentrate on groups of elements. Sager *et al.* (1980: 312) state that a visual text segment often supplies the reader with two types of information: one type is required for the development of the ongoing argument, a single datum necessary to go on with the message; the other type, where the first one is included, provides additional information, mainly used to test and verify the results.

3.3. Relationship between non-linguistic and linguistic elements

Visual aids do not appear in isolation but keep a narrow relationship with the linguistic message. They are often mixed messages, consisting of the visual and a caption. It has been claimed that verbal language is "the primary modelling system" (Lotman l967) while the others are secondary. A supporting argument frequently used is that any content expressed by other semiotic devices can also be expressed by verbal language, while the contrary is false. However, we can make an objection to this statement: there are contents expressed by non-verbal units that cannot be translated into verbal units. Gombrich places the real value of the image in "its capacity to convey information that cannot be coded in any other way" (1972: 87). Garroni (l973) states that linguistic devices are appropriate to convey a set of contents and non-linguistic devices are more appropriate to convey a different set of contents. Scientific discourse is a proof of this claim: owing to limitations of space every content is conveyed in the most economical way. Therefore visuals are used when the signified cannot be conveyed verbally or it would require too much processing effort and space. To quote Crystal:

> The immediacy and economy of presentation achieved by these methods is self-evident. It would be impossible to provide a coherent account in words of all the interrelationships found on a map, graph or tree diagram, for example . . . . On the other hand, linguistic and non-linguistic modes of expression are never totally independent of each other: verbal language is always needed in order to interpret and amplify the meaning or use on nonverbal representations (Crystal 1987: 381)

In scientific discourse text and image appear together, thus there is a relationship between them, but it should not be analysed in terms of subordination of one system to the other. As Metz (1970: 3) observes, the semiotics of the visuals must be studied in relation to that of the linguistic object that accompanies them. The visual is not an isolated element; it is related to and connected with the whole discourse in which it is inserted.

Barthes (l977) analyses the relationship between text and image in his study of the photographic images used in publicity, press, cinema, etc. Although these are totally different from the visuals used in SD, some of his statements about the relationship between text and image can also be applied to SD visuals. Barthes claims that while formerly the image was an illustration to the text, nowadays the situation has changed and the words are structurally "parasitic on the image," they load the image with cultural elements that amplify it. The SD visual is related to two different texts: the whole text of which it is a part, and the caption, or label that appears with it. In the first case text and image are in a complementary relation (Barthes' [1977] *relay* function), because they are both fragments of a more general syntagm, they interact to convey a message. The visual requires less effort on the part of the speaker, who is spared the costly verbal description. As for the caption, its function is similar to that called *anchorage* function by Barthes. It replies to the question: what is it? As Barthes remarks,

> The text helps to identify purely and simply the elements of the image; it is a matter of a denoted description of the image . . . . The

> denominative function corresponds exactly to an anchorage of all the possible (denoted) meanings of the object by recourse to a nomenclature. (1977: 39)

The linguistic message guides the identification of the visual, the caption "identifies" the image. This is a proof of the arbitrary character of the visuals, especially of the graphics, since the text shows the conventional relation between the visual and the object.

Gombrich points out that "the chance of a correct reading of the image is governed by three variables: the code, the caption and the context" (l972: 86). The mutual support of language and image makes memorisation easier, because the use of two independent channels facilitates reconstruction. There are cases in which the caption is not necessary because the visual signs are self-explanatory owing to the context. In SD the caption is practically always necessary since the identifying linguistic message can only be omitted with signs that appear as self-explanatory, owing to their location in a context supported by prior expectations based on tradition. This is not the case of SD visuals, which try to convey new messages.

Visual aids are textual units, or sense units, as Peltzer remarks (l991: 50). This claim is an attempt to recover the idea that icons are texts. It has already been stated that although the iconic text does not follow the same code as linguistic units, it fulfils the essential function of a text: to provide sense, which is, according to Coseriu (l986: 284), the content of a text. Iconic texts are functional units that can be analysed into smaller units. However, the visual text differs from the linguistic one in that the latter always belongs to a specific language, while images represent ideas that go beyond language, although they are determined by culture.

4. A TYPOLOGY OF VISUAL AIDS IN SD: IMAGES AND GRAPHICS.

A number of classifications have been made of icons, following different criteria: similarity, arbitrariness, abstraction, nature of the represented object, modes of production, etc.[4] Eco suggests that the term "icon" should be discarded and the great variety of concepts under this heading should be included in a wider semiotic classification made on the grounds of the different modes of production. The validity of sign (especially icon) classifications will not be considered here. I will try to set up a classification of a particular kind of signs, the visual aids of SD, which intends to make clear distinctions between types of signs used in different scientific disciplines. There are two main groups, which I will call "images" and "graphics," the latter being the most frequent visual aids in SD. This distinction has been made taking two binary oppositions into account: figurative/non-figurative, and polysemic/monosemic.

Images (all kind of photographs and drawings) are figurative while graphics are non-figurative. The difference lies in the status of the represented object. In the case of images it is a real object, while graphics are tokens whose type not only has been established by convention but also is not the sign of a real but of an abstract object. For instance, a triangle is a token of the geometrical figure called "triangle," which is a concept that can be found in reality only as a token not as a type. This is the reason why images are mainly built taking as a basis optical (visible) or ontological (supposed) properties of the object, while graphics are built by means of conventionalized abstract properties. The creation of an image is guided by rules of spatial similarity with the mental image of the represented visible object. Graphics are visual representations in which the key word is relational similarity, or proportionality. They are defined by a specific organisation.

Images are polysemic, while graphics are monosemic. Bertin (l970: 170) defines a monosemic system as that in which the knowledge of the signification of every sign is a requirement to know the meaning of the whole. A graphic cannot be understood until the caption has identified the particular meaning of every sign. A polysemic system is that in which the signification arises from the joining of the signs to form a whole. In a monosemic system there is not any possibility of ambiguous interpretation because all the elements have already been determined and fixed before the interpretation of the whole. The distinction between monosemic and polysemic signs seems to be based on abstraction: "the greater the abstraction of the signified the greater the monosemy and the less the ambiguity" (Peltzer 1991: 35). Therefore, graphics, owing to their monosemic character, are not ambiguous.

I shall now focus on each type of visual aid in turn.

4.1. Images

In scientific discourse we can find different types of drawings and photographs (See Fig. 1 at the end of this paper): holograms, colour photographs, black and white photographs, figurative drawings (Fig. 2), outline drawings, etc. They can be distinguished by their level of iconicity, the photograph being more iconic than the drawing.

According to Barthes (1977) the real difference between photograph and drawing lies in the presence or absence of code. He claims that the iconic message conveyed by the photograph used in SD differs from that of the rest of the signs considered here in that it is non-coded. Barthes considers the photograph as the "perfect analogon" of reality, which makes it a "message without code," a "continuous message" (1977: 77). The literal information it transmits is not formed by means of discontinuous signs and transformation rules. The drawing differs from the photograph in that it is a coded message. The reproduction of an object is the result of some transposition guided by a set of rules. On the act of drawing (the coding) a choice must be made of the pertinent features of the object that will allow its recognition. In the photograph there is no selection of significant features. Therefore, while the relationship of signified to signifier in the drawing is one of "transformation," in the photograph it is one of "recording." The claim that photographs are non-coded, on which the distinction between photograph and drawing is based, is questionable, since anthropological research has proved that people not familiarized with photography have to be taught to understand and interpret photographs.

Gombrich (l979), who does not make any allusion to the concept of code, establishes a similar distinction between two types of visual representation, one following the paradigm of the map, the other that of the mirror: the first tries to represent the physical world, the second the optic world. Drawings, which belong to the first type and provide selective information about the physical world, represent *what* we see, they are produced by a transposition process that selects the pertinent features for the identification of the represented object. The photograph, which follows the mirror paradigm, reflects the appearance of one aspect of the world, "mirroring" the way in which it changes depending on light conditions. The information it provides concerns the optic world, since it represents *the way* we see the object at a particular moment: if light conditions change the representation of the object also changes. A drawing allows us to identify an object by means of the spatial relations, a photograph is concerned with the visual appearance of the object.

The difference between the photographic and the other types of visual language (graphic or iconographic) has also, probably more adequately, been set (Peltzer 1991: 34) on the type of code: particularizing or universalizing. Photographic language is a particularizing code, it is a "mirror," an "imprint" that reflects a singular reality visually. The other types of visual aids (drawings, diagrams, etc.) are, according to Peltzer, universalizing codes, because they imply abstraction. He claims that a photograph is always the image of a particular object (for instance, a house). By contrast, when a house is drawn the maker uses the universal image of a house he has in his mind. Although a drawing can also be particularizing, as when a specific object is drawn, the possibility of abstraction makes of it a more powerful instrument than the photograph: a drawing can reflect, for instance, a particular house, but also an abstraction of the concept house, and even a non-existent object (unicorns, events that have never happened, etc.). This capacity of abstraction allows the drawing to surpass nature more easily than photographs can. By the same token, photographs can represent images that express a universal concept, but it always happens from a particular and concrete object, since they are produced from a particularized and concrete reality.

The drawings that appear in SD conform to the features of scientific visuals mentioned above (practical function, communicative purpose, etc.). The most often used type is that called "infographic": a graphic representation that tries to reflect facts or events, information about how something works or what an object is like.

A view is a very explicit drawing where all the real elements are represented keeping the same proportions as in the original. Sometimes it is accompanied by explanatory words or numbers. A rather frequent one, especially used in biomedical articles is the *section* (Fig. 3): the view of a body's inside.

Explanatory visuals (Fig. 4) represent how a process or an event happens. It is mainly used to inform about the several stages in a natural or artificial process or to reflect the connections and steps in a process or in a series of procedures.

4.2. Graphics

Graphics are used exclusively with a practical function, which accounts for the fact that the principle that guides their interpretation is that of efficacy.

Eco's consideration of different modes of production will be useful as a first step in our classification. It is necessary to point out that what we call signs are "the result of many intertwined modes of production" (Eco l979: 259). Since a sign can be produced in different ways a typology of signs based on modes of production is not definitive and clear-cut. Taking this into account, I will try to distinguish two types of graphics: those produced mainly by means of replica and those produced by invention.

Replicas "replicate an expression type which has already been conventionally correlated with a given content" (Eco l979: 245). In these cases the type exists as a cultural product so the correspondence is between a token and the already known type.

Stylizations are a case of replica (Eco l979: 238). They are replicas recognized because of their similarity not to a content model but to an expression type. The token does not reflect all the features of the type, only the pertinent ones. The double helix (Fig. 5), for instance, is a stylization.

The other type of replicas found in SD are *vectors,* defined by Eco as "features of a given system that must be added to a bundle or to a string of features from one or more other systems in order to compose a recognizable functive" (l979: 240). Graphic arrows are instances of vectors. They realise dimensional features such as "linearity," "apicality," "direction," etc. The attention of the addressee is directed towards parameters such as "left," "right," "up," "down," etc. The term "direction" we are considering in relation to vectors should be deprived of spatial connotations. The graphic arrows used in SD represent *vectors* (in the sense used in science). They are physical quantities that require, for their complete definition, not only a quantity but also a direction: these are movement, velocity, force, acceleration, etc.

Invention is the second mode of production used in SD. Signs produced in this way are undercoded because there is not a code previous to their interpretation, and their expression is not divisible into minimal units but into macrounits. According to Eco, "the producer of the sign-function chooses a new material continuum not yet segmented for that purpose and proposes a new way of organising (of giving form to) it in order to map within it the formal pertinent elements of a content type" (1979: 245).

The sign producer establishes the correlation between the elements of the expression and those of the selected content, since it is not fixed by convention. In graphics, maps, etc. the producer gives a key to interpret the elements of the expression as a code. Eco claims that what the producer does is propose a new code,[5] because the units in which the signifier is segmented do not form a part of other codes.

The invented signs in scientific discourse are visual representations of a piece of information, which reflect the correspondence between a finite series of variable concepts and an invariable component. This type of information is analogical in the same sense as an analogical computer: it represents the proportions in an analogical way, which makes them understandable. It represents in a real and concrete way, by means of analogy, some abstract data and proportions. The main use of these signs is not to represent objects as the images do, but observations, laws, etc. They are specially useful in the transcription of the data obtained after an observation. In order to set up a classification of graphic representations we need the notion of component of information, a concept of variation which is represented. A graphic consists in the transcription of every component by means of a visual variable. A "stain" of signification located in X and Y (the two dimensions of the plan) can vary in size, value, grain, colour, orientation and shape

The invented signs used in SD are of two types: diagrams and maps.

A. Diagrams. They are representations in which the spatial points in the expression correspond to non spatial aspects of the represented object. Peltzer considers them "geometrical drawings used to prove a proposition or to represent graphically the variation of an event or phenomenum"(1991: l30). They can be further divided into two types:

1. Graphics that represent relations between elements of a single component (A, B, C...). There are different types of configurations because these elements and the relations can be transcribed as points, lines or zones and they can form a line, a circle, etc. The most frequent example in SD is the genealogical map (Fig. 6)

2. Graphics that represent relations between components. There can be two or more components, whose representation can give rise to different configurations (Peltzer l99l: l30):

-Linear. The correspondences are represented by lines that express the two variable components on the two perpendicular axes of coordinates (Fig. 7).

-Rectilinear. The variable components are represented on a straight line, divided in proportional parts, which make up the invariable whole.

-Circular. The proportions of the variable component are represented as sectors in a circle, which differ in size and in colour or grain. This is the best way to represent percentages or parts of a whole (Fig. 8).

-Ortogonal. The proportions are represented by blocks with different colours or grains, the invariable component being the base (Fig. 9).

-Table. It is is a mixed message, partly graphic, partly linguistic. The linguistic messages are grouped, classified, related, etc by means of an adequate design. They are very useful to represent systematically an information having extensive quantitative numerical or linguistic data that must be read carefully (Fig. 10).

B. Maps (Fig. 11). They are representations in which spatial points in the expression correspond to spatial aspects of the represented object. The relations that are mapped onto the expression are spatial, because maps represent a spatial component which is transcribed keeping the correct proportions. Bertin (1970: l83) points out that in a diagram a spatial component only uses a dimension of the plan and the other can represent n concepts. By contrast, in a map the spatial component requires the two dimensions x and y. The map appears as a powerful information instrument because it answers a lot of questions: What is there in a particular space? What's the distribution of a particular phenomenon? Which phenomena have the same distribution? etc.

5. CONCLUSIONS

Visual aids are a powerful tool for the conveyance of information in scientific discourse. What characterizes them is their function, rather than their "nature"; that is, a visual aid in SD must have a practical communicative function, it must provide information difficult or impossible to transmit with linguistic signs. Thus, these signs are "the product of a practical intentionality."

As for their iconic nature, it has already been discussed in this paper, particularly in relation to the validity of the concept of icon. There are two points I would like to stress: there is an iconic code, used to create visual aids, although it is a weak code, different from the linguistic one; iconicity is a complex concept that should not be simply or naïvely identified with similarity or sharing properties with the object. The similarity between a visual aid and the represented object is established by convention.

Finally, it may be convenient to assess the information value of visual aids according to the amount of information they encode. An image, used to convey visual information, implies always a selection of pertinent features of the model's image, which reveals the sender's interpretation of what he considers relevant. Although the photograph has been considered a message without code by Barthes (1977), there is also a selection on the part of the speaker's, who sifts his material. The information value lies in the possibility of distinguishing the code from the message and this ease of distinction can be more important for information purposes than the "fidelity of reproduction." That is the point made by Gombrich when he states that

> The easier it is to separate the code from the content, the more we can rely on the image to communicate a particular kind of information. A selective code that is understood to be a code enables the maker of the image to filter out certain kinds of information and to encode only those features that are of interest to the recipient. (l972: 91)

Therefore, a selective representation is so informative because the recipient's attention is focused on what the sender wants to transmit. a

NOTES

1. For Peirce,

> A sign, or representamen, is something that stands to somebody for something in some respect or capacity. It addresses somebody, that is, creates in the mind of that person an equivalent sign, or perhaps a more developed sign. That sign which it creates I call it the interpretant of the first sign, the sign stands for something, its object. (Peirce 1958: 99)

The interpretant, or meaning of the sign, is what a sign produces in the interpreter. The interpretant is always a development of the sign, an increment stimulated by the first sign. Thus it is "another representation which is referred to the same object" (Eco 1970: 68) for this reason it is possible to speak of *unlimited semiosis* as an interminable process of interpretation. The triadic relation in which the sign enters implies that the interpretant is another sign which must also be interpretable and hence it presupposes in turn another sign, and so on.

2. Eco (1970: 38) points out that the code is articulated into figures, signs and supersigns. Figures (e.g. geometric elements: points, lines, circles, etc.), "the conditions of perception transcribed into graphic signs, following the rules established by the code," are numberless and the meaning of the messages they produce cannot be deduced from any code but depends on context. Figures do not represent anything but they are used to form the signs and the supersigns; their combinations produce all the possible signs. The signs, which occur as non discrete elements in a graphic continuum, "denote, with the conventional graphic devices, "sèmes" of recognition (nose, eye, cloud, etc.); or with "abstract models," symbols, conceptual diagrams of the object (sun as a circle)." Supersigns (or sèmes), which are what we call

"images" or "iconic signs" (e.g. a house), have a whole proposition as their content (e.g. "man siting on a chair").

3. An analogical computer establishes a constant proportionality between two series of entities, one being the sign vehicle of the other (for instance, x being an intensity of current that denotes a physical size (y) x1 corresponds to y1, x2 to y2 and so on). The correlation between x and y has been established arbitrarily from the outset. Analogy is rendered legitimate by the proportional relationship, which is the same between the elements of the sign vehicle and those of the object, but this relation is arbitrary, y has been give the value x by convention.

4. A criterion often used for classification is that of degree of iconicity, that is, of quantitative differences. Villafañe (l985: 39-43) establishes a scale of eleven degrees of iconicity, taking abstraction as the delimiting criterion. The first one is the natural image, the product of the perception of reality, which possesses all the perceptual properties of the object, and the last one is the non figurative representation, where all the perceptible and relational properties of the object have been abstracted.

5. In fact Eco regards invention as code making.

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ILLUSTRATIONS

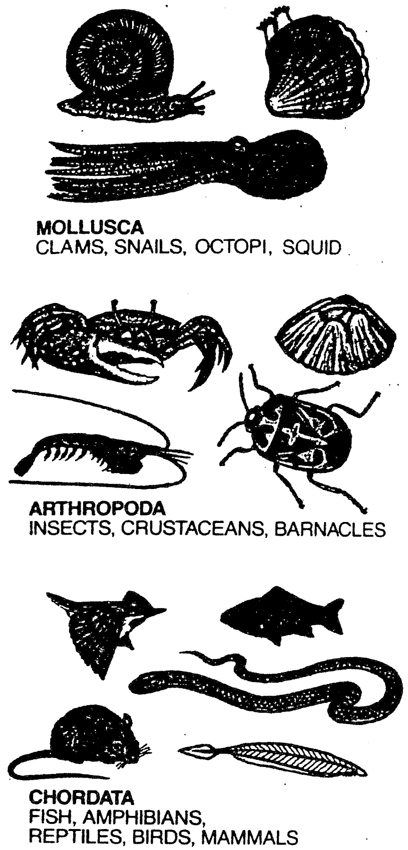
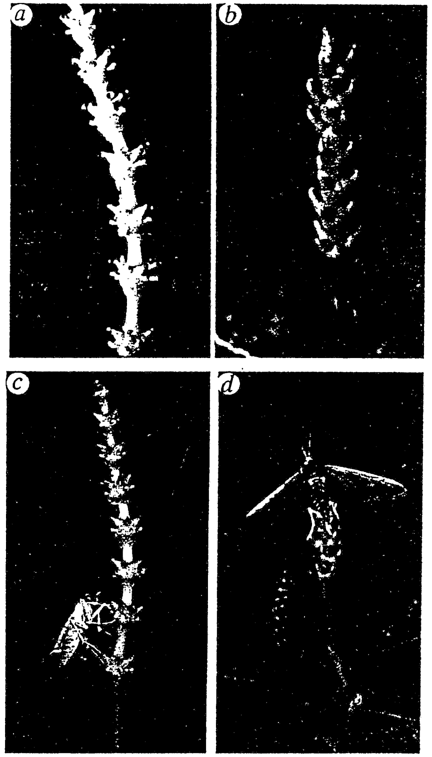


Fig. 1



Strobili of *Gnetum gnemon* in the evening in a tropical rain forest in Sarawak. *a*, Sterile ovules emitting droplets (male strobilus); *b*, fertile ovules emitting droplets (female strobilus); *c*, a male strobilus visited by a pyralid moth, *Herpetogramma* sp.; *d*, a female strobilus visited by a pyralid moth, *Hedylepta* sp.

Fig.2

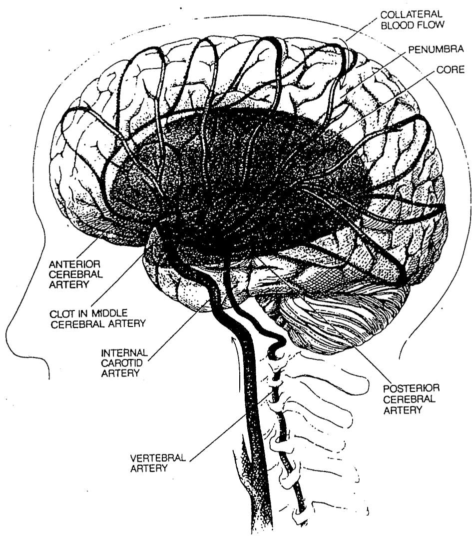


Fig. 3

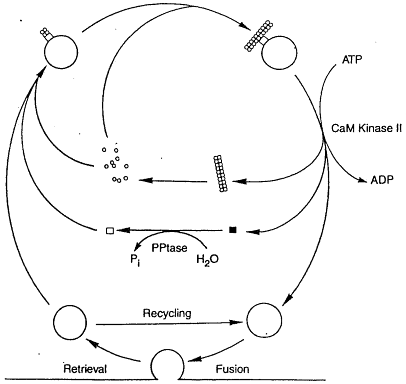
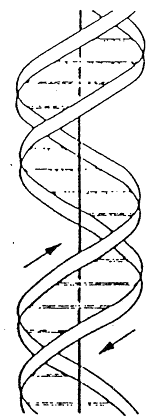


Fig. 4. Model illustrating the postulated mechanism by which the state of phosphorylation of synapsin I regulates the availability of synaptic vesicles for exocytosis. Under resting conditions, dephosphorylated synapsin I (□) cross-links synaptic vesicles (O) to actin filaments (ooooo), making them unavailable for release (reserve pool). Activation of CaM kinase II results in phosphorylation of synapsin I (■) and disruption of the complexes. The liberated vesicles can now join the releasable pool. After fusion with the plasma membrane and subsequent endocytotic retrieval, the vesicles can be either recycled within the releasable pool or resequestered within the reserve pool. Resequestration occurs because dephosphorylation of synapsin I promotes its rebinding to the vesicles and nucleation of filaments from actin monomers (∘), resulting in the reformation of complexes and the embedding of vesicles in the cytoskeletal meshwork. PPtase, protein phosphatase; P_i, inorganic phosphate.

Fig. 4



This figure is purely diagrammatic. The two ribbons symbolize the two phosphate-sugar chains, and the horizontal rods the pairs of bases holding the chains together. The vertical line marks the fibre axis.

Fig. 5

Fig. 1. (**A**) Traditional termite-roach phylogeny [adapted from findings in (*3*)]. Not all characters in the original tree are shown. Note that roaches are presented as a grade (paraphyletic group) leading to termites, and that Mastotermitidae is paraphyletic (with respect to Kalotermitidae). The striped line across the base of the tree indicates the break in the grade from termites to cockroaches. Circled letters on branches refer to the following characters that define these branches: a, symbiotic gut flagellates; b, coloniality and loss of wings; c, eusociality and deciduous wings; d, loss of mandibular tooth and *Metadevescovina* gut flagellates. (**B**) Phylogeny of Thorne and Carpenter (*4*) based on 70 morphological and behavioral characters. The cladogram was rooted with the use of inferred ancestral states.

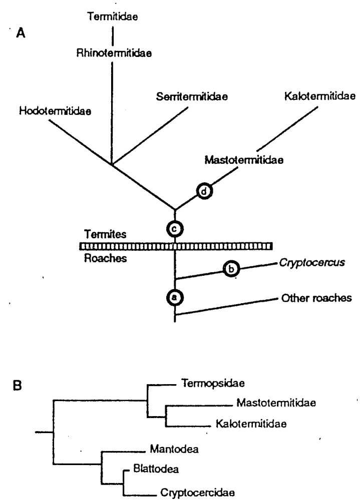
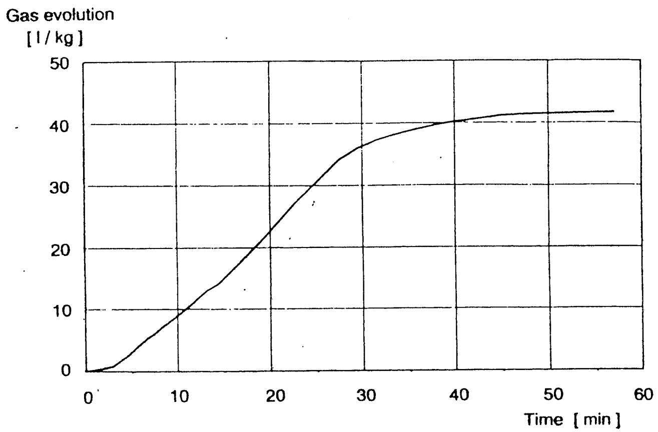


Fig. 6



Gas evolution obtained using the closed apparatus.

Fig. 7

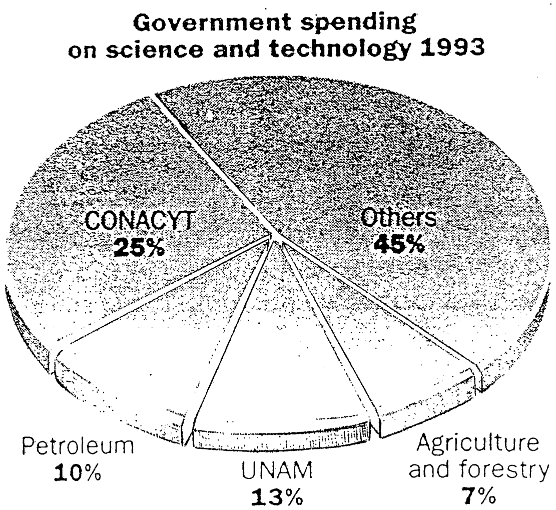
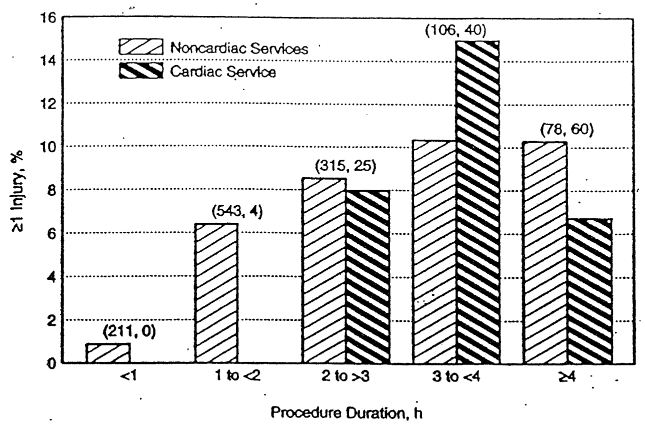


Fig. 8



Procedure injury rate by procedure duration for noncardiac (general surgery, gynecology, orthopedics, and trauma) ($P<.001$, χ^2 test for trend) and cardiac ($P=.7$, χ^2 test for trend) services. The first number in parentheses at the top of each set of bars is the number of procedures in noncardiac services and the second is the number in the cardiac service.

Fig. 9

Table 2. Representative receptors for which acidification responses to triggering have been demonstrated in the microphysiometer. The table indicates the receptor, the superfamily to which the receptor belongs and the second messenger pathway activated by the receptor, whether the response was derived from receptors native to the cells or whether the response was derived from receptors transfected into the cells, and citations for the data. N.D., not done.

Receptor	Superfamily, pathway	Native	Transfected	Reference
m1 Muscarinic acetylcholine	G protein, inositol phosphate	N.D.	Yes	*(11)*
Muscarinic, subtype unknown	G protein	Yes	N.D.	*(18)*
β_2-Adrenergic	G protein, increasing cAMP	N.D.	Yes	*(11)*
Prostaglandin E	G protein, increasing cAMP	Yes	N.D.	*(19)*
Dopamine D1	G protein, increasing cAMP	No	Yes	*(20)*
Dopamine D2	G protein, decreasing cAMP	No	Yes	*(20, 21)*
Glutamate (kainate)	Excitatory amino acid, ion channel	Yes	N.D.	*(15)*
Insulin, insulin-like growth factor	Growth factor, tyrosine kinase	Yes	N.D.	*(22)*
Epidermal growth factor	Growth factor, tyrosine kinase	Yes	Yes	*(3, 11, 14)*
γ-Interferon	Hematopoietin	Yes	N.D.	*(23)*
Interleukin-2	Hematopoietin	Yes	N.D.	*(14)*
Interleukin-4	Hematopoietin	Yes	N.D.	*(23)*
GM-CSF	Hematopoietin	Yes	N.D.	*(8)*
T cell	T cell receptor	Yes	N.D.	*(14)*

Fig. 10

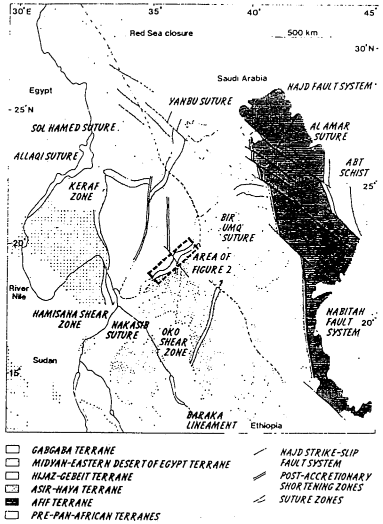


Fig. 1. Sketch geological map of the Arabian–Nubian Shield with Tertiary opening (dashed line) of the Red Sea restored (modified after Vail 1985).

Fig. 11

FUNCIONES PRAGMATICAS MARCADAS Y NO MARCADAS[1]

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1.INTRODUCCION

LA Gramática Funcional (Dik 1989) puede considerarse heredera de la tradición del Círculo Lingüístico de Praga en su distinción de tres niveles funcionales superpuestos, de manera que cada elemento está definido por un conjunto de funciones a tres niveles (pragmático o informativo, semántico y sintáctico). Así, por ejemplo, dado el enunciado en (1), el argumento *the man* desempeña la función pragmática tópico, la función semántica agente y la función sintáctica sujeto; el argumento *the door,* por su parte, tiene asignada la función pragmática foco, la función semántica paciente y la función sintáctica objeto:

(1) The man opened the door.

El tratamiento binario de la perspectiva funcional del enunciado (o estructura informativa) también puede inscribirse en la tradición lingüística de Praga, aunque el modelo propuesto por Dik difiere en algunos aspectos de la división clásica de los enunciados en tema (o punto de partida del mensaje) y rema (o juicio que se hace sobre el tema). En primer lugar, se introduce una nueva dicotomía entre las que se denominan *funciones pragmáticas clausales* (o intraclausales) y las funciones pragmáticas no clausales (o extraclausales), que incluyen, como mínimo, el tema y el apéndice.[2] El ejemplo (2) ilustra la función tema y el ejemplo (3) la función apéndice: