INFORMATION AND INFERENCE AS COMBINED COGNITIVE PROCESSES

Alfredo O. **López Alonso** *

Resumen

El concepto de *inferencia* es bastante oscuro y complejo, especialmente cuando se lo vincula con el de información y su procesamiento; ambos están estrechamente imbricados. Las inferencias pueden ser vistas como medio para acceder a distintas categorías de conceptos, relacionarlos y generar nuevas categorizaciones y conceptos. Las inferencias facilitan la construcción y la comprensión del discurso. El discurso tiene una estructura inferencial dinámica que permite formaciones y transformaciones de significados. Uno de los roles claves de las inferencias es llenar vacíos o lagunas de la información disponible, logrando representaciones que dan mayor continuidad y coherencia a los argumentos. Las inferencias construyen y completan la información textual y contextual faltante al mensaje fragmentario. El empleo racional y avanzado de la información descansa sobre implicaciones que sólo pueden dar esos recursos inferenciales. Existe un trasfondo inferencial en toda búsqueda atinada y pertinente de información y su ulterior procesamiento, por lo cual postulamos una interacción dinámica entre inferencias implícitas y explícitas de toda información que permiten anticipar aspectos imprevisibles de creatividad humana.

Palabras clave: Información e inferencia - procesos inferenciales - procesamiento de la información.

---

* Psychological Doctor. Researcher of Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET). Director of Instituto de Investigaciones Psicológicas de la Universidad del Salvador (IIPUS). E-Mail: alalonso@ciudad.com.ar

Abstract

The concept of *inference* is complex and obscure, especially when linked with that of *information processing*. Cognitively, inferences are a medium to access related categories and draw new categorizations. Inferences also facilitate comprehension of discourse. A key role of inferences is then to fill gaps in available information to complete meanings and contextual senses for the missing ones. So rational use of information rests on further implications of exclusive inferential resources. An inferential background for information search and processing is then postulated upon interacting dynamics between implicit and explicit inferences that may render unforeseeable determinants of innovation and creativity.

Key words: Information and inference - inferential processes - information processing.

Information processing has been usually referred to as *automatic processing, cascade processing,* and *conceptually data driven processing*. Inference processing is made whenever a reasoner, either human or machine, goes beyond the information given. Inferences occur in all kinds of information understanding and information reasoning. Information processing is closely imbricated with inferential processing; nevertheless, the inferential structures involved in information processing have not been suficiently studied.

Firstly, in the case of information *automatic processing* the issue has been defined as any mental operation occurring without the need for conscious initiation nor conscious control, in a way that many times have been recalled as preconscious or preattentive processes. In this case inferences are minimal. And this is really the way they happen, however automatic processes are not simply random nor hazardous processes, actually they are inferentially pre-coded and crystallized processes structured to work automatically and not to be thought each time again. Experimenters can obtain a proof of the latency of this kind of inferential processing by merely pro-

voking an effect that is incongruent or contradictory to the inferential effect automatically expected. One well known automatic phenomenon of this kind is the *Stroop Effect* (first reported by J. Ridley Stroop in 1935) by which people are much slower to name the *green color* for the incongruent word *RED* in *green ink* than for the control stimulus *XXX* in green ink. The incongruity between the color of the meaning and the color of the writing ink of the word breaks or suspend the automaticity of the implicit inferential process for a while, causing a kind of retardation deserving analysis and explanation. Automatic processing seems to be a step-by-step process in which necessary and sufficient inferences to thoroughly solving the problem were thought at one time and immediately encoded as algorithms in order not to be slowly thought about again but to be quickly unthinkingly acted. So, we consider automatic processing of data information as product of compacted inferences to be simply acted. Automatic processing is an inferentially expected process, that when incongruity appears it is because that something unexpected or not foreseen in the inferential sequence has appeared. The set of inferences made automated to reach this effect stands occult and compacted as an implicit inference behind this kind of information processing. Alternative interference and facilitation effects may occur since later studies demonstrated a small facilitation effect when ink color naming time was faster for congruent stimuli such as the word *RED* in *red ink* than for the *XXX* control word. This means contrarily that when the implicit inference or expected effect is confirmed by data, the automatic processing is accelerated, thus showing a facilitation effect. This way, interference effect seems to correspond to implicit contradiction, and facilitation effect to implicit confirmation as behind inferential effects on the automated inference. Both effects are at the verge of the line of separation or transformation between implicit and explicit inferential processes as well as between automatic and serial processes, and bottom-up and top-down processes. This provides an alternative explanation to the problem of the intricate relationship between information and inference at the level of automatic information processing.

Secondly, in the case of information *cascade processing*, this term refers to the notion that *later* stages combining information and inferential processing can be set into operation prior to the completion of information processing earlier stages (Humphreys, 1991; McClelland, 1979). A complex task can be broken down into a number of distinct stages, which, put together, enable the complete task to be inferentially performed. In addition, many of these stages can be sequentially ordered, in the sense that *early stages* must begin before *later stages*, which means that they are

inferentially ordered. Information processing models of cognitive performance typically assume that processing is based on a series of such component stages. A *discrete processing model* is one in which information is passed from one stage to another only after processing at the earlier stage is completed (Sternberg, 1969).

A system operating in cascade can be thought of as entertaining sets of hypotheses about stimulus that are inferentially confirmed or disconfirmed as more stimulus information is gathered. The way in which different variables affect a system operating in cascade is considerably more complex than the way in which variables affect a discrete processing system. Cascade models of performance have gained in popularity since the advent of *connectionist* models of information processing, many of which operate in a cascade manner. Cascade operations are also important for the way in which such models can learn inferential relations between stimuli and responses (Rumelhart, Hinton, & Williams, 1986). Tests of whether human information processing is best conceptualized in terms of a discrete or a cascade processing model have to date produced mixed results.

Thirdly, it is the case of comparing *data driven processing* to *conceptually driven processing* where the connection between information and inference becomes more evident. The distinction between these two types of informational models refers to the corresponding flow of inferential control in information processing. *Data driven processing* is a bottom-up information processing that is initiated, guided and determined by stimulus information coming in from the outside world and currently being received by the sense organs. *Conceptually driven processing* is a top-down information processing guided inferentially by the information already stored in memory; that is, guided by the prior knowledge and concepts acquired from previous experience. Inference, this way, is a basic process linking and making understandable novel inputs of information with general knowledge and previous experience. The distinction between bottom-up and top-down processing comes from computer science (Norman, & Rumelhart, 1975). Bottom-up processing is an informational sequence that starts with a low-level analysis of the sensory inputs coming from the physical features of external stimuli and ends by building upwards toward a final high-level interpretation or categorization. Top-down processing begins by the *higher level* processes generating expectations and hypotheses from immediate interpretation and categorical evaluations of the sensorial input.

Many cognitive activities such as memory, perception, and language understanding, can involve both data-driven and concept-driven processing, although their role is different and controversial. Data-driven processing is

the basic approach emphasized by Gibson's (1979) theory of direct perception, while top-down processing is the basic approach for constructivist or inferential theories of perception inaugurated by von Helmholz. For Gibson dynamic changes in visual patterns for example, provide enough stimulus information from environmental objects to be directly recognized in a way that is sufficiently rich to adopt proper actions and applications in reply. On the opposite side, the constructivist inferential approach views perception as a-priori influenced by expectations that derive from the perceiver's past experience as well as from the current context. Recognition is the product of inferences based on knowledge about how the world is organized, that works as a supplement of the sense data. The contribution of top-down processing varies with the availability of contextual information and with the quality of the stimulus information. Top-down processing offers short cuts so that a message can be understood without having to be completely analyzed.

Summarily, data-driven processes are characterized as parallel, automatic, effortless, unconscious, and relatively unaffected by capacity limitations; while concept-driven processing, by contrast, are characterized as serial, requiring conscious control, and drawing on limited capacity resources.

However, an intermediate approach between the two antagonistic above is represented by Neisser's (1967) *analysis - by - synthesis model*, which incorporates both data-driven and conceptually driven processing working interactively and altogether. This is for us the model which better reflects the information / inference interaction. Within this view, the relative contribution of each type of processing is flexibly determined by the quality of the stimulus information and the availability of contextual information. In the analysis-by-synthesis model (Cohen, 1991, p. 89) "the initial stage of data-driven analysis is followed by a stage in which an internal representation is synthesized. The synthesis is based on the information derived from the initial analysis together with conceptually driven hypotheses derived from prior knowledge. This representation is then matched against the input. If there is a match, the stimulus is recognized; if a mismatch occurs, the cycle is repeated and alternative representations are synthesized until a match is found". Interactive models of this general kind have been developed to account for language processing. Language understanding involves several levels of analysis, both low-level processes of physical analysis and higher level processes carrying out syntactic and semantic analysis. In speech and reading perception, data-driven and concept-driven processes interact systematically.

A fourth example could be represented by the *chunking phenomenon*. The concept of *chunking* refers to the cognitive representation phenomenon by which the limitations of short-term memory can be overcome by grouping or chunking the information into larger units. This reconstruction process was forwarded by Miller (1956) in his influential article entitled *The magical number seven, plus and minus two*. Miller termed *chunk* each recoded pack of information, and proposed that the immediate memory span, measured in chunks, is relatively constant (for seven plus or minus two) for different types of material. And a fifth one could rest on *categorization*, here the inference role is a visible part of the process.

Baron (1995) for whom any kind of thinking is rational whenever it helps people fulfill their goals by way of logic or by way of what is irrational but opportune, affirms that thinking about actions, beliefs, and personal goals can all be described in terms of a common framework, which asserts that thinking consists of *search* and *inference*. So, the main characteristics of thinking are that it begins with doubt and then it involves a search directed at removing the doubt, a first goal by which thinking becomes exploration. Further, we can conclude that this exploration is an active search for additional information that turns out to be necessary from an inferential approach. This way, the human information processors do not only receive external data inputs passively, rather they select them actively from a monitorial function which defines and decides inferentially what is the missing information logically or opportunely necessary to reach our goals. Inferences allow human processors to interpret and change the meaning of information according to the context and text-context relations in which information is involved.

Finally, what's about inference and about creativity with respect to available information, information meaning, information incompleteness, and information further processing going beyond our immediate and usually expected goals?

As above stated, inferences are made whenever a reasoner goes beyond the evidence given by information, but not only to complete it but to create it, that is to create new meaning about the same base of data. Inferences occur in every kind of understanding and reasoning processes. But inferences may be valid or not valid from a formal logical standpoint. However, inferences are mostly made in cases in which are only likely to be the case, rather than in cases in which are necessarily the case. Inferences usually allude to different relations to be stated between meaningful terms, but these relations can be stated in terms of formal and propositional logic, class and relation logic, set theory, modal expressions and heuristically.

From a logical standpoint basic inferences are deductive or inductive. A number of aspects of inferences are of interest to the psychologists: First, there is the question of how efficiently human beings draw conclusions which are licensed (or enabled) by the logic of a situation. Second, the same question can be asked of specified kinds of pragmatic reasoning, where the conclusion may be about the likelihood of something, rather than something necessarily being the case. But above all, and as Sanford states "inferences occur everywhere in perception, reasoning, understanding, and language comprehension. This raises the third and perhaps most important issue, that of what it is that controls and contains the inferences which one makes in a given situation, a particularly interesting issue, since in theory, most premises will allow an indeterminately large set of inferences to be made (1991, p. 187)".

Sir Frederic Bartlett (1886-1969) in his book *Remembering: An experimental and social study* (1932) advanced the view that much of the experimental work concerned with human memory lacked validity because the experiments were unrealistic. He argued that using unrealistic as well as meaningless material in memory experiments (as it was the case of Ebbinghaus, for example) made research methods unlikely to discover anything significant about memory. We think that Bartlett was stressing not only the role of meaning but also he role of inferences when stating the above prevention, since inferences are the ways to endow, transform, amplify and complete the meaning from one set of data into another set of data. That is, meaningless material allows no other than *the minimal inference* that *there is no meaning*, and perhaps opens the series of *inferential questions* such as: "What's the meaning to that matter? Why doesn't it have any meaning? or How is it possible not to find any meaning?". Questions and problem solving are inferential processes searching for response or solution meanings and inner coherence to be provided to incomplete or lacunar sets of information; that is inferences fill the gaps or missing parts of information that are necessary to reach full comprehension, coherence, logical closure and reversibility of complete information processing.

One of the most striking phenomena, combining memory and information processing, noticed by Bartlett, is that subjects introduced aspects of their own knowledge about the world so as to make the story more coherent from their own point of view. Human mind seems prone to consider automatically or spontaneously meaning and coherence as a must, or, at least, as easily replaceable by inference (or easily attainable by way of inference) when meaning and coherence are missing or not immediately available. So information meaning and coherence are mutually imbricated

with inference processing in their accessibility and availability to the categorization of data perceptually coming in from the permanently changing outer world. Ultimately, data categorization is indispensable to understand and inferentially develop further data information.

Extending neurologist Head's concept of *schema* to describe the internal body image that enables us to know the relations between body and environment, Bartlett suggested that we also have internal *schemata* dealing with our knowledge of how the world is, a concept near to that of Schank and Abelson's (1977) *scripts.* In this sense not only remembering, but also meaning and inferring from data seem to be a dynamic basic process to construct schemes of real-world representations. A recent investigation of ours own showed the alternative and different ways by which individuals construct social representations from a convergent literal meaning to a divergent inferential meaning (López Alonso, 2000).

Finally, what is creativity within the context of information and inference? *Creativity* refers to the ability to produce unusual, high-quality solutions to problems. It has often been argued that there are significant aspects of human intelligence, which are not adequately assessed by intelligence tests. Guilford (1961)**,** for example, drew a distinction between convergent thinking, which is required by most intelligence tests, and divergent thinking, which is not. However, creativity seems to be more firmly related to divergent rather than to convergent thinking. As Eysenck (1991, p. 86) states it: "Convergent thinking refers to thinking of a deductive kind in which there is a single appropriate answer, whereas divergent thinking involves non-logical processes and novel situations in which there may be several relevant answers." "Divergent thinking, or the ability to think of diverse valuable alternatives to a novel situation, forms a major part of which is often known as creativity."

Creativity has been a notoriously evasive and difficult phenomenon to study in laboratory. Many tests of divergent thinking or creativity are basically measuring originality rather than creativity. That is to say, they assess the tendency to produce unusual solutions to a problem, but do no evaluate satisfactorily the quality and usefulness of those solutions. In the results mentioned above, we have observed that a divergent meaning that is not typical, rarely implies a richer meaning. This criterion is conducive to believe that a creative genius is the same as a divergent mad man insofar as he does not get into a representation path actually showing a social or a cultural success because of valuable discovery or invention. Notwithstanding, creativity always purports some kind of divergence and unexpectedness in terms of usual information and inference.

From the complexity point of view, creativity is that emergent part of the world which is open and undetermined to unpredictable changes. That is, that part which makes concrete itself with no rational cause nor any necessary antecedent at first sight. A point at which reality is free to crack anew in any unexpected direction, and a crossroad point at which the solution to an unsolvable problem is to change the problem into another problem, or a categorization into another categorization. A point at which the informational text changes into a new context, because while the informational text is limited, the inferential context has no limitations.

Figure 1

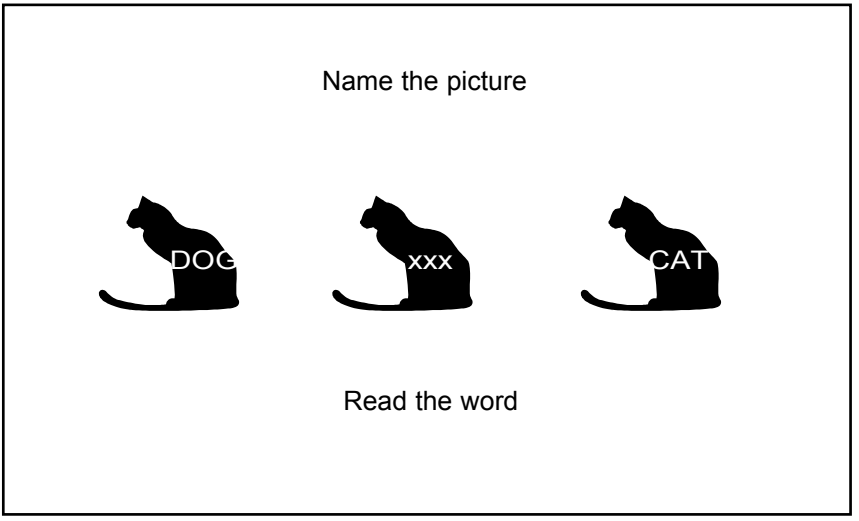

Figure 2
Stroop effect

Interference is Asymmetrical	Read the word	Response time	Name the ink color	Response time
	RED	=	RED	slower
XXX:	CAT	=	CAT	=
XXX:	DOG	=	DOG	=

Figure 3
Stroop effect

Interference is Asymmetrical	Read the word	Response time	Name the ink color	Response time
	RED	=	RED	=
XXX:	CAT	=	CAT	=
XXX:	DOG	=	DOG	=

Figure 4
Stroop effect

Interference is Asymmetrical	Read the word	Response time	Name the ink color	Response time
	RED	=	RED	faster
XXX:	CAT	=	CAT	=
XXX:	DOG	=	DOG	=

References

Baron, J. (1995). *Thinking and deciding* (2nd ed.). Cambridge: Cambridge University Press.

Bartlett, F. (1932). *Remembering: An experimental and social study*. Cambridge: Cambridge University Press.

Cohen, G. (1991). Data-driven and conceptually driven processing. In M.W. Eysenck (Ed.), *The Blackwell dictionary of cognitive psychology.* Blackwell Reference. Cambridge, MA: Basil Blackwell Inc.

Gibson, J.J. (1979). *The ecological approach to visual perception*. Boston, MA: Houghton-Mifflin.

Guilford, J.P. (1961). Factorial angles of psychology. *Psychological Review, 68*, 1-10.

Humpherys, G.W. (1991). Cascade processing. In M.W. Eysenck (Ed.), *The Blackwell dictionary of cognitive psychology*. Blackwell Reference. Cambridge, MA: Basil Blackwell.

McClelland, J.L. (1979). On the time relations of mental processes: An examination of systems of processes in cascade. *Psychological Review, 86,* 287-330.

Miller, G.A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review, 63*, 81-97.

Neisser, U. (1967). *Cognitive psychology*. NY: Appleton-Century-Crofts.

Norman, D.A., & Rumelhart, D.E. (1975). *Exploration in cognition*. San Francisco: Freeman.

Rumelhart, D.E., Hinton, G.E., & Williams, R.J. (1986). Learning internal representations by error propagation. In D.E. Rumelhart, & J.L. McClelland (Eds.), *Parallel distributed processing: Explorations in the microstructure of cognition (Vol I): Foundations*. Cambridge, MA: MIT Press.

Sanford, A.J. (1991). Inference. In Eysenck, M.W. (Ed.), *The Blackwell dictionary of cognitive psychology*. Blackwell Reference. Cambridge, MA: Basil Blackwell.

Schank, R.C., & Abelson, R.P. (1977). *Scripts, plans, goals and understanding*. Hillsdale, NJ: Erlbaum Associates.

Stenberg, S. (1969). The discovery of processing stages: Extensions of Donders' method. In W.G. Koster (Ed.), *Attention and performance II*. Amsterdam: North Holland.

Instituto de Investigaciones Psicológicas
de la Universidad del Salvador (IIPUS)
Marcelo T. de Alvear 1326 - 1er Piso
(C1058AAV) Buenos Aires - Argentina

Received: April 16, 2001
Accepted: April 30, 2001