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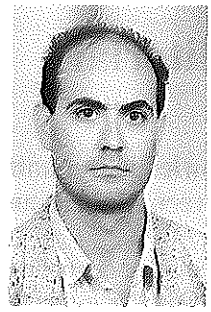

# On Some Contributions of the Cognitive Sciences and Epistemology to a Theory of Classification*

Garcia Marco, F.J., Esteban Navarro, M.A.: **On some contributions of the cognitive sciences and epistemology to a theory of classification.**
Knowl.Org. 20(1993)No.3, p.126-132, 22 refs.
Intended is first of all a preliminary review of the implications that the new approaches to the theory of classification, mainly from Cognitive Psychology and Epistemology may have for information work and research. As a secondary topic the scientific relations existing among Information Science, Epistemology, and the Cognitive Sciences are discussed. Classification is seen as a central activity in all daily and scientific activities, and, of course, of knowledge organization in information services. There is a mutual implication between classification and conceptualization, as the former moves in a natural way to the latter and the best result elaborated for classification is the concept. Research in concept theory is a need for a Theory of Classification. In this direction it is of outstanding importance to integrate the achievements of 'natural concept formation theory' (NCFT) as an alternative approach to conceptualization different from the traditional one of logicians and problem solving reseachers. In conclusion both approaches are seen as being complementary: the NCFT approach being closer to the user and the logical one being more suitable for experts, including 'expert systems'.
(Authors)

## 1. Introduction

### 1.1 Classification as a Central Resource of Human Informational Activity

Undoubtedly, classification is a central activity in documentary organization. This could not be otherwise, because classification is indeed central to human response in all the aspects of its relationship with its environment. So we sincerely believe that thinking about the background of classification will help us to improve, or at least to clarify, our practical tasks as information specialists or librarians.

Knowledge is a fundamental capability of humankind, which needs to survive and be developed as a moral and physical entity. Throughout the ages, humankind has developed a way of understanding the world which differs from that of animals. Its principal characteristic is the development of culture and communication through symbolic and articulated language. That is, human beings act according to a peculiar Weltanschauung, social habit and a communication system that controls and inspires its material, energetic and informative interaction with the rest of humanity and with its environment. Human knowledge is mainly a result of organizing informational perception and representation. Furthermore, knowledge becomes information when it is transmitted in the form of actions and messages, to be transformed after reception and processing by other individuals.

Our perception of the world is the result of the actual status of at least two factors - first the outer world, and secondly the human sensory system aided by more and more efficient and artificially developed devices. On the other hand, representation of knowledge and therefore intelligent communication, which permits our entrance into the real world, depends on the status of two factors - our conceptual and linguistic systems. These four factors model the whole of the human cognitive and communication structure. Moreover, it is the work of the human conceptual system to select, condition and determine the dimensions of the world taken into account in thinking and communicating. The result of this is classifying, ordering and organizing information to generate knowledge.

So, understanding nature implies collecting experiences through senses which are later processed and formalized into concepts and discourses by means of a process that includes, firstly, classifying, by distinguishing among elements, grouping them by relevant dimensions and building criteria for comparison. Secondly it implies ordering by placing, connecting and relating elements along spatial, temporal and other dimensions. Thirdly it involves organizing, through storing, conserving and deleting elements and establishing relationships according to different criteria, and building a knowledge system which becomes more and more complex. From these three cognitive processes result three corresponding types of concepts, which are respectively taxonomic, comparative, and quantitative or measurable.

Together with common and natural knowledge, a method of understanding reality was born. This was scientific knowledge, whose principal feature is systematic reflection on the information provided through our senses in order to achieve more reliable knowledge, capable of guiding more effective human action in the world. Cognitive science is an intricate and circular game of rapport between the human mind and the dynamic phenomenal reality devoted to improving our conceptual frameworks and networks of representation (cognitive maps). The aim is to predict, control, and model the comportment of the latter. Scientific knowledge is interactive dialogue between the phenomena and the theory which supports the praxis over these. It is in this kind of knowledge where the three capabilities of the conceptual human system mentioned above are even more important, but in this case, they are empowered by the reflection on their possibilities and limits. Thus, with a better understanding of the way in which scientific knowledge works we will have a better control and use of the gnosticological and communicative human system on the one hand and on the other hand this enables us to build a theory of theorganization of knowledge devoted to the design and implementation of information management and retrieval systems in harmony with the methods by which science is created and received. In otherwords, information systems must be in harmony with the way in which users of scientific information services behave. This paper deals mainly with the first of these conceptual human capabilities - classification.

### 1.2 Classification as a Central Aspect of Research for Many Sciences

Classification is the central point of research for many sciences. One may think mainly of mathematics, psychology, philosophy, linguistics, and computer science. But other fields are also involved in one way or another, such as in anthropology (e.g. parental systems, ethnolinguistics) and also in biology (botany and zoology - remember Linnaeus). In fact, all sciences are concerned with the problem of classification; the social and human sciences because they are dealing with human processes of which classification is a central aspect; all others because classification is a crucial part of scientific methodology.

### 1.3 The Traditional Concept of Classification Revisited

In this part of the discussion our reflections are centered on the contributions to the understanding of classification processes coming from epistemology and cognitivescience, which have modified to some extent the traditional approach to the classification problem. This has happened in two ways, by pushing it forward to its utmost consequences and by criticizing it.

In some way, the traditional concept of classification has been built mainly by logic and mathematics, as a powerful tool for understanding and modifying our world. The best abstract or theory of this approach was the work of James Boole and his set logic. Without it, modern information science could not have even been thought of. The traditional approach began to be replaced when the first calculating machines quickly evolved towards the first autonomous and intelligent processes carried out by the combination of symbolic representation of intelligent processes (software) and electronic processors (hardware). In fact, the achievement of binary computation was the result of a large melting pot in which mathematicians, logicians, engineers, and neurophysiologists took a protagonist role (1), all of them concerned with problems of information and knowledge.

## 2. Some Observations on the Subject of Interest

### 2.1 Cognitive Sciences or Cognitive Science?

The invention of the artificial mind was also a revolution in our understanding of man's mind. In psychology it brought a new interest in the cognitive aspects of human behaviour and, eventually the birth of the new science of cognition.

A very interesting point about the birth of cognitive science is that very different sciences, traditions and paradigms co-exist in it. In fact, cognitive psychology is not a compact discipline. Structural and functional linguistics and anthropology combined forces with the other 'formal' aspects of cognition. But, parallel to the rational tradition, a more empirical approach devoted to experimental research in behaviour has modified current ideas about learning and knowledge. Psychologists, biologists, and researchers in other fields of the human and social sciences began by criticizing the formal approach to the knowledge of logical tradition. A very interesting and conflicting interaction between postulators of formal models of knowledge and experimental researchers on natural intelligence began. The findings of both approaches turned out to be of critical practical importance. The formal approach provided the theoretical framework for the design of intelligent programmes. Empirical research on natural intelligence provided the necessary tools for understanding the connection between the new artificial extensions of the human mind - computers - and the human mind itself. This is the problem of the human-machine interface. In any case, both are only a part of our history. Joining forces with the formal and empirical paradigms was the functional-evolutionist approach. The heritage of the behaviourists' functional approach and the evolutionist conscience of such cognitivists as Piaget provided a contrast in the work of the great majority of research, concentrated mostly in the built-in characteristics and properties of a 'virtual' mind and its intelligent artifacts. Curiously, these approaches joined forces and the result was the advent of the Information Age. In fact, each particular cognitive researcher was a different mixture of two or three of these ingredients.

Because so many sciences and paradigms are involved in the building of the Science of Cognition, some people speak of it as a federated or confederated group of sciences, collectively referred to as the Cognitive Sciences. Others, mostly related to Artificial Intelligence (AI) research, think of a general science of both artificial and natural intelligence postulating the same principles (2). Because of this, a division exists among cognitive scientists as to those who opt for a reduction of human and artificial intelligence to the same theoretical frame and those who support an ontological difference. It is common to identify the former perspective with hard cognitive science. For purposes of this discussion, cognitive science has been defined as the science of knowledge in a broad, rather than a limited, sense, because the people working in this field are truly interdisciplinary researchers with a common object of interest.

It is not desirable to become too deeply immersed in these concerns, but it is not possible to resist the temptation to state that computing machines are the result of much effort in the understanding and formalization of the processes of the human mind, reaching back at least as far as the Greeks. These efforts culminated with the work of George Boole, in his *The Laws of the Human Mind* (3). This formalization, in addition to advances in engineering, made possible the development of computing machines. If intelligence is adaptation, one should consider both goals and methods, including methods of symbolic processing. This distinction signifies the difference between information and knowledge. One cannot use all information, only the information which makes sense to the individual, and this is knowledge.

Insofar as can be seen, replacing human beings with computing machines which are general purpose processing systems (2) does not imply degrading human status to that of deterministic behaviour of machines. It is a mere consequence of the ability of man to reproduce the natural processes of the mind with the help of external energy sources and the physical properties of other materials. The history of humankind can be understood as the attempt to surpass its own limits by extending itself into three dimensions: its image by means of visual arts (painting, photography, video, etc.), its physical capabilities by means of tools and, more recently by means of robotics, and finally its mental capabilities by means of computers.

## 2.2 Cognitive Science and Information Science: Relations and Gaps

The interest of cognitive psychology for documentation has its limits and there is a gap between cognitive science and information sciences. It must not be forgotten that human cognition is also a social process which requires specialization of functions (co-operation or power) and communication. Only in a sociological sense can documentary information be spoken of as knowledge, as it is part of the cultural heritage of humanity. As social information processes are in fact mediated by psychological processes, it seems clear that the findings of cognitive psychology are intensely relevant to information science. Optimizing the processes of information acquisition implies optimizing cognitive processes.

In conclusion, the authors believe that cognitive psychology is interesting for information scientists for two principal reasons. First of all, information science and cognitive psychology are both cognitive sciences in a broad sense. Both are interested in the way that information produces knowledge, how information is processed, and how a better adaptation of reality is achieved. Secondly, psychological processes mediate the information cycle. This happens mainly in all kinds of interface activities - those between humans and machines[1] and those among humans. This formulation of common interests puts limits on the connections between the two disciplines. Information science must equally consider the transfer of information as a social event, mediated by psychological, historical and social factors, as well as technological factors. On the other hand, information science has in some way modelled the representation of knowledge. For example, Broadbent (4) imagined memory as a great library where everything must be properly classified to be retrieved. Keeping all this in mind, this paper explores some aspects of interest with respect to relationships among epistemology, cognitive psychology and information science.

## 2.3 Epistemology, Cognitive Psychology and Information Science

The contribution of epistemology to the development of information science and its practice is very important. Epistemology is traditionally considered to be that branch of philosophy devoted to the study of the processes of human knowledge, its logic, origins and basis. Actually the study of this process is performed by a number of disciplines which emanate from it, for example psychology, logic and linguistics. Therefore today, the meaning and field of study of epistemology is more restrictive. It is the science centered on the study of the characteristics of scientific discourse and on the evolution of scientific paradigms. Thus it appears to be a more systematic and methodological reflection on the principal resources used by humans to pursue valid knowledge about reality. Psychology is mainly devoted to common and ordinary knowledge (personal and social). Epistemology is devoted specifically to scientific knowledge.

The study of epistemology is, therefore, essential for the design and implementation of better cognitive strategies for guiding the process of documentary analysis, particularly for indexing and abstracting scientific documents. The ordering and classifying of information contained in documents will be improved, thus allowing their effective retrieval only, if it is possible to discover the conceptual framework (terms, concepts, categories, propositions, hypotheses, theories, patterns, and paradigms) of their authors from the discursive elements of texts (words, sentences and paragraphs).

As epistemology studies the historical evolution of scientific paradigms, it is concerned with a key element of these paradigms - the mapping and structure of knowledge, as it exists in each particular age. In this field, it is crucial that emphasis be given to the analysis of scientific methodology and the classification strategies of nature through a branch of epistemology called taxonomy. Thus, the theory of taxonomic systems is very relevant to information science research. Scientific taxonomy is an aspect of documentary classification, because it shows the relationship of a scientific text to other texts and within its scientific context. Also, it helps to maintain universal classification systems, thesauri, and terminological databases according to the general evolution of science and of each particular scientific discipline.

Finally, from a historical perspective, epistemology is also the study of reflections made by philosophers and theorists of science in an abstract and conceptual network, traced between man (subject) and nature (object) in the process of research and knowledge, within the limits and possibilities of understanding reality and its linguistic expression. This is accomplished without misjudgement of the volitional and emotional aspects of cognition. These authors believe that the advances in epistemology in this field make an important contribution to the development of information science, especially in its attempts to develop a theory of classification. This is because documentary classification systems are in close relationship with the two principal contemporary Western approaches to human knowledge - rationalism and logical positivism.

The influence of these philosophical thoughts on the building of classification systems has not usually happened in a conscious way. Philosophical theories of knowledge are usually a synthesis of the dominant characteristics present in a given historical period and proposals to explore new fields. As a consequence, the relationship between epistemology and information science is usually the result of the unconscious impregnation of information theorists with the principal epistemological approaches of their age and sometimes conscious efforts to adopt and adapt these ideas to the field of documentation.

In this sense, the Dewey Decimal and Universal Decimal Classification systems can be thought of primarily as the results of research in taxonomy as it was developed in the 18th century in the field of the natural sciences together with the development of phenetic hierarchical structures. First of all, terminological structures and thesauri can be seen as the assumption of the image that logical atomism casts on the human representation of nature as a precipitate of structured elements. These structured elements can be reduced to basic simple linguistic and logical entitites. Secondly, terminological systems can be seen as a result of the reflections of analytical philosophers who criticized the limits and the contradictions of classical logic and of formalist theories of language, which they considered incapable of producing a proper analysis of the way in which the representation and symbolism of reality is carried out.

## 3. On Some Contributions of Cognitive Psychology to a Theory of Classification

There are many contributions of the sciences of the mind to a theory of classification, but here the concentration is on four topics, which cannot be truly separated, although it is done here in the light of heuristics. First of all, we will try to draw a map of cognition in an effort to explain why classifying is needed. Secondly, we will explore recent research in classification, or categorization in the sense that psychologists usually refer to it.

### 3.1 A Model of Cognition and the Background of Classification

If an idea common to all cognitive paradigms exists, intelligence is a complex, incremental, and circular process which requires at least four stages: perception, representation (or cognition), storage (or memory) and retrieval and then repeating the cycle. Of course, the stages differ in the way they are understood.

#### 3.1.1 The Problem of Unity and Difference: The Root of Classification

Why can one say: to know is to classify? Because human beings are complex open systems. They are different from the rest of the universe, but they are not self-reliant. Also, human beings are part of the universe, but an undifferentiated part of it. After all, difference and integration are the primitive properties of the world we know (or perhaps of our mind, if we take a nominalist point of view). When we have no information, the world does not make sense. Everything is an irreducible difference which we call chaos. But our perceptive system can establish a kind of middle point between absolute perception of difference which could not be processed, and absolute perception of unity, which would make us unable to act and therefore unable to exist in an effectively differentiated world. Thus, classification is a perceptive compromise that helps us to survive and must be based on real properties of the universe, otherwise it would be completely inefficient. Such is not the case. Classification means setting limits[2]. Limits are set as to what something is and what it is not. In this way, human beings can thrive in a complex world. From a psychological point of view, a system can be defined as something that has a perceptive entity. We can look at some configurations that tend to survive as something different from the rest of the universe. In a certain time frame they are systems. Some of these systems can to some extent recreate themselves and their own environment (lat. *informare)* in order to survive. They are intelligent systems and can be described as being alive. A very few of them are even able to understand why they survive - in particular the human system.

#### 3.1.2 From Interaction to representation (Codification): The Need for Memory

A primary concept in understanding intelligent behaviour is that of control over the environment and over itself (5). The idea is that intelligent systems can control their own behaviour and some characteristics of the environment to attain a goal. This is possible because intelligent systems get some 'information' from themselves and their media and then modify it, adapt it to situations in order to achieve their purposes. In other words, intelligent systems can present, represent or codify the interactions of the environment through their own inner interactions. More importantly, they can operate with these representations through the control of their own processes. from an evolutionary point of view; the target of these 'information' processes is logically the activities of their external and internal environments which are directly relevant to their survival and progress (interactions). But, as not all intelligent organisms have the same capabilities and tools for representation of information, their information processes are actually limited to the dimensions that can be represented and codified by the system (cognition). On the other hand, as far as intelligent organisms have a potential for interactive representation, they are not limited to the goal of survival. In fact, the processes of representation of an organism are many and are very diverse, because different parts of an organism may be involved in information representation. Also, it can be concluded that the postulate of representation processes is a theoretical need for three reasons.

First of all, behaviour would not be possible, if an inner knowledge of reality did not exist. Secondly, this knowledge must have some kind of isomorphism with reality, otherwise human behaviour would not be adaptive. Finally, knowledge is only possible in terms of the inner processes and relationships representing the intelligent organism, or in terms of its own abilities to modify its environment, because these are the only things under its control. In other words, knowledge is adaptive representation. Intelligent systems cannot themselves represent the whole universe, only those dimensions of it which are important for, or selected by the systems, depending on their own autonomy. This is done in terms of their own responsibilities for representation and also in terms of truly existent aspects of the world.

Of course, it can be said that representation is not necessary to control interactions, because control can be postulated in simple feedback terms between the system and its environment. The adaptive nature of representations can be understood in terms of energetic efficiency. The system can save energy and avoid risky situations through predictions about the consequences of its actions and about phenomena of the outer world, that is, by stimulating the functions of the environment within itself.

However, the practical problem is to determine the way in which the human system should store these interactions. As stated earlier, interactions can only be stored in terms of the physical (elements) and logical (relational) properties of the human system. That is, they must be represented. The process of representation is one of recodification. Relevant relations (interactions) between elements of the environment are translated into elements of the system. The process of representation can be formalized in terms of the correspondence between the perceptive elements of the environment as effective elements of the system and the perceptive interactions of the environment as effective interactions among elements of the system.

### 3.1.3 Elements and Relationships: The Nature of Perception

What is the nature of such representation or mapping? There are clear limits to the possibilities for representation. So the intelligent system must make choices. There has been a very interesting debate between those who believe that perception originates from elemental units, using bottom-to-top processing, and those who believe that central processes govern perception, using top-to-bottom processing. There is no doubt that perception is built from very elemental units (for example, the perception elements of a visual system). However, there is also no doubt that these units are used to build adaptive and modular representations. In some way, the world is immediately related to human senses (6) but in another way information is the result of the combination of analytical and synthetic processes. This is truly information processing (7). From a systemic point of view and having in mind the representational nature of knowledge this is by no means contradictory. The correspondence between the outer world and our inner representation is achieved in terms of both elements and interactions between those elements. Also it seems that each hemisphere of the brain specializes in each of these dimensions. Care must be taken to note that the perception of elements and of relationships are interchangeable operations and that elements can be distinguished at different levels (for example, atom, cell, organism, society, etc.) and that we formulate the existence of less obvious elements in terms of relationships (for example, society). It is the same with states and processes. A state is formalized as the result of a process and a process is inferred from a change of state. It is also important to keep in mind that there are different processes of representation in the human mind depending on the kind of codification. However, from a very general point of view, representation and codification can be considered synonymous. The term codification has been used here to denote the process of representing information in all possible forms.

### 3.1.4 Storage and Retrieval, or the Nature of Memory

As previously considered, the differences in complexity between the human system and its environment (the whole universe) are physically irreducible[3]. The biological and cultural history of humanity is characterized by the effort to reduce complexity in order to gain further autonomy. The strategy of the human system to gain autonomy is that of any other open complex system - to create deposits and to store energy, materials and information. Having in mind (literally) possible relevant interactions with appropriate responses, the human system can give a fast response to critical configurations of the environment, without succumbing to the need for lengthy reprocessing. This deposit of information is the phenomenon which is usually called memory. It seems evident that representational complexity is as important as correspondence. The more complex a representation is, the more potent is it[4]. There has been strong debate on the characteristics and kinds of memory. The evidence of different storage durations - perceptive, permanent and non-permanent or short-term) memory - has been formalized in different models of memory. These include structural (sensory, long term and short-term memory) (8) and functional or operational models (superficial processing and in-depth processing). In addition, a distinction has been established on the basis of the kind of information - episodic (data) and semantic (knowledge). It seems that an important factor that explains the duration of the memory stage is exposure to a similar configuration (well studied by behaviourists) which can be explained from an adaptive point of view. The human system has more time to do this and it seems more pertinent to process something that happens frequently. However, another important mechanism of memorization is purely emotional and even more clearly adaptive.

Something very pleasant or very unpleasant is more likely to be stored than another less intensive happening.

The short-term memory is seen as a working space where information is processed. This memory is very limited. In a very interesting and indeed amusing paper by George Miller (9), it is demonstrated that the short-term memory is only able to process seven units, plus or minus two. (Curiously the capital sins, the wonders of the world, etc. are seven in number). More interesting is the strategy that the human mind has worked out a way to overcome this limitation. Items can be joined into new units and a unit can be broken into items by a mechanism that Miller called "chunking". Items in memory can be organized, and one of the major principles of the mind is perception and operation on the basis of units (i.e. classification).

Miller did not communicate to us anything about the kinds of operations that govern "chunking". One of the groups of persons that has undoubtedly worked more on this problem is Jean Piaget and his followers. The relationship between operations such as "chunking" and classification is even better demonstrated in traditional problem-solving approaches to a theory of concepts.

### 3.1.5 From Individual to Social Representation: The Use of Signs

Human beings are used to working with labelled concepts, that is, concepts expressed by visible elements, whether they be reproductions, icons or signs. Signs are only representations and they are designed to be the subject of operations. However, what must be kept in mind (10) is that signs are a social product. They are part of a social code and can change from one society to another. As most human actions are socially conditioned, there is a functional correspondence between the world of signs and the world of social life. The achievement of external memories, thanks to the invention of alphabets resulted in the beginning of the age of documentation and librarianship.

## 3.2 The Cognitive Paradigms in Classification Research

Three different approaches to the classification problem in psychology can be distinguished

- the traditional problem-solving approach to concept formation,
- the natural concept formation theory and
- the contributions to the study of (verbal) semantic processing.

This latter approach is closely connected with the study of long-term memory.

The first approach, the classical approach, to concept formation (best represented by Bruner (11)) assumes that the classifier faced with the need for a solution, examines and abstracts the relevant dimensions of a set of items and classifies them on these bases. This is very consistent with the approach of philosophical logic and conceptology. The pertinence of an item to a category can be abstracted from relevant dimensions of properties of the set of objects that define a clear difference from the rest of the objects of the universe (intension). Inversely, from a set of objects that are postulated to be part of a category (extension), the dimensions of subcategories can be inferred. This results in a very ordered representation of the world which becomes more and more coherent and consistent. This is also the common approach in the design of classification systems and retrieval tools.

The second approach is a very strong critic of the first, both philosophically and experimentally - Rosch and Lloyd (12) must here be acknowledged with merit. Their conclusions were simple. First, not all items in a category are considered by the classifiers to be equally representative of a category. Secondly, a category is structured around a central sample which is called a prototype. Thirdly, natural categories can be considered to be at the same level. Some categories are immediately retrieved and learned first by children (basic concepts, such as 'dog'). Others require complicated operations to be retrieved or formed and are learned at a later stage. They are supraordinate concepts (such as 'society'); or subordinate concepts (such as 'atom'). For example, the concept 'dog' is acquired early in human development, but concepts, such as 'collie' or 'animal' are acquired later. This has important implications for the building of retrieval tools insofar as they are thought to be for the use of common people. The access points in such tools should be based on basic concepts, keeping in mind the middle intellectual level of the users. This also explains why special retrieval tools are always needed to serve particular situations.

Lastly, the contributions of research to semantic processing need to be considered. To accomplish this aim, two different methods of storing information with attention to the relationships established among entities must be examined. There are two kinds of memories - episodic (discrete events, spatially and temporally identified) and semantic (the ability of users to classify and understand reality).

Also, two methods by which semantic information is integrated into the long-term memory have been detected. The first method could be called sequential organization. It has been observed that there is a tendency to remember things in the same order as they were learned (13). Going far beyond this fact, Schank and Abelson (14) have studied 'sense' in relation to meaningful sequences affirming that human beings understand information by comparing it with the usual sequences that we know to happen in real life. So human beings learn how to act and how other human beings act and they learn to speak about actions.

The second method is analytico-synthetic processing. In this case, human beings explain the meaning of things by relating to their elements, to the structures they belong to, or to the properties they have. Concept nets or maps are the common models of memory that are produced from this point of view as discussed by Collins and Quillian (15) and more recently elaborated by Novak and Gowin (16). The first method is closely related to the natural concepts formation approach, while the second method is related to the traditional approach. It brings to mind the distinction that Watzlawitz (17) made between analogical and logical processing. The first method requires decisions on the basis of user familiarity and understanding of similarity. The second acts on the basis of difference and identity in terms of "that is, that is not".

A practical theory of classification should have in mind both conceptions of the categorization process. It must consider the natural processing that takes place in the minds of human beings who categorize primarily on the basis of basic concepts and analogy. Also it must take into account the benefits of logical processing, which can improve the logic of classification systems. However, perhaps the first approach should be used in the interface design, and the second one primarily in built-in documentary linguistics engineering, and in the design of expert systems for retrieving information.

## 4. Conclusion: Towards an Integrative Theory of Classification

This discussion began by describing how the traditional concept of classification was mainly a result of the historical development of epistemology, logic and mathematics, a beginning which can be admired in the more recent creation of intelligent machines. However, this was only the beginning of history, because now even mathematics, informatics and logic have been transformed through new ways of understanding classification. As a result, we now have as key research topics, fuzzy set theory against Boolean logic, connectionism against knowledge engineering and probabilistic approaches against deterministic methods. Now that the image that humanity, in its own way of thinking and being, has changed, the formal sciences are formulating a new, not so logical and not so formal, image of themselves and their world in which contemporary human beings see in the mirror of evolution.

In conclusion, these authors believe that the two approaches are complementary. Rigid logic approaches are very economical in time and resources and not so rigid approaches are usually better adapted to reality than the former. Thus we agree with Davis Ellis (18) that the belief that neither physico-logical nor cognitive paradigms alone are able to explain either classification processes or information science. After all, both are only products of that which pretends to explain (i.e. classification). Last, but not least, classification cannot be understood without reference to its aims, which are best accomplished in different ways for each individual problem.

## Notes

* Paper presented at the Joint FID/CR and ISKO Meeting, Madrid, 20 Oct.1992 preceding the 46th FID Conference and Congress, Madrid, 21-30 Oct.1992.

1 Which is now an important scientific field. In some way, the problem of Human-Machine Interaction (HMI) puts information science into the centre of the information processing sciences, because it connects both tendencies: the study of human intelligence and the study of artificial intelligence.

2 The problem of *limit* is a central aspect of philosophical enquiry (see Izuzquiza (21)) and also of mathematics. *Limit* is crucial to perception, but it can also mislead perception.

3 We must only consider the dfferences in the number of atoms.

4 We can think of the map of a city: the more precise it is, the easier can one get to a particular place.

## References

(1) Gardner, H.: The mind's new science: A history of the cognitive revolution. New York: Basic Books 1985.

(2) Phlyshyn, Z.W.: Computation and cognition: Toward a foundation for cognitive science. Cambridge, MA: MIT Press 1984.

(3) Boole, G.: The laws of the human mind.

(4) Broadbent, D.E.: The well-ordered mind. Amer.Educ.Res.J. 3(1966) p.281-295

(5) Wiener, N.: Cybernetics, or control and communication in the animal and the machine. Cambridge, MA: MIT Press 1948.

(6) Gibson, J.J.: The ecological approach to visual perception. Hillsdale, N.J.: Lawrence Erlbaum 1986.

(7) Marr, D.: Vision. San Francisco: Freeman 1982.

(8) Atkinson, R.C., Shiffrin, R.M.: Human memory: A proposed system and its control processes. In: Spence, K.W., Spence, J.T.: The psychology of learning and motivation. Vol.2. New York: Academic Press 1968. p.89-122

(9) Miller, G.A.: The magical number Seven, plus or minus two: Some limits on our capacity for processing information. Psychol.Rev. 63(1956)p.81-97

(10) Wertsch, J.V.: Vygotsky and the social formation of mind. Cambridge, MA: Harvard Univ.Press 1985.

(11) Bruner, J.S.: Beyond the information given: Studies in the psychology of knowing. New York: Norton 1973.

(12) Rosch, E.: Lloyd, B.B.: Cognition and categorisation. Hillsdale, N.J.: Lawrence Erlbaum 1978.

(13) Tulding, E.: Subjective organization and effects of repetition in multi-trial free-recall learning and verbal behaviour. (1966)No.5, p.193-197

(14) Schank, R.C., Abelson, R.P.: Scripts, plans, goals, and understanding. Hillsdale, N.J.: Lawrence Erlbaum 1977.

(15) Collins A.M., Quillian, M.R.: Retrieval time from semantic memory. J.Verbal Learning and Verbal Behaviour 8(1969)p.240-247

(16) Novak, J.D., Gowin, D.R.: Learning how to learn. Cambridge, GB: Cambridge Univ.Press 1984.

(17) Watzlawitz, P.: Teoria de la communicacion humana. Barcelona: Herder 1989 (Spanish translation)

(18) Ellis, D.: The physical and cognitive paradigm in information retrieval research. J.Doc. 48(1992)p.45-56

(19) Dahlberg, I.: Knowledge organization and terminology: Philosophical and linguistic bases. Int.Classif. 19(1992)No.2, p.65-71

(20) Dahlberg, I.: Philosophical foundations of conceptual ordering systems. In: Negrini, G. et al (Eds.): Documentary languages and databases. Frankfurt/Main: INDEKS Verl.1991. p.102-119

(21) Izuzquiza, I.: Hegel o la rebelion contra el limite: un ensayo de interpretacion. Zaragoza: Prensas Universitarias de Zaragoza 1991.

(22) Mosterin, J.: La estructura de los conceptos cientificos. In: Conceptos y teorías en la ciencia. Madrid: Alianza Editorial 1984. p.11-39

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