Slow and fast thinking, historical-cultural psychology and major trends of modern epistemology: unveiling a fundamental convergence

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Mind & Society
Cognitive Studies in Economics and Social Sciences

ISSN 1593-7879

Mind Soc
DOI 10.1007/s11299-014-0140-1

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Received: 23 April 2013 / Accepted: 11 March 2014
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Abstract There exists a fundamental convergence between some major trends of modern epistemology—as outlined, for instance, by Filmer Northrop and Henry Margenau—and the theories actually developed within sciences of the human mind where two types of thought—one implicit and, the other, explicit—tend to refer to two different lines of development. Moreover, these theories can find in the psychology of Lev Vygotsky some seminal hypotheses of a major importance. In order to highlight this convergence, we parallel the role played by structured conceptual systems in Vygotsky's conception of intellectual development and Northrop's epistemology. We show how these conceptual systems account for the notion of causality and can explain the success of scientific thought, i.e. its possible match with the real world, while this match falsely justified an overall biological model of intellectual development in Jean Piaget's work. We conclude that dual process theorists should no longer neglect cognitive tools, and especially conceptual systems, which underpin the awareness and mastery of thought that are characteristic of type 2 processes. This whole analysis leads us to maintain that human psychology is not characterized in the first instance by a need to act, but a quest for meaning.

Keywords Dual process theory · Historical-cultural psychology · Epistemology · Conceptual systems · Human development · Vygotsky

The present analysis aims at deriving teachings on human rationality from the profound convergence of certain important trends in modern epistemology, cognitive psychology and the historical-cultural psychology of Lev Vygotsky.

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Published online: 27 March 2014

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Vygotsky is a leading precursor of dualist theories since he studied human thought as being the result of interaction between two different lines of development: one ancient, associated with animal development, and the other recent, associated with man's social development. To begin with, we will establish a bridge, based on some assumptions of evolutionary psychology, between dualist theories in cognitive psychology and Vygotsky's psychology. Secondly, we will bring closer Vygotsky's conception of human tools of reasoning and certain major currents of modern epistemology, by showing the role played by structured conceptual systems in Vygotsky's theory of intellectual development and Northrop's epistemology. The synthesis we propose parallels the dual conceptions of the human mind with the dual conceptions of the formation of concepts, bringing into opposition concepts whose meaning is derived directly from experience of the outside world and concepts whose meaning is mediatized by the relationships of concepts with other concepts. Thirdly, we show how this conceptual dualism accounts for logical thinking and the notion of causality and, moreover, explains the possible match of formal scientific models with the phenomenal world – i.e. the rationality of reality. These epistemological reflections will allow us to divert some major teachings toward the analysis of human psychology. They lead us to maintain that the need to understand is an essential, if not the most essential, dimension of human thought, and to open up future research paths to dual process theorists.

1 Vygotsky and the duality of human thought

According to dual-process theories in psychology, human thought processes develop along two distinct and complementary types of processes, one (type 1) fast, effortless, automatic, contextualized and non-conscious, the other (type 2) slow, effortful, controlled, decontextualized and conscious or reflective. These two types of processes are imputed to two different evolutionary lines. The first, which is shared with animals, is evolutionary old, directed towards action (pragmatic) and undemanding of working memory, whereas the second is distinctively human, evolutionary recent, logical and demanding of working memory (Evans 2009). These distinctions do not necessarily support the hypothesis of the existence of two systems of thought. On the contrary, the two types of processes tend to operate jointly. We may, as Frankish (2009) suggests, assume that they refer to two levels of thought provided, we add, that we consider type 2 processes potential impact on type 1 processes, in human development. These processes are linked to two kinds of learning, the first implicit and associative, the other one explicit and rule-based. Finally, the second type of processes is described as supporting human rationality, by controlling cognitive simulations or "mental models" and, more generally, hypothetical reasoning.

The hypothesis of the existence of two differentiated paths of development, at the origin of two types of thought processes, lies at the heart of the Russian psychologist, Lev Vygotsky's theory. According to Vygotsky, higher mental functions are not derived from the distant evolution of elementary processes. They come from a recent evolution of the human psyche. They are the result of an

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internalization of auxiliary means of thought—i.e. cognitive tools, such as concepts, symbols and numerical system—that are social constructs from the outset. This is Vygotsky's assumption when he suggests that every function in the child's cultural development appears twice: first on the social level, and later on the individual level; first, *between* people (*interpsychological*), and then *inside* the child (*intrapsychological*): higher functions originate as actual relations between human individuals that have been internalized and therefore serve the faculties of reflection (Vygotsky [1930–1933] 1978: 57). For instance, the child begins counting in his head, using his "logical memory" by calling on internal signs; thought proper springs from the "internalization" of language, which is characterized by the transition from the child's egocentric language to internal dialogue.

The individual's acquisition of socially elaborated tools of mind interacts with his primary cognitive functions while breaking with their development: psychological activity is reconstructed on the basis of sign operations. "Although children's use of tools during their preverbal period is comparable to that of apes, as soon as speech and the use of signs are incorporated into any action, the action becomes transformed and organized along entirely new lines" (Vygotsky [1930–1933] 1978: 24). In this respect it is impossible to assimilate the role of the work tool, which helps man subject natural forces to his will, with that of the sign, which he uses to act upon himself. The tool is externally oriented whereas the sign is internally oriented. Attempts to equate the sign with the external tool, as it is the case in John Dewey's works, lose the specificity of each type of activity, artificially reducing them into one (Vygotsky [1930–1933] 1978: 53).

Human evolution has therefore led to the emergence of a radically new type of intellectual activity, which is not destined for direct action on the outside world, but is inwardly oriented towards the mind itself. The fact that higher thought processes develop first as external forms of behavior and are mediated by external signs is, as Vygotsky ([1934] 1999: 53) specifies, determined by the specific nature of the higher function which "does not arise as a continuation of elementary processes but is a social method of behavior applied to one's self."[1] In the mind, internalized cultural forms play the role of symbolic stimuli upon which individuals can act by subjecting their own powers to their will: "for higher functions, the central feature is self-generated stimulation, that is, the creation and use of artificial stimuli which become the immediate causes of behavior"—or else, of thought processes. The internalization of external cognitive tools correlatively underpins the development of thought to a higher level of control that corresponds to voluntary action.

This internalization—which is, in Vygotsky's works, at the basis of slow thought processes—is "the distinguishing feature of human psychology, the basis of the qualitative leap from animal to human psychology". This new evolutionary line, which is not a product of biological evolutionary processes but of mankind's historical and cultural dimension, is the line that drives human development: "In the process of development, the child not only matures, but also *becomes rearmed*. Precisely this

[1] Note that Frankish (2009: 94) develops also this idea which is at the root of Vygotsky's theory from the work of Dennett's *Consciousness Explained* (chap. 7), published in 1991: actions involved have been originally, according to Dennett, overt one, as talking aloud to oneself, drawing diagrams etc., before becoming covert auto-stimulation.

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'rearmament' causes the greatest development and change that we observe in the child as he transforms into a cultural adult" (Vygotsky and Luria [1930] 1993: 168).

The internalization of abstract cognitive tools is closely related to the recursive character of human thought. Recursion refers to the possibility of using thought to fit elements into one another in a hierarchical way. In a recent work, the New Zealand psychologist, Michael Corballis (2011), defends that recursion—we only find elementary recursion in some animals—is what distinguishes human psychology from animal psychology. Thanks to the recursive capacities of the mind, the internalization of cognitive tools—with, particularly, the psychological construction of conceptual structures—permits human intellectual capacities to increase tenfold.

According to Michael Corballis, recursion has developed from two capacities: mental time travel, which implies being able to insert events into the present consciousness, and theory of mind, which implies being able to put oneself in the place of another person in order to understand him/her. These capacities are only present at an elementary level in some animals. Corballis notes that monkeys respond to transitive acts (linked to objects), but not to intransitive acts (when a movement is mimed). The internalization of intransitive acts on the basis of the sharing of episodic information through mimes could have paved the way toward the understanding of acts that are symbolic rather than linked to objects—the way, therefore, toward applying symbolic acts to oneself.

Hominoids were bipeds and this meant their hands were free for communication by gestures. Language could have evolved on the basis of the sharing of episodic information through mimes, which would have become more abstract, more linked to the face, the mouth and to voice control to produce in the end an infinite combination of articulated sounds. The recursive capacities of the mind would have been developed adaptively by natural selection over the last two million years because they underpin first and foremost mental time travel and theory of mind. These capacities would have depended on the development of the working memory's potential and the potential for hierarchical organization.

Note that, for Jean Piaget, the development of general structures of thought is conceived as a continuous process from elementary functions to the extended capacities of deductive thought. Everything takes place as if Piaget was only interested in the general properties of recursion in human thought. These properties are supposed to be based on a natural progress of logical-mathematical skills developed by the subject's interaction with his/her environment. Piaget gave the name of reflective abstraction to a reconstruction process that allows the integration of an operating structure from a step or previous level into a richer, higher level structure. This *sui generis* process (following a biological model of development) represented by reflective abstraction would be motivated internally by a movement of equilibrium—that refers to an economic or physical metaphor—which would require the subject to qualitatively raise the level of understanding of his/her instruments of knowledge (Piaget [1967] 1971: 292). This dynamic has been contradicted by the fact that the stages it defines may or may not be respected by children or adults in specific areas according to whether they have acquired adequate conceptual structures or not. Since every concept is in some way linked to others, the total body of concepts acquired during a lifetime influences the

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acquisition and use of other concepts, and this also explains why most children are unable to engage in general abstract reasoning before the age of eleven or twelve (Novak1977: 122).

The development of Man's recursive faculties is therefore not the product of a child's natural intellectual maturation based on his/her interaction with the environment but is rather the product of a distinctive, historical and cultural line of development that is linked to the possibility of using auxiliary means of thinking and is dependent on these means. According to Vygotsky, one of the elements proving the existence of a development path that is specific to man is that animals, even the most intelligent, are not capable of developing their intellectual capacities through imitation or learning (Vygotsky [1934] 1986: 188)—and in this respect we have seen that animals cannot internalize cognitive tools that are not linked to objects, as is the case for children. Animals are only capable of learning through training dressage. Children, on the contrary, develop through collaboration and imitation, on the basis of the interiorization of countless cognitive tools, which are the historical products of human culture, particularly structured conceptual systems that are transmitted by formal education. Hence, human development may be characterized by a twofold dynamic: the externalization of memory—by the constitution of a cultural memory—and the recursive internalization by individuals of structuring elements of this cultural memory.

2 Vygotsky and major currents in modern epistemology

We can now introduce the fundamental convergence between Vygotsky's psychology and major currents in modern epistemology which are expressed in the work of Emile Meyerson, Filmer Northrop, Henry Margenau, Gaston Bachelard, Karl Popper and, today, Nancy Cartwright amongst others. In spite of the specific aspects of their respective epistemologies, what brings these philosophers together is a certain rapport between scientific constructs and explanation. In this regard, their epistemological theories are in opposition to all forms of empiricism inherited from classical empiricism that lead to getting rid of explanation, either because they reduce science to a system of relationships (positivism) or because they pose the problem of knowledge essentially in terms of the subject confronted with the object—as observed by Popper (1972). The convergence between historical–cultural psychology and modern epistemology is based on the dualist theory of concepts they share, which enlightens the issue of human understanding as well as the problem of explanation in science. It opposes spontaneous or intuitive concepts with scientific or postulated concepts, and is especially developed in the works of Northrop and Margenau.

To characterize the effects of specifically human learning, Vygotsky distinguishes two types of concepts: spontaneous concepts and scientific concepts. Prior to attending school, children's minds develop through interaction with adults or more advanced children as a collateral result of multiple activities. This is the case, for example, regarding where the acquisition of the mother tongue is concerned. The sense of the concepts formed spontaneously in children's minds refers to their

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concrete experience. That's why the concepts of pre-school children are empirical, subconscious and non-systematic.

In opposition to these spontaneous concepts, concepts that are the object of schooling, and named "scientific" by Vygotsky, are acquired based on conscious processes. The specific feature of scientific concepts, as opposed to common, every day or spontaneous notions, is that they are defined by their relations to other concepts. More precisely, scientific concepts are an integral part of a system of concepts in which they exist independently of real objects: the central fact that determines the nature of differences between everyday concepts and scientific concepts is the absence or existence of a system. Besides, it is the structuring into a system of concepts that explains awareness. That's why scientific concepts are conscious or, else, voluntary. The existence of such a system allows one to establish supra-empirical relationships between abstract elements, and thus accounts for hypothetical-deductive reasoning.

Vasily Davydov ([1972] 1990: 118) adds an important remark. The organization into systems, which explains awareness, is not sufficient to specify "theoretical" concepts, which mostly correspond to what Vygotsky has in mind when speaking of scientific concepts. A theoretical concept is not only an integral part of a system of concepts, but also, theoretical concepts have their own field of application that is distinct from that of "empirical" concepts. Indeed, they do not refer to features that are common to all the particular objects constituting a class. They do not apply to elements of the world, but to *interconnections between elements of the world.* Such relationships are not defined by mere induction which can only establish statistical relationships. They cannot be observed directly by the senses because they do not exist as an independent reality defined by elements of the outside world. Nor do they bear the nature of necessity a priori. The imputation of (causal) relationships between elements of reality can only—we will come back to this later—be mediatized through the intermediary of theoretical systems or models. With the system, relationships between concepts are established, and these make it possible to follow out chains of deductive reasoning and, more specifically, to construct causal relations and to manipulate symbolic objects of thought into mental simulations.

The meanings of everyday or spontaneous concepts are founded on the experience of the objects these notions denote, these participate in type 1 fast thought processes. While it is the structuring into a system of concepts that accounts for type 2 slow thought processes. Depending on the types of objects they deal with, chains of reasoning can be differentiated along a continuum, going from intuitive or concrete reasoning to formal reasoning. The more a theory is "naive", the more specific the objects it handles, since not just any object lends itself to classification. By contrast, formal thought easily produces definitions for the abstract objects it deals with. Such definitions are based on relationships between concepts. According to Vygotsky, during schooling a student will acquire many concepts of a scientific or theoretical nature, over a relatively short period of time. This learning is developmental in the sense that it leads to development of the individual capacities to bring into play type 2 processes. Therefore, the progressive internalization of conceptual systems—i.e., the acquisition of scientific or theoretical concepts—

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supports the higher functions of human thought and plays a crucial role in children's development, allowing them to reach a higher level of control of their thought.

Besides, type 1 and type 2 processes tend to co-exist in the mind, the latter supported by the former, which obtains for them an intuitive or sensitive apprehension of the world and, in return, transforms them by playing on their own structure and engaging awareness in their respect. With school learning, type 2 processes take the advantage over type 1 processes (Vygotsky 1934; Luria 1976).

To summarize, the main assumptions of Vygotsky's developmental psychology are in conflict with the various naturalist premises proposing a unitary model of development, whether they are derived from behaviorism, or more generally from functionalism, or from genetic epistemology. These assumptions, based on a dualist theory of concepts, are as follows:

1. Human development is the fruit of two lines of development, one stemming from biological evolution, in continuity with animal development, and the other stemming from Man's social existence and based on the use of auxiliary means of thought.
    a During the course of a child's cultural development, cognitive functions first appear as an external social activity (between people) and are reconstructed in an internal way by the individuals to become the instruments of a self-stimulation of thinking.
2. The two lines of development in play respectively lead to the formation of two types of concepts. The first, called spontaneous concepts, are unconscious and refer directly to elements of experience of the outside world. The second, called scientific concepts, are conscious or intentional and owe their meaning to an internal hierarchical system of reciprocal relationships.
    a The difference in nature of spontaneous concepts and scientific concepts lies in whether or not there is a system, which underpins the awareness and mastery that characterizes slow thought processes.
3. The development dynamics of spontaneous concepts are in opposition to those of scientific concepts, the former are of the bottom-up type (their starting point is a direct relationship with the object) and the latter are of the top-down type (their starting point is a mediatized relationship with the object).
4. In the human development process there is interaction between these two evolutionary lines; the higher thought processes rely on the lower processes and influence them in return by engaging a structuring of spontaneous concepts, giving them access to a higher level of mastery.

Returning to epistemology, we note that a similar distinction between concepts "by intuition or inspection" and concepts "by postulation" is to be found at the heart of Northrop's theory of concepts. The meaning of concepts by intuition or inspection carries us back toward elements of the experience that they denote. By contrast, concepts "by postulation" (which correspond to theoretical concepts defined earlier) have no denotation. Their meaning is founded on properties and relations that

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interconnect them within theoretical frameworks or else, conceptual systems—i.e. they are mediatized by all of the concepts to which the theoretical concepts are linked. As they do not refer to the outside world, they can't be directly matched with observable elements in reality. The color blue no longer refers to the experience of a feeling but, for example, to a wave length, the meaning of which depends on a set of theoretical constructs. In the same way, the word « force » can designate for the subject an immediate experience, something apprehended as a muscular sensation such as an impulse. But in the language of a physics professor, force has a different connotation; it refers to something more abstract that exists independently of tactile or kinesthetic sensations which, moreover, are linked to the idea of physical force in a measurable way. Newton's law describes it as the product of mass time acceleration, supposing a very different entity. This is the conceptualized aspect of force, and this aspect is not given as a simple perceptual representation. For those who are not physics specialists, temperature signifies heat or cold, something that is felt by the senses. This feeling has nothing to do directly with the role of temperature in thermodynamic equations or what is measured by thermometers. These examples drawn from physics (Margenau 1950: 223*ff*) must not allow us to lose sight of the fact that it is the same, in varying degrees, for all notions that support our understanding of the world and those around us. For example, the founding principles of our liberal democratic societies do not refer directly to individual experiences. They rest on intellectually constructed concepts, which confer a meaning that is absolute and independent of the variability of particular real-life situations, for both the idea of equality before the law and the idea of universal human rights.

Therefore, as the relations between scientific concepts and reality are not direct, Northrop uses the notion of "epistemic correlations" to identify them. More precisely, epistemic correlations allow scientific concepts to have empirical meaning by linking the entities postulated via scientific concepts to "concepts by intuition or by inspection" that denote real entities or factors (Northrop 1947: 143–44). [2] The term "epistemic" expresses the fact that such correlations link together two worlds each with a different nature. These correlations should not be confused with the ones normally referred to in the sciences linking factors that belong to a single horizon of knowledge.

To illustrate these conceptions, we will now examine a diagram offered by Margenau (see Fig. 1)—whose epistemology is very close to Northrop's theory of concepts—concerning relations between scientific constructs and observable or experiential reality. "Nature", identifying the totality of the immediate data of experience, is represented by a limit area, in this diagram a vertical line marked "N". Formal relations are indicated by single lines and epistemic correlations by double lines. All constructs are labeled C or C'. Scientific constructs are mutually connected in multiple ways, including possible passages toward empirical reality, enabled by epistemic correlations. They do not necessarily all have an empirical entity corresponding to them. If constructs (C') do not have multiple relations, they

[2] An epistemic correlation is a relation joining an unobserved component of anything designated by a concept by postulation to its directly inspected component denoted by a concept by intuition (Northrop 1947: 119).

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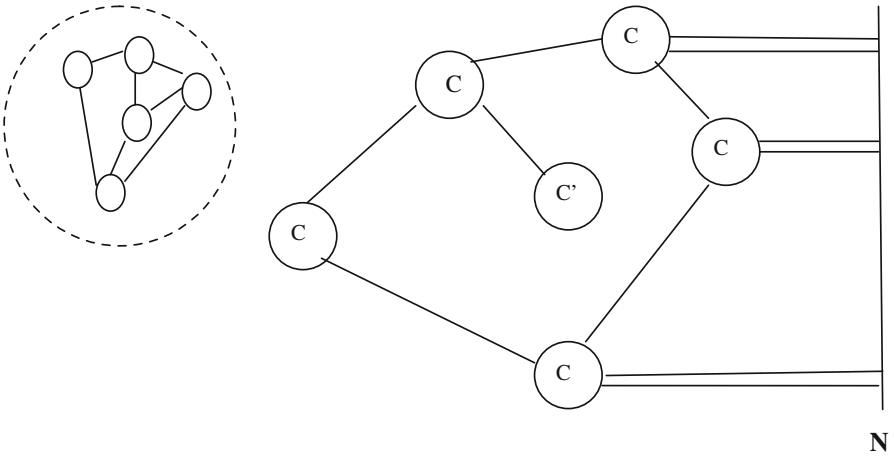

Fig. 1 Theoretical constructs and experience. *Source*: Margenau 1950, based on figure 5.1, p. 85

don't play any part in the theory (for example the color of an electron). Other constructs (included in the dotted-line circle) may constitute an isolated group, which is coherent but without any known connection to the empirical world.

The dualism of Northrop's theory of concepts tends to integrate the whole epistemology of Western science. Northrop (1959: 199) explains that the latter is a correlation of two epistemologies: "(1) critical realism with its indirect modes of verification, its scientific objects and relations for which *esse* is not *percipi* and its real universals; and (2) existentialism or radically empirical positivism with its direct mode of verification, its unique particular entities and relations for all of which *esse est percipi* and its nominalistic universals." Northrop defines his own epistemology in terms of "logical realism in epistemic correlation with radical empiricism". Critical—or logical—realism refers to a constructed reality, that of more or less closed systems which therefore defines a public world. Radical empiricism refers to various kinds of empiricisms rooted in classical empiricism, the name evoking the philosophy of pragmatism, as defined by William James.

As it is the case with Vygotsky's dualist theory of concepts, these epistemological conceptions maintain links with the rapid thought processes that are associated with the direct apprehension of the world on the one hand, and with the slow processes associated with the rationalization of reality on the other.

We show in the following how structured conceptual systems account for the notion of causality and can explain the success of scientific thought—its possible match with the real world—while this match falsely justified an overall biological model of intellectual development in Piaget's work.

3 Conceptual systems and causality

Some reflection on the notion of causality allows an understanding of the role played by theoretical constructs, as opposed to empirical observations, in the

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rationalization of reality. The impossibility of establishing a necessary relation between facts of experience was highlighted by David Hume. A generalization can never give the assurance of being true. A repetition of particular cases offers an idea of what occurs most often, but does not tell us what will always happen. Such is the limit of induction. We expect to see the sun rise tomorrow but, Hume tells us, we would demonstrate in vain that the proposition "the sun will not rise tomorrow" is false. Hume denies that we might have an idea of causality other than by the fact that two events have always succeeded one another, stating, as a general proposition that admits no exception that "the knowledge of this relation is not, in any instance, attained by reasonings a priori, but arises entirely from experience, when we find that any particular objects are constantly conjoined with each other" (Hume 1748: chapter on cause and effect).

Hume is partly mistaken. He did not understand the hypothesis function of scientific constructs. We believe we can deduce from observation that all men are mortal. But, in reality, our certainty about the mortality of all men is founded not only on observation, but also on the elementary theoretical constructs that corroborate it. In reality, we mean something more. We introduce implicit elements concerning the aging process that make death inevitable. This inevitability stems from the theoretical constructs we have in hand (Margenau 1950: 389*ff*). It is these constructs that allow us to establish causal relationships. These relationships do not refer directly to the phenomenal world, but are true concerning the theoretical system constructed. This is why Popper (1972) proposes deductive logic as a solution to Hume's problem, laws and theories being hypothetical or conjectural.

Discussing the meaning of causality in scientific analysis, Margenau makes an important distinction between partial and total causes—as did also Meyerson (1908: 34–36). In ordinary language we tend to employ the concept of cause by speaking of partial causes. For example, pneumonia (state C) is the cause of death (state B) of a person. No systematic link connects the disease to death. Here the logical connection is in reality the following: If (not C) then (not B); if the person had not caught pneumonia, the person would not be dead.

No affirmation supports an invariable sequence of the form, "If A, then B". Nevertheless, the principle of causality "asserts that a given state is invariably followed, in time, by another specifiable state." Such a sequence assumes that we have examined the sum total of pertinent events preceding the set of given events represented by state B. In other words, the principle of causality requires for its application completely closed and finished systems of events. Totally closed systems do not exist in nature. The form, "If A, then B" cannot apply to the world of experience, because causality is not a property of data. Then, causality is a relation between constructs, more particularly between states of a theoretical system. The systems that lend themselves to being developed according to logical analysis are therefore intellectual constructions; in formal terms the problem of explanation amounts to establishing causal relations (which can be characterized by the relation, "If A, then B") between states of a theoretical system, that is, a model.

The notion of causality therefore appears as a methodological principle expressing a kind of consistency expected of nature. That translates into the identity in time of the invoked factors, which is a central theme in Meyerson's

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works. Scientific models tend to account for observed phenomenon through the combination of pre-existing elements—defined by theoretical conceptual systems—and such elements are scientific constructs. By doing this, they respond to a major factor in human understanding: identity in time.

In this way, thought becomes explanatory—through the modeling of generative mechanisms—based on the construction of concepts identifying stable elements in time; such stability is achieved only by theoretical elements whose meaning relies on concepts-to-concepts links. Thus, these elements are not directly inferred from experience but represent plausible hypotheses. We note that this construction defines a movement toward explanation that is never definitive and that is why description and explanation have a relative status: explanation at a given level may become description at a higher level, where theoretical analysis involves factors of a greater generality (Margenau 1950: 167–171). The greatest generality refers back to a trans-situational truth, in the sense of the concept of capacity in Cartwright (1989).

4 On the harmony between mathematics and the real world

The fundamental agreement between formal thought and reality has always been a major preoccupation of philosophers. We have progressed toward abstraction, creating concepts that are more and more removed from concrete reality. We have established links between formal concepts and reality—the epistemological correlations Northrop mentions—and this enterprise has been particularly successful, to the extent that these links have revealed aspects of reality that scientists could not have found without them. One example amongst many is the agreement of Riemannian geometry with the theory of general relativity, which links geometry with gravitational theory (Einstein 1926). This agreement is even more mysterious since it brings into contact theoretical constructs that are, to a great extent, creations of the mind, and the phenomenal world.

There is no need to recall previous assumptions brought to this question—from the essentially mathematical nature of reality to the analogy of procedures used by intelligence to apprehend reality and reason mathematically. This second path follows the basic teachings of Kant: the agreement between our understanding and reality exists, but is only partial. Mathematics allows us to shed light only on a very limited part of physical reality and mathematics has its own developments that cannot, due to their complexity, be applied to reality. Still, the reasons for this agreement, or partial agreement, remain an enigma (Meyerson 1931: 713).

Two responses to this enigma proposed in the 20th century place naturalist conceptions in opposition to dualist conceptions—within the meaning of Northrop's epistemology mentioned earlier—in knowledge theory.

The first response brings the concept of evolution into play and refers to the combined action of the environment and the individual. It was developed to term by Piaget and came to represent a particularly strong motif in his research into genetic epistemology.

In two words, for Piaget, the agreement between our understanding and reality relies on the formation of logical-mathematical structures in the course of the

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subject's interaction with his environment, and accounts for the great role played by mathematics in the apprehension of physical reality. Logical-mathematical structures represent operating structures of intelligence that underpin the possibility of decoupling thought from objects. Since such human faculties would be rooted in man relation with his environment, mathematical structures can be fitted to the phenomenal world.

Specifically, Piaget ([1967] 1971: 342) assumes that logical-mathematical structures are derived, in the course of human development, by "reflective abstractions"—which we discussed previously regarding the development of recursive faculties in the human mind—from the general co-ordinations of action. According to Piaget, this internal evolution of the subject's general cognitive structures, which is the result of the individual's interactions with his/her environment, drives to equilibrium, that is reversibility, or else, awareness—corresponding, in Piaget's terms, to the "closure of operating structures" mediating experience.[3] The idea of closure, mentioned above regarding theoretical systems, is embodied here and accounts for general mental competencies, while being essentially applied to the coordination of actions. Piaget thought that these processes could account for the potential role of mathematics in the apprehension of physical reality. The only alternative hypothesis opposed by him to this argument is the possibility that mathematical structures might be derived not only from the actions of the subject upon objects but also from the objects themselves, since physical experiments would gradually bring about modifications in them. Piaget ([1967] 1971: 344) rejects this idea that mathematics could have been progressively adapted to the physical universe, noting that the history of mathematics reveals its internal and endogenous development, independent of representations of the physical world. Having only considered such an alternative—the "progressive adjustment of the mathematical framework and the experimental content in the course of the experiment itself"—Piaget finds himself comforted in the idea that the harmony between mathematics and reality is rooted in a prior, biological agreement developed by the organism during the subject's interaction with his/her environment, an agreement that is inherent to the general coordination of the subject's actions.

The importance of Piaget's argument, within the framework of the theoretical edifice he developed, is such that Piaget ([1967] 1971: 342) does not hesitate to write that if he was mistaken, his "interpretation would need some rather basic revision. It would just be one of those unfortunate things that happen."

[3] In the process described by Piaget, we find the process of system closure that logical thought applies itself to. Piaget [1967] (1971:292) remarks that logical-mathematical structures are not innate because then they would lose their necessity, innate characters being differentiated according to the biological inheritance of species. Moreover, he states that children do not immediately recognize relationships of transitivity, which imply, for example, that if $A < B$ and $B < C$ then $A < C$. Nor are these structures acquired, because then they could only be imperfectly approached by the mind. On the contrary, they represent an a priori condition of rational experience. They would be constructed during development endogenously under the effect of an "equilibration" movement susceptible of repeating itself in a meaningful way in each generation without being hereditary. It is this equilibration movement that he compares to the perception of a perfect circle from a form that in reality is irregular, which would make possible the closing of operating structures that are indispensable for the establishment of logical links.

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Nevertheless, Piaget manifestly was mistaken. On the one hand, it is hard to see how only basic logical-mathematical structures, which interest intellectual development in Piaget's framework, could take into account the posed problem, which is that of an extraordinary coincidence of mathematical models developed by formal thought and reality; on the other hand, the a priori separation of thought structures from their content drastically limits his scope for interpretation and underlies his confidence in a postulation that, in reality, is no more than a stop-gap solution.

Margenau explains this coincidence of formal thought and reality in a much more convincing way, revealing that it is not as strong as it might appear. Concept to concept relationships in the "C field" (Fig. 1) refer to what he calls "constitutive definitions" (the definition of time as the independent variable in the laws of motion for instance), whereas the epistemological correlations (or rules of correspondence in Margenau's terminology) between theoretical and empirical concepts refer to "epistemic definitions" (the definition of time by reference to clocks, for instance). Note that different epistemic and constitutive definitions may apply to a same physical entity. The feeling that there is a close coincidence between formal thought and observed reality is supported by the belief that constitutive definitions apply to reality. In this respect, maintaining the idea of pure a priori knowledge—i.e. true without, or prior to, experience—is, according to Margenau, symptomatic of a failure to recognize the difference between constitutive and epistemic definitions—in other words, we may say, a failure to recognize the duality of the knowing mind.[4] This failure results in the assertion of direct correspondences between observed reality and human constructs such as, in Piaget's argument, the direct applicability of mathematical structures to nature. Actually, the difficulty in understanding why nature obeys formal laws disappears when you grasp the fact that formal laws do not apply to immediate experience. There are parameters that enable an adjustment to take place, between the real world and its formal representation. This adjustment is accomplished by means of epistemic definitions: "a freedom in choosing them gives science the flexibility it needs to grasp experience, and it takes away the character of the miraculous from the fact of nature's obedience to laws". (Margenau 1950: 242).

To explain this further, we can refer to social sciences theoretical models. Formal automatons simulate the shadows of reality projected upon a given projection plane. The shadows refer to the world, while the automatons are formal constructs. The elements of models are formal constructions, evolving in a closed system, while social reality is an open one. Note that the links between these two worlds do not place, analogically, in opposition two worlds of a similar nature. So that there is no much sense in maintaining that our formal automatons participate in a counterfactual reality (Sugden 2000). While modeling the generative mechanisms of social phenomena, we assume that the connections between various factors of the model, defined by constructed concepts, and various real factors, that is, factors abstracted

[4] Note the existence of a limit form of duality in the belief in pure a priori. As Northrop (1946:196) explains, Kant saw that our knowledge from both common sense and scientific objects is composed of two parts, one empirically given through the senses and the other given theoretically, on the basis of postulated, unperceived elements; but Kant incorrectly saw this theoretical component of knowledge as categorical and necessary rather than, as is the case, simply hypothetical and confirmed only indirectly by his deductive consequences.

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from the world of experience and denoted by empirical concepts, are epistemically valid. In other words, the theoretical model is supposed to represent the internal logic of different situations that are subsumed under the phenomenon that is explained. A certain degree of proximity to observational data that we may manage to attain is possible because of the existence of interactions between parameters accounting for some flexibility in their possible interpretation (fixed by epistemic definitions here). And when we attempt to express the phenomena we are studying in the language of the model, we impute the complex effects of real processes that are going on to parameters and algorithms that we have formally introduced into the process. The rationality of reality appear then as a consequence of dualism of worlds—knowledge systems and experiential reality—rather than the consequence of a biological adaptation of the mind.

5 Human rationality: a quest for meaning

The dualisms exposed by modern epistemology and the psychology of learning come together on the basis of a theory of concepts that allows a bridge to be built between them. This is why epistemology can enrich understanding of human psychology, which reveals two types of processes that originate from two different evolutionary lines. It should be said that the two aspects of thought marking these dualisms generally appear, in the theoretical frameworks presented here, to be intrinsically complementary, rather than in competition with each other.

On the one hand, rapid processes are directed toward action. They develop based on experience of reality in comparable circumstances. In this respect, they participate in the establishment of connections between phenomena—i.e. in the legality of experience. Thus, rapid processes underpin the development of habits, which are organized according to the expected satisfaction to be procured in comparable circumstances.

On the other hand, slow processes are directed toward the mastery of thought itself, through the manipulation of mental constructs that are stable entities relatively autonomous regarding the concrete circumstances.

We might mention here that this characteristic is not recognized by certain trends in educational research that influence contemporary educational policies. All forms of "situated learning" approaches—including competency-based approaches—are based on the idea that knowledge and structures of situations are so closely linked that it is preferable to define knowledge on the basis of relationships between the knowing subject and the situation. Major shortcomings of these approaches have been highlighted by Herbert Simon (Vera and Simon 1993; Anderson et al. 1996, 1997). Anderson et al. (1996:5) argue against four central claims of situated learning with respect to education they summarize as follows: (1) action is grounded in the concrete situation in which it occurs; (2) knowledge does not transfer between tasks; (3) training by abstraction is of little use; and (4) instruction must be done in complex, social environments. These arguments put forward are interlinked and oppose the theoretical premise of a unitary model of intellectual development to the dualist conception. They involve important issues for education since they bring

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into play the effectiveness of "apprenticeship training"—or "concrete training"—and "training by abstraction" methods. Whereas advocates of situated-learning approaches claim that the "transfer" between tasks depends on the number of elements common to the situations in which they are carried out, Simon and his colleagues maintain, for example, that the transfer between areas varies directly with the number of symbolic components that are shared. They observe that advocates of situated learning focus on examples that, at best, show that particular skills practiced in real-life situations do not generalize to school situations, whereas abstract instruction in many fields—even when narrowly applied, such as sexing day-old chicks—can prove to be infinitely more effective than years of concrete practice. Practice is important but it does not directly serve the construction of meaning. Correspondingly, as Anderson, Reder and Simon maintain, the importance of the social structure of learning does not imply that all learning involves socially organized activity. This implication underlies contemporaneous socio-constructivism which, we note, improperly claims Vygotsky as its founding father.

We can assume that slow processes have developed through the building of abstract intellectual constructs because they allow great economy of thought. In the first place, the meaning of each construct refers to the meaning of many others, whereas with respect to directly observable data described by concept by intuition, the apprehension of phenomena requires "almost as many different ideas as there are different facts" (Northrop 1960: 29). Next, from a finite number of elements—identified by concepts to concepts links—multiple phenomena can be represented. This economy is already illustrated by the properties of human language, which differs from all forms of non-human communication because of recursion (Hauser et al. 2002): a limited number of elements and combination methods can engender infinite possibilities of expression. In the same way that language, with a finite number of words, allows us to express an infinite number of ideas, science, with a finite number of elements, allows us to account for an infinite number of phenomena. Based on such a generative power, the possibility of simulating change through the combination of pre-existing elements—i.e. stable or identical in time—underpins the very idea of causality and lies at the foundations of human understanding. Identity, writes Meyerson, is the eternal framework of our mind. Science is impregnated with it, even if it does not constitute all of science.

These qualities of theoretical construct, identity and generative power are at the root not of action but of understanding. That is coherent with the idea that Science does not aim first for action, but understanding. The faculty of understanding is not derived from the faculty to act, as suppose philosophies and psychologies that have their roots in evolutionism such as Comtism, Bergsonism, Pragmatism, Functionalism, Behaviorism and Genetic psychology etc. Understanding is part of quite a different movement, an action by the mind on itself. It marks an irreducible break from animal development which is indefinitely linked to action on the world. Action according to the legality of experience is a prolongation of reflex. It leads to conformity through reference to similar circumstances. In the end, it offers no adaptive advantage in a changing world. On the contrary, the creative manipulation of defined elements allows the domination of change by understanding. It increases

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potential for action tenfold. Meyerson (1931: 609) concluded his analysis of thought and thinking that science does not only have action as its goal but aims above all for understanding, tending toward a "progressive rationalization of reality". And it is quite unlikely that this tendency toward rationalization of reality is derived from experience itself, from action.

As far as natural reasoning lies between the two poles of thinking: intuitive or concrete reasoning on one hand, formal reasoning on the other hand, epistemology opens onto psychology. The fundamentally convergent theoretical works which were evoked here give meaning to the human mind specificity, linked to its potential for recursion, underpinning the possibility of conceptual systems, identity, causality and understanding, as well as, to a large extent, human imagination and creation. Higher forms of intelligence cannot arise from lower forms through individual forms of development alone. Vygotsky teaches that human development is the consequence of the historical dimension of mankind. It proceeds from an internalization of social constructs, or even scientific constructs, the meaning of which refers not to the world directly, but to other constructs. In other words, they have only an indirect relationship with experience: the later serves as illustration, not anchor. Economy of human thought is such that, by sacrificing rapidity, facility and direct reference to the world, it gains in the potential for mastery and creation. But that's not all; from this it creates a public world that makes debate and the accumulation of knowledge possible.

The most important conclusion this detour through epistemology allows us to reach, is that we can understand nothing of human psychology if we suppose that it originates from a need to act. It appears clear that it is characterized in the first instance by a need to understand, a quest for meaning.

6 Some final remarks

Modern epistemology and historical-cultural psychology are, from a fundamental standpoint, coherent with dual processes theories. They should constitute for them fruitful sources of reflection that can allow them to go beyond some of their current limits. It appears to us that the most important aspect is their tendency to neglect the fact that thought is not a faculty in itself, independent of the cognitive tools required for its deployment. In other words, it is not sufficient to describe learning underlying type 2 processes as rule-based to capture the cognitive conditions of such processes. This tendency to separate the general forms of thinking from knowledge was one of the failings in Piaget's psychology, which meant he missed the role played by the historical dimension of mankind in the very development of the child's capacity to reason logically. This shows that dual process theories could go further in explanation of human reasoning on the basis of Vygotsky's assumptions, in the same way that, in developmental psychology, Vygotsky went further than did Piaget, whose works today have possibly descriptive but not explicative value.

The key point here, which is common to both historical-cultural psychology and modern epistemology, is a theory of concepts that underpins the forms of logical reasoning and which we have illustrated with regard to the question of causality.

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More generally, it is organization into hierarchized systems of concepts that underpins awareness and the mastery of thought processes themselves, which are characteristic of type 2 processes. Abstract reasoning abilities and the scope and complexity of faculties of recursion depend on the structuring of conceptual systems. This is why such faculties differ for each field depending on the knowledge developed, and demand of the child the acquisition of numerous concepts before they can be deployed. In this respect, it is important to consider that a key function, which supports human rationality and is closely linked to cognitive decoupling (Stanovich 2009), is the use of auxiliary means of thought.

More specifically, Vygotsky's theory on the development of conceptual corpora in the child and the interaction of the two (biological and historical) lines of development, which actually modifies the elementary processes, can also be a source of interesting hypotheses for contemporary psychological research.

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