Logical Errors and Psychological Errors

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The article first examines the main errors committed by subjects studied within the psychology of reasoning, referring to the theories of natural logic and mental models. It then highlights some assumptions that lead these theories to difficulties in explaining everyday reasoning: the assumption that subjects, during reasoning, always (a) possess hypotheses and (b) follow strategies; (c) the closed-world assumption, meaning that the most relevant knowledge is that provided by the experimenter. For the analysis of the first two "errors," an analogy is drawn with the general domain of inductive or concept-formation tasks; for the third, reference is made to evidence emerging from the use of new experimental paradigms, such as the study of "semantic deprivation." In conclusion, some differences between natural logic and formal logic are highlighted, and tasks for studying reasoning from a more natural psychological perspective are examined.

1. Introduction

Behind the questions raised regarding the relationship between everyday logic and formal logic, hidden expectations likely exist. When we wonder how they relate, whether they are identical, or if they have something in common, what is actually in the background is a much more ambitious question—perhaps too ambitious for psychology—which is whether human beings are rational.

Sometimes in discussions among psychologists, this question emerges explicitly, but I do not believe that psychology has the credentials to provide an answer, assuming it is even possible to do so. This is also because the answer obviously depends on what is meant by rationality, which is not easy to say, even though recent attempts to define and classify types of rationality are not lacking (e.g., Evans, 1993).

There are, however, other less ambitious but still important reasons that prompt a deeper psychological exploration of this relationship between common logic and standard logic. For one, there is currently significant interest in so-called "naive" theories of the world, and there is also a major resurgence of *naive psychology*, common sense, or *folk psychology*. Following research on how people spontaneously conceive situations studied in scientific fields, for example, in physics (such as the classic research on so-called naive physics) (see McCloskey, 1983), it was natural to move on to how people conceive of the facts studied by psychology: mental or behavioral facts.

Parallel to this, there is also a tendency to overcome the isolation of a certain cognitive psychology within the laboratory and on artificial tasks—a tendency made evident primarily by Gibson's *ecological* perspective, which now finds increasingly broad consensus (cf. Greco, 1995). These are fairly recent trends, which, however, have not yet influenced all sectors of psychology. And among the sectors that seem to have been influenced the least is precisely the psychology of reasoning.

Yet it seems clear that if the study of reasoning were limited to specific laboratory tasks or situations (such as the four-card task, to name the most famous) and did not claim to generalize to everyday reasoning, its interest would be equal to that of the psychology of crossword puzzles (as Oaksford and Chater, 1995, have said). Indeed, traditionally, the situations used by psychology in the study of reasoning are precisely laboratory, artificial situations, different from those encountered daily. More precisely, psychology has chosen to study tasks and situations classically proposed by philosophy (and later by logic), prioritizing those in which it is easy to make errors (the so-called fallacies).

If, therefore, those who study the psychology of reasoning usually focus on the logical errors that people make when reasoning, here instead I intend to speak about some "psychological errors" (in the sense of errors in doing psychology) committed by psychologists of reasoning.

To do this, I will first briefly recall the main tasks and situations that have been studied by the psychology of reasoning, along with the respective errors committed by subjects. I will then refer to the two most important theoretical frameworks concerning reasoning, namely the theory of natural logic and that of mental models, without delving into great detail but merely to observe how they are not so different in certain respects and are not free from difficulties when discussing common reasoning. In particular, I will then outline what I have defined as "psychological errors," which, as we will see, concern: a) assuming that strategies and hypotheses are natural; b) assuming that reasoning takes place in a closed world. Finally, I will try to outline some characteristics of natural logic compared to formal logic and how reasoning could be studied from a more natural psychological perspective.

Table 1 - Some difficulties and fallacies in deductive reasoning and their explanation

Category	***Errors in drawing the conclusion from the premises***	
a) relational (linear series or order of magnitude problems)	• Aldo is taller than Bruno • Carlo is taller than Aldo → Who is taller? (C > A > B) → Or: "Bruno is taller than Carlo": true or false?	<u>Particularly difficult examples:</u> • Bruno is not as tall as Aldo • Bruno is not as short as Carlo → ?
	Classic fallacies	
b) propositional b1) non-quantified (conditionals)	*affirming the consequent* • If it rains, then I get wet (If P then Q) • I get wet (Q) • Therefore, it rains (Therefore P)	*denying the antecedent* • It does not rain (not P) • Therefore, I do not get wet (Therefore not Q)
b2) quantified / syllogisms	***Conflation between truth and validity*** • All children love school • All schoolchildren are children • Therefore: all schoolchildren love school → *(valid but not necessarily true*	
	Other errors	
	atmosphere effect • Some A are B • Some B are C → Therefore, some A are C *(invalid)*	*conversion errors (undistributed middle)* • All A are B • All C are B → Therefore, all A are C → *(invalid - perhaps the second premise is converted into "All B are C")*

2. Main Types of Reasoning and Respective Errors

To frame the topic, it is useful to briefly recall (without claiming to be exhaustive) the main tasks or situations that have been studied within the field of the psychology of reasoning, along with the primary difficulties and "errors" that have been highlighted.

The main types of reasoning are *deductive, inductive*, and *probabilistic*. Within deductive reasoning, the most important types are *relational, conditional*, and *syllogistic* (see Table 1). In relational reasoning, the most common errors occur in *drawing the conclusion* from the premises; in conditional reasoning, classic fallacies occur, such as *affirming the consequent* or *denying the antecedent*; in *syllogisms*, the most relevant aspect is above all the fact that what is true or plausible is confused with what is formally valid (in addition to more technical errors like the atmosphere effect or conversion errors).

In inductive reasoning, difficulties are encountered in rationally performing tasks of rule discovery or verification, such as Wason's tasks: the selection task (Wason, 1966) and the 2-4-6 task (Wason, 1960). In these cases, a difficulty in conforming to logic seems to emerge, as well as a tendency toward hypothesis confirmation when it would be more rational to attempt to falsify them.

In probabilistic reasoning, the greatest difficulties consist in not evaluating probability based on objective parameters like frequency, but on subjective ones like the greater availability or accessibility of certain representations, the presence of stereotypes, etc.

3. Psychological Explanations of Reasoning and Its Errors

Not all of these various types of reasoning have been studied to the same extent. The most common are *propositional deductive reasoning* (that of conditionals and syllogisms) or certain tasks that have enjoyed extraordinary success, such as the selection task (called the "four-card task")[1].

However, even upon a summary analysis of the problems studied, the limitations of the very facts chosen for explanation appear evident, as they clearly almost never refer to spontaneous reasoning carried out in natural situations.

Furthermore, already in the choice of facts considered "facts of reasoning," the prevailing idea (more or less explicit) appears clear: to explain everyday reasoning, one must explain why errors are made with respect to logical norms—a "psychology of error," which involves different explanations for correct thinking and incorrect thinking (cf. Mosconi, 1990).

This means there is no single theory explaining how people *normally* reason. Moreover, even to explain the difficulties in different types of reasoning, there is no single theory. Rather, the impression is that there are many ad hoc theories to explain various problems. The main approaches, as mentioned, apply primarily to deductive reasoning and are essentially two: natural logic and mental models.

"Natural Logic"

The way the first approach proceeds is, in my view, paradigmatic. Psychology attempted to start first of all from the standard approach to the study of reasoning—that of logicians—but realized (and really, a minimum of observation was enough, because it is obvious) that people normally do not use formal logic. Too bad, they said to themselves, because logic, precisely as a system of *formal* rules, was so attractive as a clear, clean, general theory of how we reason! The idea was therefore to see if formal logic could be replaced with a more psychological formal logic. Thus was born the approach of so-called *natural logic*, presented by Braine (1978) and which remains one of the competing approaches in the study of reasoning (Braine, 1994).

Braine (1978), primarily to explain syllogistic reasoning, described a system different from standard logic, which nevertheless remained a formal system but was somewhat more flexible, taking into account that in natural language, connectives (such as "if... then," "or," "and") have a broader meaning than in logic. For example, "if... then" sometimes refers to a conditional, other times to a biconditional. The idea then was to eliminate these ambiguities and identify *natural inference schemas* that people use without being aware of them.

These natural schemas are syntactic, and therefore, from this point of view, there is no difference compared to the standard logical approach, because it continues to maintain that people reason by

[1] The selection task would deserve a discussion on its own because it is usually presented as deductive but in reality it has important inductive components. As is well known, subjects are presented with four cards depicting a vowel, an odd number, a consonant, and an even number, telling them that they have been taken from a deck in which each card has a letter on one side and a number on the other; one must say which cards it is necessary and sufficient to turn over to check a rule such as "if on one side there is a vowel, on the other there is an even number". Subjects usually indicate the card with a vowel but do not mention the one with an odd number, which is equally indispensable to turn over. Now it is true that in appearance one must check a proposition of a conditional nature, but subjects must do so starting from specific examples (the cards to turn over), therefore in reality it is a matter of inductively discovering the compliance with a rule.

following formal rules. Braine's system works by using (instead of axioms as in logic) so-called inference rules. In the author's classic example:

Either Ford or Carter won. Ford did not win.
Therefore, Carter won.

the rules can be expressed in formal terms as inference schemas (in this case: *p or q, not p, therefore q*).

Braine admitted that this *logical* aspect is not the only relevant one, but that there is also an aspect he calls *performance*, which includes comprehension processes (since it is admitted that one must first understand the premises) and reasoning strategies (to apply the rules) similar to the heuristics used in problem-solving. And it is precisely in this performance aspect that, according to him, the difference between formal and practical reasoning lies: *"it is a matter of heuristics and strategies rather than logic"* (Braine, 1978, p. 5).

On this basis, errors and fallacies depend on the fact that the use of abstract rules is contaminated by practical or conversational assumptions: if we eliminate these sources of distortion, according to Braine and his followers, people reason correctly.

From the Cognitive Approach to Mental Models

The second approach to the study of reasoning, which has perhaps enjoyed the most success, is that of *mental models*. Although it seems to be a completely different perspective from that of natural logic, we will see that in reality, they share some common points.

Before entering into details, it is appropriate to examine how the idea of mental models came about. Considering the enterprise of identifying a natural logic, the question arises from the very beginning: if we notice that people almost never follow these so-called natural rules, how can we say they are natural? The task envisioned for the psychology of reasoning was then somewhat reformulated. The problem must be that people are not always able to use logic. We must try to understand why people do not properly apply the formal schemas that would lead to correct reasoning (those identified first by logicians and later made more flexible by psychologists). Why do people not follow them naturally?

The cognitivist perspective of information processing contributed to this approach, replying: the rules exist; however, we are unable to follow them perfectly because our cognitive system has limitations. The problems would therefore essentially concern the basic cognitive processes involved in reasoning, such as language, representation, and memory. At an even more foundational level, still following the computational metaphor, limitations may concern the quality of available data or usable resources.

For example, a complex linguistic formulation may require too many transformations. Thus, certain difficulties in linear series are explained by the fact that representing *"Aldo is not as tall as Bruno..."* is more difficult than *"Aldo is shorter than Bruno."* Or this explains the classic phenomenon observed by Wason and Johnson-Laird, whereby sentences with a negation are harder to understand and use than positive ones.

The problem could also be discursive or communicational in nature. The logical point of view is not equivalent to that of expressive intent in what the premises of syllogisms communicate. Saying that Aldo is taller than Bruno is not the same as saying Bruno is shorter than Aldo (even though they are logically equivalent), because the *focus* is different: in the first case, we want to say something about Aldo; in the second case, the primary subject of our interest is Bruno. Here we can already highlight a point we will return to: namely, that to understand errors, it is not always sufficient to

limit oneself to considering the material presented to subjects in an experiment, but it is often necessary to broaden the scope to the context.

Other errors could stem from difficulties in performing abstract mental operations (converting a premise to fit the other, etc.). For a certain period, this was an explanation for the four-card task, after Legrenzi (Johnson-Laird et al., 1972) invented the post office story.[2] For still other errors, it is believed that it could be a matter of representation: not using the right symbols or not using the right strategies or programs (in this sense, the influence of artificial intelligence was significant, whereby reasoning was considered equivalent to problem-solving).

However, as is well known, within the nature of the cognitivist perspective itself, there is a tendency to propose models of mental facts in terms of representations and processes. This is what, more recently, has led in some cases to adopting a different point of view from the initial one, in which the role of psychology was to explain why one deviates from the formal norm. Increasingly, truly "special" or "dedicated" processes—to use a computer science term—have been hypothesized for handling logical problems and reasoning. And so the idea of the formal system has remained somewhat in the background, to the point of being abandoned by some. Within this strand, the theory of mental models (MM) by Johnson-Laird (1983) matured, achieving enormous success.

For Johnson-Laird, inference schemas like Braine's are not used in deduction (see O'Brien et al., 1994, for a comparison) but it is a matter of forming representations "isomorphic" to the state of the world (models, indeed), which are integrated as the premises are read. And the usual cognitive limitations can create problems in doing this. According to MM theory, therefore, actual conclusions are not drawn; instead, it is sufficient to describe the final mental model, reading the representation resulting from manipulation, to find the conclusion or see if a proposed conclusion is correct. Testing the validity of a line of reasoning, from this perspective, means searching for alternative models or counterexamples that can invalidate the interpretation reached.

What makes MMs so attractive is actually the fact that they simultaneously take into account both abstract and concrete aspects, both formal and iconic ones. This, among other things, makes them highly generalizable and applicable to different contexts: it is perhaps the only theory that claims to cover various types of reasoning, both deductive (relational, propositional, syllogistic) and inductive (the four-card problem).

In essence, MMs attempt to transcend logical schemas by making explicit the transition from the idea of manipulating formal rules to the idea of *manipulating representations*. In this respect, MM theory is a typical product of the cognitivist perspective.[3]

Natural Logic and Mental Models: Common Aspects

The two perspectives we have discussed, natural logic and mental models, constitute the two main souls within the psychology of reasoning (though not the only ones: we will examine other approaches later). As mentioned, even though these perspectives have sometimes sparked lively discussions, which at first glance might suggest they are in sharp opposition, upon closer inspection, they share several things in common.

[2] Legrenzi discovered that the correct answer was much easier and "natural" when using concrete envelopes to check postage rather than abstract material like the four cards..

[3] In reality there are different souls, sometimes in contradiction, within cognitivism. In some cases the cognitivist approach to reasoning reveals that the need for a mental logic is still alive, since for it – under the influence of artificial intelligence models – it is essential to have formal rules to be able to set up simulations. On the other hand today, with the appearance of connectionist models also in the sector of reasoning (see especially the work of Sun, 1994), one begins to question even from a computational point of view the necessity of rules, at least for the component of analogy detection, whose importance in reasoning is re-evaluated. But these are still little-traveled paths.

First, both theories emphasize that if what is expressed by the propositions to be evaluated is not always treated as required by formal logic, these are extra-logical problems of comprehension or processing. In short, what hinders reasoning is the *performance* component (comprehension, strategies, etc.), as Braine (1978) called it, not the *logical* component, which independently of the former—that is, in a vacuum—would function perfectly.

If fallacies can therefore be explained by cognitive limitations, we can consider them as deviations, if not outright pathologies. But this obviously does not touch upon the assumption that there are nonetheless rules for "normal" or natural logical reasoning (the kind highlighted by logicians or the most capable psychologists). In short, there is no disagreement regarding the *existence of a mental logic*. Johnson-Laird himself admitted that MMs are not incompatible with logic (making it merely a question of parsimony). In reality, as has been rightly observed (Oaksford and Chater, 1995), the dispute is not whether a mental logic exists, but how it is implemented in the mind. In one case, it involves the manipulation of formal rules of inference; in the other, the manipulation of representations and the search for counterexamples.

For both approaches, people possess basic logical competencies, and the problems concern execution. If people had enough time, motivation, and efficient cognitive processes, they would always arrive at logically correct conclusions.[4] Finally, another point of contact is that, as noted at the beginning, both theories tend to prioritize the study of error over that of the normal process.

4. "Psychological Errors" in the Study of Reasoning

The problems we have outlined are, in my view, connected to other more fundamental aspects typically encountered by classic theories of reasoning, and through which both approaches examined can still be linked. These are "psychological errors," as I defined them earlier, committed when studying reasoning. Without claiming to provide a systematic or exhaustive list, the most important are:

- Presupposing that, when faced with a reasoning task, subjects "naturally" follow *strategies*; referring in any case to more or less formal schemas corresponding to or implementable in strategies (e.g., manipulating rules or representations);
- Presupposing that, when faced with an inductive task, subjects "naturally" formulate *hypotheses*;
- Assuming that the relevant knowledge (necessary and sufficient to solve the task) is exclusively that provided in the instructions and data (the *closed-world* assumption).

A. Strategies and Hypotheses

We will consider the first two "errors" together. The fact that systematic procedures or strategies are followed in reasoning, and that one proceeds by formulating hypotheses, are basic assumptions that have almost never been questioned. For this reason, they have not been made the object of specific research to see if things are truly so, or at least if they are so when discussing *everyday* reasoning.

There is, however, a domain—not strictly of reasoning but closely related to it—where the use of systematic procedures and hypotheses has been investigated, namely the study of concept discovery and categorization.

In fact, there many affinities between these processes and reasoning, and it can be observed that subjects' difficulties can be similar. In categorization, too, there are deductive and inductive tasks,

[4] In this, they are different for example from the approach of Evans (1984), according to whom subjects tend to simply take into consideration the elements present in the material provided by the experimenter, for example what is mentioned in the premises, which is not rational at all.

and errors can be made in each. There is the task where a rule defining a category is given, and one must discover the attributes characterizing the exemplars belonging to that category (deductive task). Alternatively, there is the task where examples belonging to a category are given, and the task is to discover the underlying rule (inductive task).

Many experiments aim to see what *hypotheses* are made by subjects and what *strategies* (systematic procedures) are adopted. Here, too, rational procedures were initially envisioned (consider the famous scanning and focusing strategies identified by Bruner et al., 1956), but it was also seen that there are difficulties and confounding factors. For example, regarding the discovery of attributes, it immediately became evident that it is more difficult to discover attributes with more complex rules than merely conjunctive ones (i.e., tasks with disjunctive, conditional, or biconditional rules: Bourne et al., 1976). Furthermore, it was understood that one of the main factors that can confuse is the *salience* of attributes, meaning the fact that certain attributes are noticed more easily, which does not mean they are necessarily relevant or distinctive.[5] Therefore, what is most obvious can conflict with what is correct.

Strategies and hypotheses are also affected by expectations and the way the task is presented. To support these claims, I will present the results of an investigation I conducted on the 2-4-6 task (Greco, 1991). The task, originally proposed by Wason, is very well known: one must find the rule behind the triplet 2-4-6 by proposing other triplets to test; subjects usually formulate rules like "even numbers increasing by 2" or "numbers increasing by 2," failing to realize that the incredibly simple rule was merely "any numbers in ascending order." The most frequent explanation for this phenomenon refers to a flaw in the rationality of common thinking, namely the tendency toward confirmation rather than disconfirmation of one's hypotheses.

Well, in this research, it clearly emerged that to evaluate this, it is not enough to know the hypotheses, but one must also take expectations into account. Even when subjects are forced to explicitate hypotheses (something they would not do naturally), it is not possible to determine with certainty whether they are following a confirmation or disconfirmation strategy simply by examining whether the triplets they propose conflict with the formulated hypothesis. For example, if a subject has advanced the hypothesis "even numbers," it is not a given that by proposing the triplet "4-6-8" for the test they want to confirm it, or if they present "3-5-7" they want to disconfirm it.

In fact, confirmation or disconfirmation depends not only on the hypothesis but also on *what response is expected*: testing "3-5-7" does not have the same meaning if the subject expects the experimenter to answer YES or NO. In short, triplets can conflict with the hypothesis but not necessarily to disconfirm it, just as they can be congruent with the hypothesis yet with the intention of falsifying it. In experiments on the 2-4-6 task, account has never been taken of these expectations or "intentions," or there has been a pretense of reconstructing them objectively based on the comparison between hypotheses and tested examples. And this is in the best-case scenario, namely when subjects were forced to explicitate hypotheses. But the evaluation of the tendency toward confirmation has always been made by considering how many examples are congruent with the "current hypothesis," even when in reality the subjects had *no hypothesis* at all but were perhaps exploring the data unsystematically. Indeed, if there is no hypothesis, there is also no strategy.

We can also add that the context in which the task takes place is not irrelevant. Analyzing that experiment reveals that the 2-4-6 task, as it is presented, is too artificial and also subtly misleading if examined, for example, through the lens of Grice's conversational maxims: the triplet chosen as an example (2-4-6) says more than necessary for a rule as general as "ascending numbers" to be hypothesized.

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[5] For example, for an airplane the shape of the wings is more salient; however, it is not certain that it can be pertinent to distinguish enemy and friendly airplanes. If the distinctive attributes are also salient, the task – in the example, of the anti-aircraft defense – is facilitated, otherwise hindered.

Regarding strategies, support for what I state also comes from other experiments on categorization (Greco, 1997). In these experiments, it emerges very clearly from protocol analysis how people almost never follow systematic (rational) procedures in searching for rules or attributes, but instead, inconsistencies and contradictions are frequent. Given these inconsistencies, subjects are then unable to explain their choices a posteriori, and often say they followed rules that are different from those they actually followed (revealable by an objective analysis of the protocol). There is also much evidence that categorization processes can occur unconsciously (in the sense that the criteria followed are outside of awareness) (see, e.g., Wattenmaker, 1993).

The error of the psychologist of reasoning in this case, therefore, is to believe that subjects *always* formulate *hypotheses* and always follow *strategies*, only to then investigate why the right hypotheses and strategies are missing. If being rational means this, it can safely be said that people are not rational.

However, instead of investigating concepts like strategies and hypotheses, one can do so on their precursors, as they manifest themselves naturally. Before dealing with *strategies*, it may be preferable to study what I have called the "use of evidence" in reasoning (Greco, 1991). I refer to an investigative style that is independent of reasoning proper and is linked to implicit assumptions or individual styles not directly linked to the specific task. Strategies—as standardized systems of using evidence—come at the end, and arise from expectations, mental models, resource management, procedures, and so on.

Strategies are not external to the task and formally applied to it; rather, they are part of the representation of the task itself (one thing in a certain case is done this way, in another case it is done another way). Adopting the idea of a representation by schemas or scripts (Schank and Abelson, 1977), the fact that certain pieces of evidence are expected rather than others could depend on the slots contained in the scripts activated from time to time.

Regarding hypotheses as well, they are different from expectations or anticipations because they are more elaborate, explicit, and formalizable. Naturally, they arise from expectations, but not immediately; rather, through a process of comparison between expectations and data, which must be studied.

The analogy between the field of reasoning and the sector of concept study is also interesting because concepts was one of the first fields in which an ecological perspective gained ground. With the introduction of the study of everyday concepts, rather than abstract geometric shapes, artificiality was overcome starting from Rosch's perspective of natural categories (1973) and from research conducted within the ecological perspective (see Neisser, 1987).

From these perspectives, lessons have been drawn that can also interest the study of reasoning. In particular, it has become clear that:

- concepts are not isolated but situated in relation to pre-existing ones;
- we do not normally encounter an ordered succession of examples;
- we encounter representative examples of a category, not "negative" examples of another.

In reasoning, similar considerations can be made, because in everyday thinking:

- we do not consider each premise in isolation from the other premises and other relevant knowledge in the context;
- we do not systematically consider pairs of premises to formulate conclusions;
- when we formulate negations, we do not do so to negate propositions, but facts or events.

B. The Closed-World Assumption: "Semantic Deprivation"

Let us move on to the third error, what I have called the closed-world assumption. The thesis I intend to support is that to explain common reasoning, it cannot be considered in a vacuum. As a

psychological and not a logical object, common reasoning can only be studied *embedded in a context*, in which processes taking place over time, states of knowledge, goals, and objectives are important. Otherwise, it is like a situation we studied and defined as *semantic deprivation*.

What happens if we place a person in a situation where they face a task but do not know what task it is? A situation in which, unlike what is normally done, the instructions are not as clear and explicit as possible, but instead the subject does not know what is expected of them, does not know what to do? Can the use of logic be expected?

This is the situation in which we placed our subjects in a very complex experiment (Greco, 1996), the details of which we will not describe, but of which it is worth considering some interesting aspects. To obtain a situation where there was a precise task but no predetermined meaning, we resorted to a trick. We told the subjects that we were studying subliminal perception (i.e., the ability to be influenced by stimuli below a threshold) and subjected them to a fake test (presenting simple noise in headphones), making some randomly chosen subjects appear highly sensitive to subliminal stimuli, and others uninfluencable.

Then we played other noises to these subjects and told them those were the instructions. Then we placed them in front of a computer that, every time they pressed a key, showed letters, numbers, colored spots—a fixed sequence actually independent of what the subjects did.

What happened? As in the perception of incongruity, which cannot be detected by those who do not have sufficient knowledge to understand where it stems from, those who did not expect to be sensitive to subliminal stimuli (and therefore to have understood the so-called instructions) were less disoriented, more rational, and in the end declared that they felt up to the task, finding the experience more meaningful.

Those who had been defined as "sensitive" to subliminal stimuli, instead, were more cautious, did not easily organize a strategy; in short, expectations and the effort of interpretation (systematically frustrated) led them to be less constructive and less rational. The task could have very well been structured logically (if I press A, this happens... but not if I pressed B...). Instead, people simply do not do this; they do not reveal a "natural" logic. The analysis of videotapes (done by judges unaware of the goals of the research) revealed that in most cases, subjects moved without a precise strategy, with low confidence in what they were doing, and not in a rational and systematic manner.

Based on these considerations, we can say that asking subjects—as is usually done in psychological experiments—to perform inferences, deductions, and so on, in a semantic vacuum is like studying the functioning of lungs in the absence of air. One can certainly study apnea, but one must not say that they are studying respiration: it is a different thing.

Other Approaches to the Psychology of Reasoning

The observations made so far do not apply only to the theories of natural logic and mental models. Other approaches to the psychology of reasoning are not exempt either, such as so-called *pragmatic reasoning schemas* (Cheng and Holyoak, 1985), *social contracts* by Cosmides (1989), the *probabilistic* approach of Oaksford and Chater (1994), and the study of *non-monotonic* reasoning (Ginsberg, 1987). In this venue, it is obviously not possible to analyze all these perspectives in detail, but I will mention some points worthy of note.

The authors who proposed *pragmatic reasoning schemas* (Cheng and Holyoak, 1985) to explain the selection task hypothesize specific rules for special situations or contexts, such as permission, obligation, or causality. These are therefore content-dependent rules, rules more in the sense of schemas or scripts, like slots to be filled, highly *domain-specific*. For example, a rule of the permission schema states: if action *x* is performed, then precondition *y* must be satisfied. These are not formulations of abstract rationality, but rules linked to the goals a person has in acting (which is why

they are called "pragmatic"). Another approach, which from this point of view is similar, is that of Cosmides (1989), who speaks of *social contracts*—that is, systems of rules that are not abstract but appeal to another specific knowledge, this time that of the domain of social exchanges (rules of the type: if you want to have a benefit, you must pay a cost, and the like).

Pragmatic schemas and social contracts make interesting steps forward, as they refer to specific goals enacted in particular situations and therefore allow for more precise references to the personal context. The major limitation of these two approaches is that they are formulated as production systems, which are a typical example of *strategy* in problem-solving. Furthermore, precisely because they concern highly specific contexts, not only do they not escape the problem of the closed world, but perhaps they even amplify it.

Then there is a strand that has taken hold more recently, which we can define as *probabilistic*, represented especially by Oaksford and Chater (1994), which applies statistical theories such as Bayes' theorem to reasoning. In practice, correct (or rational) reasoning is considered the choice of the optimal alternative. "Alternative" refers to hypotheses or behaviors; "optimal" can mean adapted to the environment or what allows for more information, less uncertainty following an event.[6] Other models, of logicist inspiration and especially within artificial intelligence, have turned to the study of *non-monotonic* or default reasoning, which allows starting from incomplete premises, or arriving at conclusions that are not certain but plausible.

What renders these approaches interesting for common-sense reasoning is their characteristic of going beyond modal logic, which requires *necessarily* valid conclusions. However, the difficulties we highlighted above are not avoided. The probabilistic approach, quite apart from the debatable idea of rationality as "optimal adaptation to the environment," is, as noted, fundamentally based on the analysis of *hypotheses* formulated by subjects and alternative ones, defined in probabilistic terms. Yet the point we have highlighted here is that subjects do not always possess hypotheses, or at least not explicit hypotheses.

Regarding non-monotonic reasoning, the necessity of broadening the field to context emerges when one faces premises that lead to conflicting conclusions, as in the example by Oaksford and Chater (1995):

1. *If x is a university student and there is no reason to suppose otherwise, then x IS NOT fit.*
2. *If x is an athlete and there is no reason to suppose otherwise, then x IS fit.*
3. *Aldo is a university student and an athlete.*

The order in which one considers (1) or (2) renders the other inapplicable, or the sole (non-informative) conclusion is that Aldo either is fit or is not fit. Conversely, in common sense, the obvious conclusion is that normally university students are sluggish, but they are not so if we know they are athletes (because then they exercise). This is one of many cases in which it is evident how damaging the *closed-world* assumption is, along with the postulate that the sole knowledge is that of the premises, without taking into account contextual factors external to the representation of the specific task.

5. Conclusion

Many investigations into reasoning are focused on the errors committed by subjects when facing logical problems; here, instead, we have spoken of certain "errors" committed by those who, in order to study common reasoning, compare it with that of logicians. Among the difficulties we have

[6] Optimal behavior is given by information gain: I.G. = I(Hi) - I(Hi | D), that is, the information gain is equal to the prior probability of an hypothesis minus the probability of the same, given D. The information gain is derived probabilistically, using the probabilities of each hypothesis and the conditional probabilities that, given each hypothesis, "useful" changes are produced in the data.

highlighted are postulates often contradicted by empirical evidence, such as attributing to subjects strategies they do not possess or hypotheses they do not formulate. The most serious inadequacy, however, probably concerns the proposal of excessively artificial tasks, and there is no doubt that the study of common reasoning will require a revision of the very tasks required of subjects.

Sometimes, to study "natural" reasoning, psychologists start from formally well-defined situations and add a thematic seasoning. They invent stories to color the abstract schema with concrete material. Thus are born tasks like the selection task, with countless variants in which subjects must evaluate cards with vowels and numbers, then imagine being postal workers and checking envelopes, or think of trips and locations, and so forth (an example has even been proposed involving people who fell ill because they ate tripe, people who did not eat it and fell ill, etc.). But the results have been contradictory, and their interpretation has given rise to endless discussions. For example, precisely with the selection task, it was observed that procedures that worked in Italy gave rise to different results in the United States or China, simply because the context was insufficiently defined, and subjects in reality interpreted the task differently. At times knowledge or expectations were different (see postal rules in different countries of the world), at times the theme gave the impression of having to evaluate a question of truth-falsity, at other times a question of obedience-transgression of a rule (a deontic context opposed to a thematic one).

Attempting to color a formal structure with concrete data, but inevitably in a limited manner, was perhaps another "psychological error." It might be preferable either to study reasoning in totally abstract terms as formal logic does, or to provide truly rich thematic situations in "ecological" terms. Studying reasoning in intermediate situations between the abstract and the concrete—in which there are artificial ambiguities induced by the task—is risky. An experiment by Cheng and Holyoak (1985) showed that, paradoxically, it was easier to solve the four-card task when given a formal rule (*if one wishes to do A, then first precondition B must have been satisfied*) compared to the classic rule that speaks of cards with vowels and numbers but is substantially arbitrary.

Unlike what has occurred in other sectors of psychology, such as perception or categorization, a study of reasoning in truly "ecological" terms has perhaps not yet been initiated. The options for a study of this type remain to be explored, but in my view, a significant part must concern contextual analysis. The reasoning of formal logic, unlike common reasoning, is stripped of context. An "ecological" study of reasoning, by contrast, should consider the analysis of contextual factors as a priority and could leverage the contribution of specific research on contexts, such as those presented in this same volume by Penco and Bouquet. We have distinguished elsewhere (Greco, 1996) between two types of context in empirical situations studied in psychology: a *proximal* context (all the constraints of the specific situation: instructions, stimuli, experimenter, aspects more evident than others, perceptual illusions, etc.) and a *distal* one (prior knowledge, expectations, goals, etc.). In reasoning tasks performed "in a vacuum," both of these contexts have been removed. If one is doing *formal logic*, which is obviously a respectable object of study, it is correct that it should be so. If, however, the investigation intends to concern "common logic," then one must clarify that this procedure is inadequate and recognize the peculiar characteristics of this logic. Furthermore, greater attention is necessary toward other aspects that are less obvious from a logical standpoint but relevant from a psychological one, such as the fact that reasonings—as psychological processes—unfold over time and can comprise different states. Or, to take another example, the fact that evident aspects (salience), or "naive" forms of causal thought, prevail over what is correct. In short, it is a matter of studying situations in which common sense truly enters, with its requirement to fill *all* relevant slots.

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