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Scattered naive theories: why the human mind is isomorphic to the internet web

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Abstract

This paper constitutes an attempt to derive the epistemological consequences of what is known in cognitive, developmental, and social psychology on the nature of naive theories. The process of cognitive development and knowledge acquisition is such that uncoordinated knowledge must result. There is no process active in long-term memory to harmonize inconsistent parts. Coordination takes place in working memory (WM), and cognitive psychology has long established its extreme exiguity. Units of explanation and domains of coherence are therefore small. This is, indeed, a limitation of our cognition, but it is tenable pragmatically. Naive theories, on any one issue, do not form, psychologically, cognitively, a natural kind. These theses about how our knowledge is acquired, organized, accessed, and used help to bring out how one should think about naive theories. © 2001 Elsevier Science Ltd. All rights reserved.

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"You mean, said Arthur, you mean you can see into my mind?"
"Yes", said Marvin. Arthur stared in astonishment.
"And..?" he said.
"It amazes me how you can manage to live in anything that small."

The Restaurant at the End of the Universe
Douglas Adams 1980

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0. Introduction

This paper attempts to draw an integrative picture of naive knowledge and understanding. In countless interviews of people about everyday topics (illness, weather, economics, couple formation, old age, dieting, etc.), I was struck by how poorly they (we) can justify their assertions, how hesitant they are, and how often they change their mind when challenged. Outside our domains of expertise, our understanding is extremely shallow. Individual judgements are largely made independently from one another, each with a backing that involves only a very small part of our potential, of our store of knowledge, and our critical faculties. Coordination, I will claim, takes place in working memory (WM), and cognitive psychology has long since established how cramped a space this is. Units of explanation and domains of coherence are therefore small. The claim is not that our formulated ideas form an almost haphazard collection of random fragments, though I do think that we tend to be overgenerous in our unreflective assessment of the coherence they exhibit. Some factors lead to coherence beyond the cognitive efforts of the individual. The domain may be "imported" already structured. This is the case with the many domains that have substantial practical or social importance, and were structured by the society at large. Alternatively, the domain may be one where the conditions for sub-representational learning are fulfilled. The circumstances for this to occur are not well-understood at present, but enabling factors include frequency of encounter, availability of feedback, and specialized readiness, perhaps an inborn "acquisition device" or preparedness to learn (Elman et al., 1996; Keil, 1994). But whenever these conditions are not met, people do not structure their formulated knowledge spontaneously. In everyday life, that is, most of the time, in free conversations, in interviews, even on topics of interest to them, their ideas tend to be unsystematic and are often incoherent. This incoherence is not usually noticed by those who hold the ideas, and it is only when inconsistent beliefs are brought together to consciousness that an attempt is made to harmonize them.

The following short excerpt from an interview will serve as an opening example:

> *Do you know what it means to "catch a cold"?* Yes. *Do you believe there is such thing*. Yes. *What is it, what happens*?. It's when you go outside on a cold day and are not dressed properly, and it is very cold, then the body reacts by catching a cold. *What are additional symptoms?* A runny nose, headaches, sometimes backaches. *What causes this?* Exposure to cold. *What exactly happens to the body when this happens?* I believe that the coldness affects the body defenses, the body is not strong enough to defend itself against the cold, and then you catch a cold. *What causes the cold then?* You cannot say it is germs, because it is not germs. The body is busy warming itself and … Wait wait wait, I have an idea: the body fights the coldness, it is busy warming itself and then all kinds of germs come inside the body and cause the cold and throat aches. *And what is the difference with a 'flu'?* A 'flu' is caused by germs … *Let's make some order—you said many things. So, you go outside on a cold day, not dressed properly and your hair is wet. What happens?* The body is busy warming itself, and then it gets cold, germs attack it, or it just

catches a cold. *Is this how you always thought about it?* No, I didn't think about the whole process. I am always careful to dress warmly when it is cool at night, but I did not think about why I do so.

People "know" that one is liable to "catch a cold" from exposure to cold. They must have on occasion felt a shiver when out in a cold rain. They also know that illnesses are caused by germs. These pieces of knowledge sat quietly together in our subjects' mind until they were questioned about just how exposure to the cold may bring about the "cold". At this point, and then only, did they become aware of the tension between the two beliefs, whereupon they tried to find, on the spot, some way to reconcile the two beliefs, which usually took the form of a facilitation effect: exposure to cold facilitates the invasion.[2]

It is, therefore, inappropriate to study someone's naive theory on "what is a cold, and how do you catch one," or on the relation between birth order and personality traits, or on how dieting helps to reduce weight, to mention some topics we studied. Our beliefs on such topics do not form, cognitively, a natural kind. From the cognitivist perspective, the question has no real object and should be reframed. In the following pages, I will present a number of theses about how our knowledge is acquired, organized and accessed; these will help to bring out how one should think about putative naive theories.

1. Knowledge is heterogeneous

Knowledge consists of different cognitive sub-systems. In the following sections, we will review several ways in which this saying is true.

1.1. Declarative and procedural knowledge

The distinction between declarative and procedural knowledge is intuitive and ancient, and received an early formulation in the work of Piaget, who studied sensori-motor and representational knowledge, as well as the transition from the former to the latter[3] (Furth, 1975; Piaget, 1951, 1978). The succession of cognitive tools that develop in the course of childhood leave their mark. Vermersch (1979), referring mainly to Piaget's work, contends that developmental psychology is relevant to understand the modalities of adults' cognitive functioning: "adults display a plurality of cognitive modes of cognitive functioning that may be defined

[2] Actually, this is not the case. Roy d'Andrade (1995) reports the result of scientific studies that fail to demonstrate such an effect, even though many Americans believe it is real, but he does not explain the origin of this misconception. The need to reconcile incompatible beliefs readily accounts for it.

[3] His book, called in English "Play, dreams and imitation in childhood," is called in French "*La formation du symbôle chez l'enfant: imitation, jeu et rêve, image et représentation*" that is: "The formation of the symbol in the child: Imitation, play and dream, image and representation". The badly maimed title was presumably thought to be more saleable.

and identified on the basis of the discontinuous character of the development of cognitive instruments (p. 63)."

Ryle (1949) distinguished "knowing that" and "knowing how". Under Ryle's formulation, declarative knowledge can be "declared", which implies a propositional form, and conscious knowledge (Knowlton, 1997). The distinction forms the basis of Anderson's well-known ACT models (Anderson, 1983, 1993), albeit in modified form. In ACT, procedural knowledge itself is represented in a propositional fashion by the so-called "production rules" (Clark & Toribio, 1998; Newell, 1990), while concepts and productions are connected by webs of associations that determine the probability of their being activated and, therefore, the likelihood of their affecting ongoing cognitive activity. This departure is fundamental to the model, since the condition for activating a production rule is formulated in terms of the very concepts that form the declarative knowledge.

Sloman (1996a, b), in an extensive review of the literature, made the case for a related contrast between *associative* and *rule-based processing*. One system is associative because its computations reflect similarity structure and relations of temporal contiguity. The other is rule-based because it operates on symbolic structures that have logical content and variables, and because its computations have the properties that are normally assigned to rules. Detailed review of numerous phenomena reported in the literature and, in particular, the existence of simultaneous contradictory beliefs is marshaled as evidence for separate associative and rule-based systems. A related illustration is provided by the classic Müller–Lyer illusion, where two lines are *known* to be the same in size, yet *perceived* to be of different sizes.

The distinction between the two knowledge systems underlies the debate in a fairly well-researched substantive field, that of naive or intuitive physics. It has long been known (e.g., McCloskey, 1983; Piaget & Garcia, 1974; Shanon, 1976) that adults' knowledge of simple trajectories is systematically flawed. There are two classes of explanations for there findings. The first postulates a general mental model that dictates the form of their errors, such as an Aristotelian or medieval model of mechanics. A problem with this view is that people seem not to be internally consistent (Cooke & Breedin, 1994; diSessa, 1993; Kaiser et al., 1992; Ranney, 1994). The second view is that such knowledge as people have about mechanics consists in a collection of non-verbal cognitive tools (Cooke & Breedin, 1994; Yates et al. 1988). These may have evolved independently to handle a variety of phenomena individually, and are, therefore, situation-specific and not necessarily consistent with one another. The relations between the two types of knowledge are complex. According to Cooke and Breedin (1994), the theory, to the extent that one is requested, is "constructed on the fly". Keil (1994) similarly contrasts explanation and expertise: "Some forms of expertise might be based on explanatory systems or combinations thereof, whereas others would be based on our fallback mechanisms of association and automatization (p. 252)." Explanation he goes on to claim, would rely on a small number of construal systems, while expertise would be constituted of a multitude of tiny systems.

While these dichotomies of procedural/declarative or associative/rule-based are convenient, they collapse several distinctions (Gigerenzer & Regier, 1996).

Procedural knowledge itself can take several different forms. It may rely on individual traces of many exemplars and past encounters, as in instance theory (Logan, 1988), Hintzman's (1986) Minerva model (see also Aha, 1998), or the sedimentation of many encounters (as in neural nets or classical learning models). The variety of ways of representing knowledge constitutes a fundamental feature of our cognitive makeup (Shanks, 1997). Congenial views have also been arrived at in the brain-systems literature, where declarative knowledge has been operationalized as that which amnesic patients cannot learn, or only with great difficulty (Knowlton, 1997; Shimamura, 1986). The prevailing view is that its converse, "non-declarative knowledge", does not correspond to a single system, but covers multiple implicit processing systems that may have different properties (Squire, Knowlton, & Musen, 1993). It turns out that an impressive range of learning phenomena can be demonstrated in amnesics: skills, priming effects, artificial grammars, fuzzy categories, and exemplar-based knowledge are all preserved, which implies, in this perspective, that these manifestations of learning do not rely on declarative knowledge (Knowlton, 1997).

The following illustration relates to a topic to which our subjects (young men and women) had given extensive though: what makes for a stable couple (Sher, 1999). The topic itself is of central and personal importance to young adults (aged 20–30); it forms the focus of frequent gossiping, the background of many movies and books. If a topic like this was not systematized in a theory, what will?

> The interview included several phases. (1) List 3 women and 3 men you know well, by their first names. Would Male 2 and Female 1 form a stable couple? would Female 2 with Male 3? (2) Explain your responses. (3) Suppose you were a professional matchmaker, what would you be looking for? (4) Please list several couples you know well. (5) Do your principles fit these couples?
>
> When asked whether, say, Ariel and Yael, would form a stable couple, subjects pondered for a while, then produced confidently an answer, though as a rule they had the greatest difficulty in justifying it. There is no telling what exactly went on in their mind, but it certainly did not consist in checking whether a certain known formula was true of the proposed union. In the next phase of the experiment, they were asked, in effect, what are the conditions for forming a stable union? Subjects almost always claimed at the outset that resemblance is a first requirement (in personality, interests, phase in life, background, even physical resemblance). After a while, they took this back, and became puzzled, for that theory rarely fits the couples they know. Some then proceeded to say that some properties must be similar, others need not, but find it hard to specify this further. Some also introduce, later on, the importance of complementary properties, such that partners balance each other. "He is quiet, she is outgoing. He gives her peace; she forces him to get out of himself." And many subjects conclude that love is irrational: it is a special kind of "chemistry", it has to "click"—which is an avowal of failure.

Clearly, more than one system involving knowledge about stable unions is at work here. Subjects feel fairly confident in deciding, intuitively, non-declaratively, whether a proposed match could be successful, they are personally acquainted with existing couples, exemplars that could constitute an empirical basis for induction, and they have some principled, declarative notions about what to look for in a match. But as soon as these systems were confronted, confusion prevailed. An array of independent implicit systems may be perfect to enable functioning in different circumstances, but scarcely supports the development of coherent, comprehensive naive theories.

Our knowledge relies on diverse systems. In the cognitivist sense, this means that different representational formats coexist in our cognitive system. In the brain-systems perspective, different brain structures are involved in representing knowledge. The formation of knowledge in each, and the interactions between the systems, constitute one source of discrepancy between the constituents of knowledge.

1.2. The formation of propositional systems leads to inconsistency

Let us now focus on *propositional knowledge*. We will see that the ways in which knowledge is formed lead to inconsistencies. We may distinguish two modes of propositional system formation, according to which of its two aspects, "propositional" and "system", precedes the other.

1.2.1. Reflective abstraction

The first mode might be called, following Piaget, reflective abstraction (1978) or "cognitive phenocopy" (Piaget, 1974). In this mode, a given knowledge domain in the propositional system does not form as such initially, but is based on a pre-existing associative or sensori-motor knowledge. Knowledge of non-propositional systems occurs in extracting and exploiting regularities in the environment. That knowledge is consequently embedded in an enactive system that generates predictions or behavior, and therefore at first is restricted to the specific context in which it was acquired. For example, in the case of naive physics discussed above, people may develop separate systems for predicting trajectories of curve balls and catching them, that of bombs dropping from airplanes, or of objects rolling off a steep cliff. The systems involved in throwing objects so as to attain a given aim need not be the same as that involved in catching an object or in predicting a trajectory from the side. Indeed, they rely on different systems according to whether they have to predict a motion or judge its naturalness. Kaiser, Proffitt, Whelan, and Hecht (1992) report that when presented with animations of certain motion problems, people judge their own predictions to be unnatural and select natural motions as appearing correct.

Reflective abstraction involves the twin aspects of change of representational type and restructuring at a higher level, possibly by way of various implicit levels (Dienes & Perner, 1999; Piaget, 1978, 1985). Such a transformation to an explicit level has, of course, important consequences. If we consider it from the perspective of the declarative subject, it makes the system "cognitively penetrable", paving the way for the subject to become aware of the structure of his or her beliefs, and, in particular, of contradictions. The powerful range of linguistic and logical reasoning tools becomes, in principle, applicable. For Piaget, sensori-motor knowledge is situated (Bickhard & Campbell, 1989; Furth, 1975), so that the transition does not merely consist in extracting information implicit in an enactive system, but also in internalizing the environment separately from the subject's reaction to it. The difficulty in doing this is the source of cognitive egocentrism. We might add that, if several systems are subject to reflective abstraction, the resulting egocentric representations need not readily be coordinated.

Karmiloff-Smith (1992), a developmental psychologist, studied and elaborated this "bottom-up" direction, from systems of implicit knowledge embedded in procedures, to a level of explicitly defined knowledge not available to verbal report, and finally a level available to verbal report. In her view, "Both innately specified knowledge and newly acquired knowledge are initially procedurally encoded, activated as a response to external stimuli. The procedure as a whole is available to other operators, but its component parts are not" (Karmiloff-Smith, 1993).[4] Of course, reflective abstraction need not occur, or may take place only very partially, and knowledge may remain largely at the implicit level, a fact increasingly emphasized by students of culture (Bloch, 1998; Bourdieu, 1990; D'Andrade, 1995; Strauss & Quinn, 1998) and of organizations (Baumard, 1999; Sparrow, 1998). Procedural, sensori-motor, enactive systems develop independently to solve different pragmatic requirements. There is, therefore, every reason to expect coordination between them to be difficult, and extracting the propositional content implicit in them to yield different theories. This, then, is another source of disparity.

1.2.2. Integration into a system

The second mode of propositional system formation goes from the acquisition of individual propositions to their coordination into a system. Individual propositions can be acquired before a system is fully ready to accept them. An early proponent of this approach in education was Vigotsky, who distinguished "spontaneous" and "scientific" concepts (Vigotsky, 1986): it is well to teach rather remote topics to children, he taught, since this will enable them to form a good conceptual system unencumbered by the associations of everyday concepts.

Wilkes (1997) reviewed the literature on "accumulative memory", his term for the ability to accumulate information about the world and maintaining control over the open-ended and constantly changing inventory of memory records. His summary is that: "(1) memory records can be organised to avoid interference (not always very successfully); (2) records may be integrated over time (not always very exhaustively); and (3) records may be updated (not always very extensively). We may do all of theses things some of the time, but there are many occasions when our efforts are, at best, perfunctory" (p. 172). Even these conclusions are probably too optimistic, since, most of the work reviewed is concerned with laboratory experiments, where context effects are minimized. Wilkes conclusion is inescapable: "accumulative

[4] Karmiloff-Smith too acknowledges that when knowledge is directly encoded in linguistic form, the process is different.

memory has evolved to make information available when needed, not to put it on trial. There are other ways and times for doing this'' (p. 173).

These two ways in which propositional systems form, reflective abstraction of non-propositional systems and coordination of individually acquired propositions, lead to the same outcome: uncoordinated knowledge.

1.3. Cultural diversity

The need for coordinating propositional knowledge is less than would seem from the previous analysis, and there is no proliferation of wholly unrelated individual propositions because propositions we come to accept do not emerge individually. A relevant distinction is developed by Sperber (1990, 1997), a cognitive anthropologist, who discusses two systems: intuitive and reflective beliefs. Intuitive beliefs are derived, or derivable, from perception, and are limited to basic concepts referring to perceptually identifiable phenomena and to innately performed unanalyzed abstract concepts.[5] More important to our present point are ''reflective beliefs''. A reflective belief is a proposition held by someone to be true on indirect grounds, such as trust in someone who asserts that it is true. To hold a reflective belief, one need not even have a well-developed conceptual system that gives it meaning. One way or another, the belief in which they are embedded validates them.

While it may be true that even individual, unconnected prepositions may disseminate widely in a society, (Sperber strikingly uses the term epidemiology in this context), beliefs acquired from others will usually partake of systems whose properties are ultimately the reason why society or individuals adhere to them. Socialization into a culture or social group provides, therefore, a great deal of such coherence (see, e.g., Breakwell & Canter, 1993; Carey & Spelke, 1994; Doise, 1989; Duveen & Lloyd, 1990).

But saying that there are coherent systems in culture or education does not mean that those systems cohere with one another. On the contrary, several such systems will typically co-exist. Here is an illustration, from a study of parents' understanding of the epilepsy that afflicted their child.

One of our informants was a Bedouin mother who attributed her child's epilepsy variously to the bad eye (an evil neighbor living nearby); a spirit that entered the child while she was lying down; it was her own fault for having eaten lemons and salt during her pregnancy; and the illness could also be traced to the child itself being such a fine, delicate, beautiful child (a designated victim). A second informant was an orthodox Jewish father who said that: illness runs in the family, yet he worried that his son was struck because he does not study the Talmud enough; he too attributed the condition to the bad eye, and also to a sudden fear felt by the child upon seeing foreign workers.

These explanations are not necessarily incompatible: some are predispositions, others pertain to moral retribution, course of illness, or episode triggers. The point

[5] These might be identified with the outcome of reflective abstraction, as discussed in the previous section.

here is that all offered as explanations, and no attempt was made to coordinate them. As Kleinman (1988) noted, "illness is always a cultural construction," and when there are several explanations, the patient's health-seeking behavior is characterized by simultaneous resort to several sources of relief: physician, dervish, rabbi, etc.

Here are some more examples in the medical domain. Quintero and Nichter (1996), who studied understanding of addiction, found five expert discourses on addiction (the physiological perspective, the cultural constructivist model, the psychological model, the political economy model, and the disease model) and some additional ones amongst the lay population. Similar findings were presented by Zani (1993) in her study of mental illness, by Leiser, Doitsch and Meyer (1996), who studied the many sources of beliefs about everyday high fever in mothers, and by Stainton-Rogers (1991), who identified seven attitudes to health and illness. Mulhall (1996), analyzing the "myth of stress in nursing and medicine", shows in detail how the concept of stress, besides explaining misfortune, has also an ideological and a political function. "The lay and professional concepts of stress blur into each other and are mutually re-enforcing. Stress in both area is taken as a real concept, which does, however, vary widely (p. 457)." Since the concept is useful but used for such widely divergent functions, it is understandable that it is "stamped with a hallmark of authority/ambiguity".

1.4. Domain-specific knowledge

A final factor contributing to the heterogeneity of our knowledge is our mental endowment at birth. Many investigators have come to ascribe to the new-born human infant a preparedness to develop specific cognitive stances, each characterized by a typical domain of application, an ontology, and accounted for by its evolutionary relevance (Carey & Gelman, 1991; Gardner, 1983; Hirschfeld & Gelman, 1994; Keil, 1990,1994; Rosser, 1994; Spelke, et al. 1992; Wellman & Gelman, 1992; Wellman & Inagaki, 1997). Each such stance represents a particular appropriate way of looking at aspects of the world, but when two such apply to the same object, they cannot readily be coordinated. Consider, for example, the psychological and the physical stance applied to the mind, resulting in vexing problems such as the relation of body and psyche (how can pills such as anti-depressants affect mood? Where are thoughts localized, in the head?) or the tension between the moral and the instrumental views of the economic world (Leiser, Sevón, & Levy, 1990; Watson, 1996; Williamson & Wearing, 1996).

Another source of inconsistency may perhaps be found in the conceptions that develop successively in the same individual. Developmentalists have not yet come to a definitive conclusion as to how new conceptualizations relate to previous ones, but if the previous ones are conserved alongside the new one, an additional inconsistency may result. Consider understanding of biology, which is known to evolve in normal humans from a simple collection of individual biological facts, into a functional theory. This implies a reanalysis of animals as living things with a universal life cycle and the role of body parts and function in maintaining life. From a comparison of normal children with children afflicted with Williams Syndrome, Johnson and Carey (1998) were able to show that the shift to the functional view goes beyond the acquisition of new knowledge formulated over an existing conceptual base (which is accessible to Williams Syndrome children). It involves genuine conceptual change. But what happens to the superseded conceptualization? When the two do not conflict, both may continue to exist. According to Chi (1992), however, even when there is a conflict, the older conceptual system is not *transformed* into the new one (as some would have it). The new conceptual system grows alongside the first and dominates but does not eradicate the older one. If the older conception is not obliterated, intellectual history leaves its mark on later functioning. As an anecdotal illustration, the philosopher Gaston Bachelard (1940) defined "epistemological profiles" of concepts, a notion that applies to a given individual, at a given stage of his or her intellectual history. For himself, he tells us, the concept "mass" is partly naive realism, partly positivist, strongly classic rationalist, and so on. The importance of the naive realist and classic rationalist dimensions in his mental makeup are a consequence of his specific life history: before he became a celebrated philosopher, Bachelard was a postal office clerk and had to weigh letters and parcels, and later spent several years as a high school science teacher. Similarly, if we consider our own notions of monetary value, we may perhaps recognize both a mature conception (the value of an object is determined by the intersection of the demand and supply curves) and an older, absolute one (every object has its real, intrinsic value—whoever takes more is overcharging).

2. Coordination

2.1. Spotting relevance

In the previous section, we saw that our knowledge is based on many sub-systems, but of different types and from different causes: there are declarative and several non-declarative modes of knowledge, cultural systems, and inborn content-related cognitive stances. Different tasks engage different cognitive structures and, since these were never coordinated, their respective output is uncoordinated. The following illustration brings this out.

Subjects were interviewed about the relation between birth order and personality traits. The procedure involved the following steps: (1) Subjects were given a pile of index cards and asked to write down properties (such as vain, social, clever, dominant, etc.) and place them on one of three piles, labeled Firstborn, Middle Child, and Youngest Child. (2) They were then given a prepared set of cards with additional traits, and asked to distribute or discard each card, then (3) requested to justify their choices. (4) In a fourth step, they wrote down a list of people they know who are firstborns. (5) Finally, they had to say whether the properties they listed for Firstborns actually fit their chosen instances, and discuss discrepancies.

Our subjects were very rapid in attributing the traits to the three positions (steps 1 and 2), but tended to find it very difficult to justify their choice (3). Indeed, they often retreated, were puzzled, and sometimes looked as though they were trying to solve a poser prepared by someone else. Further, they were little common explanatory principles underlying the justifications they provided across traits and across piles. There were also no special relations between the instances provided (4) and the traits attributed, except usually for one chosen example ("my big brother, my youngest daughter"). When we asked more pointed questions confronting the various steps, we elicited the whole range of reactions betraying perplexity: avoidance tactics, hesitations, creative generation, retraction, and extensive use of "non-explanatory" explanations. We counted how many explanations had actually some contents, as opposed to circular, vacuous explanations. Overall, there were 68 causal accounts, against 95 vacuous explanations.

Writing of properties was fast, associative, non-critical; justifying them involved a range of independent explanations, but no overall explanatory system. There are many vignettes, such as that the middle child is "sandwiched" between older and younger siblings, the youngest is spoiled by doting parents, the eldest has younger sibs and parents give him or her more responsibilities. The subject then derives personality traits from these (the eldest is therefore more responsible, the youngest a self-centered little brat). The inductive base, when it is used, is as slender as can be : there is usually just one paradigmatic case (all firstborns are like my older brother), and no spontaneous reference to any other cases. When the list of names generated in the last step is directly examined, it is typically found that it does not fit the pattern. People can and will discuss the relations between birth order and personality without having any systematic account of the link between the two, and propose such links on the basis of an uncoordinated mix of associations, homely truths, episodic memories and folk-psychological principles.

I submit that there is no spontaneous, unconscious mechanism responsible for scouring long-term memory (LTM), finding mutually relevant items and coordinating them. We referred earlier to Wilkes' (1997) discussion of "accumulative memory", from which it was concluded that the dynamics of cumulative knowledge (Leiser, 1996, 1997) cannot lead to a spontaneous coordination between knowledge sources and modes. Hence coordination, to the extent it takes place, must involve WM.

This is also the conclusion that emerges from the work of Baumard (1999). Baumard studied a group of professionals specializing in collecting and interpreting intelligence and analyzed their "exemplary management of knowledge". That knowledge itself consists mostly of small bits of information whose implications are ordinarily not clear cut. The work of those professionals, on a given topic, may be broken down into three clearly marked phases. In the first, the objective is to accumulate impressions. The second phase is one of deliberate learning, concentrating on such avenues and topics that seem to emerge from the first. This remains intuitive; the professional deliberately refrains from forming hypotheses, but searches for knowledge that may be relevant to impressions gleaned during the first phase. In the third phase, he becomes aware of a "complex web of convergences" that he then attempts to explicate. This is hardly a case of naive theory (remember that Baumard's subjects were highly professional information specialists). But even here, it is seen that knowledge accumulates in LTM, while the patterns that form are *deliberately* exploited, first to formulate and pursue promising lines of enquiry, and later to integrate, interpret and explicate the accumulated data.

To pursue this claim, let us remember the striking (to them too) lack of consistency exhibited by naive adults interviewed on everyday topics, as in our opening example where we asked adults about the common cold. People believe that exposure to cold, damp weather may cause a cold (Helman, 1978). This knowledge is presumably acquired from parents' warnings about going outside in the winter without proper attire, especially with wet hair, etc. They also must have on occasion experienced a shiver when out in a cold rain. Further, people have been exposed extensively to the medical model, and also know that illnesses are caused by germs of some sort. Only when questioned pointedly by the experimenter did they realize the tension between their beliefs. Sometimes, the conflict was expressed by long pauses, at others the subjects were quite explicit: "Hmm … I never thought about this … wait a minute, I have an idea, I can tell you what I think …". Awareness of the conflict and its occasional reconciliation awaited our questioning. Conversely, since most such contradictions are not brought into the open, they remain latent without any mechanism to identify them.

Coordination must take the form of a series of searches in LTM on the basis of retrieval cues generated in WM. However, this search may not be very effectual. According to the "encoding specificity principle", information acquired in a specific context tends to be retrieved better in a similar context than otherwise (Godden & Baddeley, 1975; Tulving & Osler, 1968). Moreover, retrieval cues tend to be superficial only (Brown, 1989; Gentner, Rattermann, & Forbus, 1993; Gentner & Toupin, 1986; Gick & Holyoak, 1980; Holyoak & Koh, 1987; Holyoak, Novick, & Meltz, 1994; Morton, Hammersley, & Bekerian, 1985).

2.1.1. *Human mind and the internet*

We will discuss in a later section the difficulties and limitations of resolving inconsistencies, once they are identified, but will first present an analogy to summarize the argument so far. Since our mental makeup at birth and the mechanisms and conditions of knowledge acquisition generate separate systems, and since there are no general mechanisms responsible for spotting and improving coherence in LTM behind the scene, as it were, coherence will be local at best, and attempts to harmonize knowledge will be based on probes originating from the contents of WM (Ranney, 1995). Every period finds its own analogies (Gigerenzer & Goldstein, 1996; Marshall, 1977), and the preceding summary suggests a novel—if predictable—one to the human mind: the world wide web. Specifically, I shall claim that *naive thinkers using their*

LTM are akin to internet users trying to understand a new topic on the basis of a www search.

People have a vast store of distributed information, and several search "portals" engines and agents, which allow us to frame search cues and define searches. These may all be set to work in parallel. The result of such a search "swarm" is a set of pointers to various contents that we can bring to the fore and study. The material itself is highly variable. Some may be episodic, an anecdotal piece of information, some might be sites devoted to one aspect of the subject at hand, or to some other subject that is obliquely related to the topic of the query. Some search engines rely on some indexing that takes place before the search, others are based on surface features.

The reliability of the various returns is also variable. Many of the sites found will themselves have further links to other sites, and so on recursively, while some may be permanently or temporarily unavailable. The person who initiated the search may decide to pursue one line of search and ignore others, or choose to integrate information assembled from various hits. After there are some returns and the user has begun working on them, the search engines may deliver new pointers that may then be ignored or stored and perhaps incorporated in the emerging understanding. Managing the hits is a complex skill.

The history and the properties of the Internet explains why it is so opposite a metaphor (see also Granic & Laney, 2000 who develop other consequences of the Net's organization). Information always accrued in numerous locations in isolation from one another in terms of purposes, methods, ontology, and so forth. With the advent of the world-wide web and the consequent progress in availability, it has become more natural to consider all that information as belonging by right to a single subject (humanity? the "noosphere"?) so that its fragmentation, incoherence and lack of interconnectivity came to be seen as defects that can and should be remedied.

This perceived need to integrate information distributed in the net has spawned research efforts at I3, "Intelligent Information Integration".[6] The mission of these projects includes handling heterogeneity of all kinds (semantic, schematic, vocabulary, data), resolving inconsistencies, developing languages for information integration and techniques for intelligent information retrieval from Web sources: finding, extracting and synthesizing it. This mission, it turns out, is extremely difficult, for reasons directly related to what precedes. Information developed in unrelated projects have different pragmatic aims and rely on different conceptual approaches. The principal source of difficulty is in handling incommensurable statements. A typical approach to I3 is taken by the Context Interchange Project (COINS)[7] at the Sloan School of Management, MIT, which favors a *declarative* approach. This requires that interoperating sources and receivers describe unambiguously the assumptions which they make in

[6] See e.g. http://www.tzi.de/grp/i3/projects-class_fr.html; http://www.irit.fr/GRACQ/.

[7] See http://rombutan.mit.edu/arpa.html.

the routine representation and interpretation of data. However, meaningful integration requires a conceptualization of the underlying domains which are shared among the component systems. These shared domain models are referred to as the underlying shared *ontologies*.[8] Data bases must be built in accordance with the ontology, if later coordination is to be possible. But when the data bases and their ontologies have evolved independently, there arises the problem of integrating existing ontologies, and this, Uschold et al. (1998) conclude in their survey, is very hard.

Returning now to naive theories, propositions are couched in a language, partake of a culture, belong to particular domains or approaches (medicine, psychology, science, religion, ethics) and these are bound up in different ontologies. Any language game must possess its own, but separate games need not mesh. Moscovici (1990) put it well: "… ordinary knowledge, common sense if you prefer, is really something other than an 'expertise' in everyday thinking. It implies a combination … of very different types of thought and of information. It is thus distinguished from specialized or expert knowledge which, to the contrary, attempts to follow a single type of thought and to deal with a single category of information".

Knowledge typically remains fragmented (diSessa, 1997; diSessa & Sherin, 1998) and it is only when challenged that people will try to combine the fragments to construct an overall account. However, success is certainly not guaranteed, as there is no known method to combine disparate conceptualizations. For instance Biswas et al. (1997) describe their subjects' thinking about electricity as follows: "Students are active problem solvers who try to capitalize on whatever knowledge they have at their disposal. This includes qualitative knowledge about relationships, practical facts, mathematical formulas, and metaphors. Students have difficulty integrating their different representations into a mutually constraining understanding. Consequently, even though students switch between representations, they do not always make bridges between the different representations (p. 171)".

Building an explanation is often done on the fly, with all it implies in terms of hesitation, instability, and dependence on context effects. Let us return briefly to our metaphor of the web-user grappling with the bountiful output of search engines. Skill at framing retrieval cues and at managing the resulting flow of information can yield quite different performances, even though different users are exploiting the same net. We found it useful to group our subjects' approach to our questioning by the following typology of answering styles: Associatives, Coherents, and Flexibles. These are really ideal types, but the typology clarifies the opposing requirements subjects and trying to satisfy.

[8] Ontologies in developing knowledge is a profound domain (see e.g., Foucault, 1972; diSessa & Sherin, 1998 for a recent psychologically informed effort). For our purposes, we may rely on the simpler way the term is used in Artificial Intelligence, in the contexts of knowledge acquisition and of knowledge sharing: an ontology is a specification of a conceptualization, a description of the concepts and relationships that can exist for an agent (Gruber, 1993). A more precise analysis distinguishes two meanings: (1) a *conceptualization*: an intensional semantic structure which encodes the implicit rules constraining the structure of a piece of reality; and (2) an *ontological theory*: a set of formulas intended to be always true according to a certain conceptualization (Guarino & Giaretta, 1995).

Associatives rely on personal experience, simple superficial analogies, and various information tidbits. They then get stuck, and begin to collect further information either in parallel or successively. If in parallel, sets of unrelated information pile up; their discourse consists of simple sentences and juxtapositions. If successively, one association evokes the next one. Syntactically, they produce few complex sentences; each question raises one set of responses, not necessarily connected to the next; they tend to be unaware of contradictions, and to resort to evasive tactics when confronted.

Coherents are more deliberate: they retrieve (or only report) information more or less coherent with their earlier statements, which form the main retrieval clue. They remain aware throughout of what the claimed, but also of outstanding problems or gaps. Syntactically, their speech is more abstract, general, conceptual; sentences are clearly coordinated. A last feature: they are very rarely found.

Flexibles raise many associations, examine them critically to see what may be used, attempt various avenues, and frequently retreat from earlier statements. Their retrieval cues define a wide search beam, and the Flexibles attempt to coordinate the results on the spot, without lasting commitment to any one explanation.

All three styles apply unmodified to our metaphor of search on the internet web. Our questions force our subjects, for the first time, to collect what they have in LTM on a given topic, and to actually do what availability of language representation makes possible: confrontation of the different sources of knowledge. Subjects may be more or less nimble at the task. The main conclusion, however, is that they did not engage in it before that time.

Since knowledge is not integrated, retrieval is haphazard and context effects rampant. The local nature of our judgements is well established in the methodology of survey making. The design of questionnaires requires attention to the effects of context and of the habitual partial retrieval of information (Higgins, 1996; Schwarz, 1995, 1999; Wilson & Hodges, 1992). Perhaps the most striking field where the context-bound and uncoordinated nature of our knowledge is evident is that of decision making by professionals such as business managers and politicians. It has been shown convincingly that decision makers do not habitually incorporate all the relevant factors in their decisions. The context of the decision, the vagaries of the discussion all affect powerfully the decision taken. A consequence of the narrow focus is that decisions are susceptible to manipulation by a range of "presentation" or context effects (Baron, 1994; Bazerman, 1994). Decision-making training attempts to fight these biases by systematic elicitation and integration techniques (Goodwin & Wright, 1991).

These guided, deliberate attempts to be exhaustive are necessary because, in the absence of an integrated knowledge, there is no way to tell whether some relevant information was overlooked, solely by looking at what information was used in reaching a decision. Fodor (1983) based his provocative theorem on the "impossibility of cognitive science" on the observation that everything can, in principle, be relevant to everything else. This is indeed true, but only in principle. Also the advance of psychology over philosophy comes precisely in worrying about what information is, in fact, brought to bear on specific problems. To answer a question, the subjects need to marshal such information they have. To this end, they send retrieval cues whose returns give rise to a subjective feeling of knowing (FOK). That FOK is unreliable. It is based on the size of the "echo" evoked by the retrieval cues, and as Koriat (1995) observed in the context of specific memory retrieval: "Although such clues may not be articulated enough to support an analytic, calculated inference, they can still act in mass to produce the subjective feeling that the target is there and will be recalled or recognized in the future (p. 322)." This feeling seems to be based on the overall familiarity of the retrieval cue (Metcalfe & Shimamura, 1994; Reder & Ritter, 1992), as well as on partial information retrieved from memory (Koriat, 1994). Neither of these sources of FOK seems to involve access to the actual contents of the items retrieved; they rely only on the overall number of items and on how familiar they are felt to be (Markman & Dietrich, 1998).

When the subject experiences a FOK based on his or her search cues, all he or she knows is how much material was activated by that first cue. There may be highly relevant material available but for the moment not accessed, and nothing is known to the subject about the quality and nature of the elements responsible for the size of the echo. In the course of a study we made on students' understanding of dieting, we asked our subjects for a self-appraisal of the extent of their knowledge. This appraisal was done twice, once before the interview, which included a variety of questions on how to lose weight and why various methods are more or less effective, and again at the end of the interview. Strikingly, most subjects changed their appraisal. Some did this in the direction of an increase. Here are some examples of justifications: "I changed my mind because I figured 'what do I know about dieting, I never followed a diet in my whole life' but then suddenly I realized there is a lot I do know, from TV, from grade four. I suddenly remembered. While I was thinking I remembered things that people talk about and that I heard at home, at school, in the army, the newspapers, and I think that I understand a little better than I thought before". "Apparently it all was asleep in my memory, and I did not realize how much I knew." Others decreased their appraisal: I realized I was not able to organize all this stuff, to define them properly, and there suddenly are a million contradictions that I never thought about." Specifically, girls who reported being engaged a lot in dieting ended with lower scores than before: "all my life I am into dieting, so I figured I knew a lot".

2.2. Coordination mechanisms

Harmonization of declarative knowledge must involve the contents of WM, and we saw that most inconsistencies will not be noticed, simply because the relevant information will not be brought together in WM. Search for incompatible information does not take place spontaneously. Once information is present together in WM, there are two classes of mechanism that may serve to coordinate the pieces, corresponding to two classes of processes: automatic and parallel, on the one hand, and controlled and serial, on the other.[9] However, since there are strong limits on the number of propositions that can be considered together, large-scale integration is usually beyond our cognitive means.

2.2.1. Parallel constraint satisfaction models

In these systems, the degree of coherence of any two propositions or attitudes is known, and the system, starting from a given level of support for each proposition, attempts to adjust the level of belief in each proposition so to obtain a maximally coherent system. Such a system is not fully conscious, though it relies on the concurrent presence in working memory of the set of propositions to be co-adapted. Its output is closed, in that no new propositions enter the set once the process is started, and its output is a novel set of degrees of belief in those propositions. Some beliefs are rejected, others are upheld. Read and Miller (1994) observe, in this context, that evaluation of coherence is only local: The greater the degree of attention paid to a node, the greater the amount of activation it can send to other nodes (Holyoak & Simon, 1999; Ranney & Schank, 1998; Read & Miller, 1994; Shultz & Lepper, 1992; Thagard, 1989,1992).

Holyoak & Simon (1999), for instance, asked their subjects to rate their support for a range of seemingly unrelated propositions and found at first, as expected, no particular correlations between these judgements. When they presented these propositions, but this time in the context of a trial so that each of the propositions either supports or weakens the case of one of the parties in the trial, it was found that subjects move towards coherence. If a subject judged in favor of one party, she also tended to agree to all of the propositions that support that verdict. A kind of backwards reasoning is involved, from the conclusion (the verdict) to the antecedents, so as to obtain a maximally coherent position. Such a system is not fully conscious, but relies on the concurrent presence in working memory of the set of propositions to be coadapted.

A broadly similar parallel-constraint satisfaction model was also proposed (Kunda & Thagard 1996) to account for the information flow between stereotypes, behaviors, and traits, and how multiple stereotypes jointly affect impressions. Such constraint satisfaction networks are relatively automatic processes that require little conscious processes.

An apparent objection could come from the work by McGuire (1990), who claims that when a change is directly induced in one part of a belief system, it produces predictable adjustments in other parts. For instance, a core events desirability will be adjusted to its likelihood and therefore to its pattern of salient antecedents. McGuire studies thought systems (the term is taken to include attitudes, cognitions, and

[9] We are concerned in this section with general mechanisms for the harmonization of knowledge. There exist also other specialized mechanisms. For instance, Kruglanski (1989) showed that various effects (the algebra of love/hate relations, aggression/support, halo effects, dissonance, etc.) are all fundamentally issues of logical coherence. On the other hand, it is perfectly possible that each of these special cases is represented by a different neural, even hormonal, system. The coherence mechanisms could be specialized and distinct, despite their having the same logical or even computational structure.

beliefs) of "moderate complexity–consisting of a dozen or so 'topics of awareness'"—usually a core event that might befall the person, and its salient antecedents and consequences. He manipulates the desirability or likelihood judgements of a core event, and studies the patterns of salient antecedents and consequences evoked by mention of the core event. While McGuire concludes that thoughts are "organized into connected and coherent minisystems", the pattern of evocation does not imply anything about the prior organization of the topics into such a minisystem. Actually, his findings only show that desirability and likelihood affect the search differentially when evocation takes place.

2.2.2. Deliberation

The second way to integration consists in taking a set of incompletely coordinated propositions, and constructing an account that would encompass them all as far as possible. Deliberation is a ... deliberate, controlled, serial activity consisting in the confrontation of propositions, searching for evidence to decide what to believe, the use of various cognitive moves to remove seeming contradictions (distinctions, dissociations, explanations, auxiliary hypotheses, exceptions, etc.). Its output—if successful—is an "account" that may involve many propositions *beyond* those of the starting set: propositions retrieved or based on contents of the LTM, and novel constructions, created to remove existing inconsistencies. Finding individual explanations is a task we are rather skilled in, consisting as it does in searching for an explanation in our store (Abelson & Lalljee, 1988; Pennington & Hastie, 1988) or constructing a new one, on the basis of preexisting knowledge and patterns of cooccurrence. However, coordinating explanations is not an activity one spontaneously engages in: one is happy with finding the individual explanation, whereas building a wider explanatory theory is not a natural activity.

A special cognitive task is explanation. Providing a complete explanatory system is not a task one usually engages in. People are happy with the most perfunctory or vacuous explanation: aspirin has headache-curing properties, just as in Molière's play its "*dormitive*" (sleep inducting) powers explain why poppy makes you sleepy. Knowing just the relation is not useless: it does predict that taking aspirin will help you with your headache; when you have a headache, you know what to do. But a narrowly pragmatic focus may not always be enough, and success is sometimes served by getting a grip on a causal explanation.

Toulmin (1958) developed a theory of scientific argument based on the roles that propositions play within an argument. A claim is supported by data, and the warrant is the general rule by virtue of which the data are a support for the claim; a backing is a reason for accepting a warrant. It may be a recursive justification (treating the original warrant as a claim to be justified), or it may be an appeal to authority or some other reason for belief. Thagard (1998), who analyzes the relations between patterns of correlations, causes, and mechanisms with the view of explaining disease, in his chosen example, offers a broadly similar theory. Patterns of relative sizes of correlation may help us to formulate causal dependencies (Cheng, 1997; Glymour, 1998) while conversely, a postulated mechanism and pattern of causal dependency helps us focus on the relevant relative correlations. However, in all such cases, the number of propositions involved in establishing a causal explanation remains very small, as it has to stay within the narrow confines of what we can cognitively handle.

If the topic at hand is important to the thinker, there will be a corresponding set of propositions such that several of its members will frequently be activated concurrently, in various combinations. If she coordinates a subset every time, little by little the whole may well become coordinated. However, this is a process that would take a long time, and there is no guarantee that it will converge: it may also result in oscillation between various positions. In any event, it will usually happen in the mind of serious scientists in their chosen field, not in everyday activity. This fits in with the conclusion reached by Carey and Spelke (1994): major theory changes occur in the mind of scientists or other specialists (and can be imparted to individuals by a process of education).

This view would be opposed by many, especially cognitive developmentalists, whose very domain is focused on the elaboration of novel theories by their subjects. For Karmiloff-Smith (1993) "The child is a spontaneous theory-builder (about language, physics, etc.)." Similar views are held by Gopnik and Wellman (1992), Vosniadou and Brewer (1992), Carey (1991). There is no gainsaying that theories do develop in childhood and there is no doubt that their cognitive competences develop with age. But regarding the process itself, nothing precludes its taking place in the working memory of children too. Consider the study by Vosniadou and Brewer (1992; building on the work by Nussbaum & Sharoni-Dagan, 1983), which showed that individual children are actually quite consistent in their distorted and varied understanding of the shape of the earth. Briefly, children are faced with two apparently incompatible sets of data about the earth: it appears flat, yet they receive information about it being spherical. Faced with this contradiction, children develop special models that somehow reconcile the two views. For instance, some claim that the earth is a disk (i.e., both flat and round), see themselves as on standing on a flat surface inside a hollow sphere, or differentiate between the flat surface they stand on and the celestial object called planet earth. While Vosniadou and Brewer demonstrate how far the children are consistent in holding on to a given view, they too recognize that for some (perhaps the more outlandish models) the child constructs the model "on the fly", when confronted by the experimenters' questions. Certainly, in working with children on Piagetian tasks, it is extremely common to see them resolving the contradiction there and then, after their initial puzzlement.

Children's resolution of such contradictions may well be based on conscious deliberation too. Consider for instance a study by Mazens and Lautrey (2000), who studied children's understanding of sound, and more specifically whether sound could traverse solids. At first, their answers seemed incoherent: sometimes sound was believed to pass through solids sometimes not, without any apparent system. Further study revealed the logic of their judgements. Sound can pass through solids provided one out of two conditions is fulfilled: if the sound is *stronger* than the material, or if there are *holes* in the material. Further, children have fairly systematic notions about the relative strength of sounds and various materials, and as to whether or not they have holes in them. The theory involved attributed to the sound properties of materials: substantiality, permanence, weight, etc. One can see how children arrived at this theory. On the one hand, knowledge about complex domains relies on the accumulation of information about the frequency statistics of the stimuli and respond to new events on the basis of their featural overlap with stored representations. They had to summarize from past experience when sound did traverse an obstacle and when it was blocked or muffled. This knowledge is collected, but need not be verbalized or ever consciously accessed under normal circumstances. When children were pointedly requested to explain their apparent fluctuations, they had to formulate their knowledge, and for this had to rely on and adapt their existing concepts.

Summarizing, they had to perform two operations: (1) Extract the regularities from their experience: This part is akin to data mining techniques: factor analysis, cluster analysis, multi-dimensional scaling, where a number of dimensions, factors or clusters are identifiable (Purkhardt & Stockdale, 1993), or connectionist systems, in which the weights on connections between units reflect the degree of statistical relatedness of the elements (Shanks, 1997). (2) Formulate the regularity and interpret it. This process involves already existing concepts and notions (Cheng, 1997) that guide the process. Ultimately, they assimilated the process of sound traversal of materials to that of traversal of one material by another: it will take place when sound can seep through the obstacle, or if it can force its way through, and they did so by consciously formulating.

In any event, since even adults do *not* construct extensive coherent accounts on most topics, the degree of coherence in children's theories should not be exaggerated. Researchers and other practitioners who engage in mapping cognitions find directed graphs or "conceptual structures"—a graphic notation for typed first-order logic (Sowa, 1992)—very serviceable (Axelrod, 1976; Laukkanen, 1994, 1996; Sevón, 1984), to the point that a range of commercial software now exists to facilitate this type of mapping. The basic elements of such graphs are pairwise links between propositions or concepts. The "map" consists in bringing a set of such links together in the same graph. A common finding is that people typically refer only to pairwise links or chains of such links. People can readily point at two quantities, and describe how changes in one effect changes in the other. When these binary relations are combined into a map, patterns emerge, and these often come as a novelty to those very people who provided the binary relations. In that sense, the overall structure may not be ascribed to the respondents, who remain unaware of it. For instance, Williamson and Wearing (1996) mapped painstakingly the economic cognition of their subjects. They concluded that, where there exists an overall cognitive map that includes all the links mentioned by at least some subjects, individual subjects only mention small parts of that overall cognitive map, and none were aware of the whole. Some investigators have commented on how rare it is for subjects to mention features of the overall structure of their understanding, such as loops (Bougon & Weick, 1977; Eden & Ackerman, 1998; Weick & Bougon, 1986; White, 1995a,b), while Senge (1990) calls for "seeing interrelationships rather than linear cause-effect chains".

The reason for this is that lay knowledge is pragmatic, goal-oriented: Given a proposition (a causal explanation, a generalization), evaluate whether is it true. Given a situation, try and predict what will happen. Thinking is therefore narrowly focused, and satisfied with a local account. Studying the patterns formed by individually useful link is not useful. Cognitive maps are no longer considered as a representation of what is "in the mind" of the person who provided the individual links. On the contrary, drawing such maps may be used as a tool to help (usually) managers to get a grip on their own understanding, beneficial precisely because they do not have an overall grasp of its structure (Buzan, 1993; Eden, 1994, 1992). This was already observed long ago by Evans-Pritchard (1937, cited in Moscovici, 1992): common sense observes only certain links in the causal chain. Science observes them all, or at least most of them.

We argued that the requirement that coordination take place in working memory, coupled with the size limitation of working memory precludes large-scale integration. This is what must have amazed Marvin, the "paranoid android" of Adam's fiction: the human cognitive system described here may seem so ineffectual as to be evolutionarily implausible, and this is a claim worth examining more closely. We commented on three deficiencies: *Explanatory systems* are overly simple. As we saw, patterns of relative sizes of correlation may help us to formulate causal dependencies while, conversely, a postulated mechanism helps us focus on the relevant relative correlations. Individual, local explanations are enough for solving local problems, and our mental apparatus handles them satisfactorily (White, 1984). In Paleolithic times, humans were not expected to combine various explanatory schemata into a unified grand theory.

Decision making. Everyday decisions in pragmatic domains are usually handled very well by existing mechanisms. Remember Sperber's distinction of intuitive and reflective beliefs. Intuitive beliefs are derived, or derivable, from perception, and are limited to basic concepts referring to perceptually identifiable phenomena and to innately performed unanalyzed abstract concepts. In such familiar domains, the help of decision support systems is not required. The failures of decision making we saw concern decisions in remote professional domains.

Coordination of ontologies of conceptual systems independently evolved is restricted. Since there is no known way of doing this, the failure of our cognitive system cannot constitute an argument. "Muddling through" may actually be the best policy. We might need to draw on what turns out to be several disciplines to make a decision, several sets of considerations may be involved as for instance, in economics, where social, moral, economic, and interpersonal considerations all converge (Watson, 1996; Williamson and Wearing, 1996) or in the above excerpt of accounts of "why my child is epileptic". When called upon to decide on a course of action, the best we can do may well be to select a dominant conception, or to weight several, without any attempt at deeper integration.

The limitations described here are real enough, and sometimes severe, but may have been evolutionarily irrelevant.

3. Conclusions

Many years ago, Moore and Newell (1963) suggested the following definition of understanding: "A system understands knowledge to the extent it uses it whenever it is appropriate". By that definition, there is little we really understand.

As we stated above, it is inappropriate to ask what is a subject's understanding or naive theory on any given topic, because our knowledge relevant to a given topic does not form, psychologically, a natural kind.

How should research proceed? Another analogy may be useful here, this time from political sociology. Consider the question, "what does Europe think about including Turkey in the European Union?", or "what do the Israeli people think about the status of Jerusalem when peace is achieved? These questions reflect legitimate concerns. Of course all Europeans or Israelis do not hold the same view, but a reasonable operationalization might produce a mean opinion, or a breakdown of various views. Much more appropriate, however, would be to distinguish the various groups and currents that underlie the distribution of opinions. Thus, one could point to distinctions between respondents on the basis of their cultural background, economic circumstances, geography, religion, age and so forth. Such a finer analysis is not only important to generate a representative sample, but more deeply, it is essential to understand the dynamics of the positions, and to predict their future evolution, on the basis of predictable demographic changes, economic and cultural development, educational intervention and so on.

The same state of affairs results intra-psychologically as well. It is not enough to obtain a respondent's report on his or her naive theory. We must endeavor to identify the miscellaneous cognitive systems that contribute or constitute the naive theory, see when each is brought to bear, how they interact and what affects the outcome. The process of knowledge acquisition is such that lack of consistency is the normal state. If contradictions and inconsistencies are resolved in or under the control of WM, a first central question is: *What contradictions are tackled?* This depends naturally on which ones are encountered, and which will be noticed, which in turn depends on what is retrieved from LTM: what retrieval cues are formulated and what they retrieve, what types of associative pathways exist and how they affect retrieval. But it also depends on how the subject manages the search and keeps track of the information retrieved. The second central question is: *How are inconsistencies resolved?* What are the mechanisms to resolve inconsistencies of various kinds, once they are noted?

The subject who tries to build a coherent account may be likened to someone trying to put together the pieces of a puzzle into an image (Williams & Hollan, 1981). Subjects may feel (FOK) that they have a fairly large set of pieces. But the image is misleading, and so may be their feeling. Not only are many pieces are missing, but the pieces belong to different puzzles, or to none, while the player is welcome to make new ones. Still, the metaphor captures an essential feature, one that Piaget called *la raison constituante* in contradistinction to *la raison constituée*: investigating a naive theory is studying a process more than it is studying a product.

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