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Theories and Applications

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CHAPTER 9

A Dialectical Constructivist View of Representation: Role of Mental Attention, Executives, and Symbols

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Representation certainly implies the constitution of a symbolic function, i.e., of a differentiation of signifiers from significates, for it consists of evoking non-present significates and it cannot evoke them without using differentiated signifiers.

—Piaget (1975, p. 170, translated by JPL)

I have ***proposed*** *that ... conceptual representation begins early and develops in parallel with the sensorimotor system. In my view neither system is derivable from the other... except insofar as one must perceive stable perceptual displays in order to analyze them.... Perceptual analysis uses attentive processing*

—Mandler (1998, p. 273)

If I understand a new mechanical contrivance, it is a concept for me, even if I do not give it a name. The functional relation, transferable to an indeterminate manifold, is the concept

—Burkamp (quoted in Cassirer, 1929/1957, p. 328)

Plato was the first thinker to formulate the dialectical view that humans partake of two distinct worlds of conscious existence (two modes of knowing/processing), "the world of ideas and that of the senses, the world of being and that of becoming, the noetic (intelligible) world and the world of appearance" (Jaspers, 1957/1962, p. 30). The world of ideas, or of being, categorizes the world of the senses, or becoming, making possible human knowledge. Implicit in this description are problems that Plato did not solve and that cognitive science currently is facing. One of these problems is how to differentiate two irreducible modes of cognitive processing, the *conceptual* (logological, logico-mathematical, or generic knowledge—high cognitive functions) versus the *experiential* (mereological, perceptual-motor/spatiotemporal, infralogical, or knowledge of particulars—low cognitive functions); and at the same time explain the emergence of both modes of processing from the same origin: as resulting from interactions among innateness (maturation) and experience (learning, whether culturally mediated or direct). A second problem is that of continuous *representation:* How can direct-perceptual or conceptual-processual forms (codes, schemes) adapt to the evolving constraints of hard reality (the world of the senses and of learned experience) so as to embody these constraints, even in truly novel situations where subjects lack proper representational forms? We refer to these as *Plato's problems,* because Plato's formulation, having created an absolute dichotomy between "conceptual" and "experiential," caused the problems' emergence.

Central to Plato's problems is the issue of how "representation" develops: the ability of humans and high mammals to generate and store in memory (i.e., learn) stand-by "models," real or imagined, of cognitive states of affairs, whether external or mental. There is no consensus in the psychological literature about how to explain the emergence and growth of representation, and there is little awareness that the problems of representation are in fact the same as the problems of Plato (Pascual-Leone, 1996). Here we sketch a dialectical constructivist model that can unify various current alternative views on representation and help to solve the problems of representation.

The epigraphs of this chapter highlight the key controversial issues we address. The quotation from Piaget states explicitly his classic view on representation: The organism requires symbols (defined as Piaget did in this quote) to produce representations. We deny this claim and correct it as follows: No complex executive-driven (i.e., operational) representation is possible without the symbolic function. We believe, however, that simpler representations are possible before the symbolic function has appeared, and these representations are not reducible to coordinations among sensorimotor schemes (i.e., information-bearing processes). This may be Mandler's meaning in the second epigraph. Here she seems to equate "concept" with "representation"; this is a broad interpretation of concepts, which other developmentalists currently share (e.g., Baillargeon, Kotovsky, & Needham, 1995; Case & Okamoto, 1996; Halford, 1993; Houde, 1992). The quotation from Cassirer shows that this broad interpretation of concepts has early distinguished precursors. Cassirer intimated here what his books explain: Whether verbally abstracted or not, a functional relation abstracted as a type (i.e., generically) is a concept, because it is then transferable to any experience (or "manifold") that is a token of it. Thus a concept broadly defined is, like any representation, characterized by what we call *reductive* abstraction: the extracting from a manifold of experiences the common functional or perceptual characteristics, so as to constitute a cognitive "invariant" that can stand for them all (Pascual-Leone, 1987, *1995;* Pascual-Leone & Irwin, 1994; Pascual-Leone & Johnson, 1991; Pascual-Leone & Morra, 1991). We have long claimed that reductive abstraction requires mental attention, both to boost with activation the relevant schemes to be highlighted from the manifold and to actively inhibit or interrupt from the experiential manifold other irrelevant schemes. Mandler (1998; see second epigraph), neo-Piagetians (e.g., Case, *1992;* Demetriou, Efklides, & Platsidou, 1993; Halford, 1993; Houde, 1992), developmental neuropsychologists (e.g., Bell, 1989; Diamond, 1988), and many other researchers today might agree with our model of mental attention, because it explicates intuitions they all share.

As Mandler *(1998)* has emphasized, current theories of representation must be contrasted with that of Piaget, whose work synthesizes the classic view. Thus, we begin by summarizing in a number of "P" points Piaget's theory of representation. In a parallel series of "DC" points, we then summarize our dialectical constructivist correction to Piaget's theory. Against this background, we next present a summary of our theory (theory of constructive operators), and finally, illustrate the application of this theory by task analyzing four representational tasks studied by other researchers.

A DIALECTICAL CONSTRUCTIVIST CRITIQUE OF PIAGET'S THEORY

Piaget's view on representation is stated clearly and concisely in a published statement in honor of the French psychologist Wallon (Piaget, 1975). We summarize in seven points Piaget's position, quoting him whenever possible:

P1. "The young child does not manifest any representation, in the sense of evoking objects or events not directly perceptible or not signalled by perceptual indices. His behaviour is exclusively sensorimotor, or sensori-tonic or emotive, etc." (Piaget, 1975, p. *169,* translation, here and elsewhere, by JPL). "In contrast, during the second year, and in particular during its second half, takes place this event of capital importance for human thought, i.e., the birth of representation, which enables intelligence to become internalized into proper thought. How does it happen?" (Piaget, 1975, pp. 169-170).

P2. Representation is made possible by the developmental emergence of a symbolic /semiotic function (see first epigraph). Piaget understood by symbolic function a mode of cognitive (semiotic) processing characterized by "a differentiation of the signifiers and the significates" (Piaget, 1975, p. 170).

P3. Representation is made possible by complex mechanisms of structural learning, called "reflective abstraction"—a sort of learning often intended by current terms such as "representational redescription" (Karmiloff-Smith, 1992), *chunking,* and so forth. Reflective abstraction generates *mental* or conceptual (preoperational or operational) *schemes,* which are the main, but not the only, organismic cause of "re-presentations." The mechanism of reflective abstraction is innate "regulations" (endogenous organismic reorganizations). Because reflective abstraction is a recursive organismic function, mental schemes appear at different levels of reflective abstraction (there are schemes of schemes of schemes, etc.). And to each level of abstraction corresponds a different level of mental representation (representation, re-representation, etc.). In contrast, Piaget (Beth & Piaget, 1966) called "empirical abstraction" the sort of experiential learning of content that is possible without having/using reflective abstraction. Empirical abstraction is a sort of abstraction that babies exhibit in surprising ways. It serves to generate *sensorimotor schemes,* which produce both the subject's perceptual "presentations" and actions.

P4. In his effort to explain the ability of thought to represent change—transformations—as well as state descriptions, Piaget came to recognize a key dialectical pair of scheme modes: the *operative,* which for Piaget was primary, and the *figurative,* regarded by him as secondarily derived. Operative schemes were his alternative to the "responses" or "activities" of learning theoreticians, the neuroscientists' "efferent processes," and the "procedures/procedural processes" of cognitive science. Figurative schemes stood for the "stimuli" or "patterned cues" of learning theoreticians, the neuroscientists' "afferent processes," semioticians' "signs," and cognitive science's "perceptual," "representational," and "declarative" processes, and/or "mental models."

P5. Unlike cognitive science, which often conflates the dimensional category operative/figurative with the category experiential/conceptual, Piaget's theory tacitly maintains the distinction by claiming that at all levels of reflective abstraction, from experiential (sensorimotor) to conceptual processes, one finds the two kinds of representation: operative and figurative.

P6. Operative representations emerge, according to Piaget (1975), as a consequence of "coordinations among actions as such" (p. 178). Actions "as such" are concrete actions, that is, performance implementations of sets of compatible operative schemes from lower levels of abstraction. These coordinations serve to abstract the relations of coactivation and cofunctionality in praxis (i.e., in goal-directed activities) which, due to characteristics of either reality or the organism, obtain among schemes. Thus coordinations constitute "operative shells" or "macros" that reflectively abstract operative courses of action. In this manner, the courses of action become easier and eventually are internalized when the operative "shell" structure in question (explicated later as an L-structure) can be activated from within, by purely mental activation. Vygotsky and his school, despite terminological and substantive differences, have very similar notions of internalization (Pascual-Leone, 1996).

P7. "To the figurative aspect of knowing one can attribute perceptions, imitation in all its forms, and the many varieties of mental image: three grand categories that have in common the bearing exclusively on configurations (and the translating into figures or figural symbols all movements, and even transformations, that the subject attempts to perceive or reproduce)" (Piaget, 1975, p. 176). For Piaget these figurative schemes emerge from coordinations of a special sort, caused by a patterning (due to coactivations and cofunctionality) of the schemes that receptor-driven exploratory activities elicit. These perceptually driven coordinations of schemes are often more or less iconic (Piaget would say configural) in the sense that the patterning "imitates" in its structure the real form of spatiotemporal, or of part–whole object relations, found in the subject's environment. In this figurative structuring not only the resistances of reality play a role, but also the subject's own innate perceptual, sensori-tonic, and bodily postural coordinations, as well as his or her innate dispositions to imitate and to iconically explore the perceived environment, his or her emotions and affective goals that implicitly drive these explorations, and also his or her innate disposition to reflectively abstract these configural coordinations in the form of mental images. All these are factors that distinctly characterize figurative representations: "the figurative aspect of the representation depends on the sensori-tonic or postural system by the intermediate of imitation and the mental image" (Piaget, 1975, p. 178).

We do not review here the criticisms, often justified, that Piaget's theory of representation has received. A recent chapter by Mandler (1998) outlines criticisms from the perspective of current experimental information-processing theorizing. Instead, we give a set of seven alternative dialectical constructivist (DC) points, which correspond to and correct the seven Piaget (P) points just described.

DC 1. Contrary to Piaget, and like the moderates among neo-nativist infancy researchers (e.g., Baillargeon et al., 1995; Karmiloff-Smith, 1992; Legerstee, 1992; Mandler, 1992; Wynn, 1992b), but for theoretically different reasons, we believe that simple representation can be found prior to the symbolic function that begins in the infant's second year. This is particularly so in facilitating situations (see later discussion). By simple or *content representations* we understand schemes (usually figurative), which are either innate or reductively abstracted from experience, and which act as signifiers (signals) for other schemes (figurative or operative) that in praxis are related to the content representations either indexically (i.e., via associative learning) or iconically (i.e., via a configural similarity relation produced by innate mechanisms or biases). Reductive abstraction (Pascual-Leone, 1984; Pascual-Leone & Irwin, 1994, 1998) is the distinguishing characteristic of content representation vis-a-vis direct perception; this is a form of reflective abstraction such that common features or relations, found across instances, are retained in the abstracted scheme, but differential or distinguishing features of each token experience are actively disregarded via active inhibition—what we call *interruption* (or I-operator). A possible instance of content representation is the distal-object schemes (or "image-schemas"—Mandler, 1992) that infants develop between 5 and 8 months (or even earlier) vis-a-vis physical objects in their environment, which they do by reductively abstracting a scheme—a content-structural "invariant"—that stands for and represents the manifold of perceptual manifestations that the physical object(s) in question produce(s) under exploratory praxis and perceptual analysis. These simple distal-object or distal-relation schemes were already seen by Piaget (e.g., his concept of incomplete object-permanence schemes—"permanence of objects without location"), but neo-nativist infancy researchers have appreciated more fully their theoretical importance.

Separate from content representation is *direct perception,* that is, enduring schemes (perceptual knowledge) that are not representational. Piaget (his "empirical abstraction") and, much more so, J. J. Gibson and his school, have emphasized the existence of direct perception. Direct perceptions and content representations are constructively different, although both are based on perceptual signals. Direct perception is based solely on direct collation of experiences (i.e., constructive abstraction without reduction of information) and is driven by ecological relations found within contexts. In contrast, content representation is based on reductive abstraction (i.e., reflective abstraction with reduction of information) and is driven *by ecological* relations (i.e., relations actually induced by the external infrastructure of experience) found *across* contexts. Content representations are either unconscious ("implicit") or potentially conscious (i.e., "explicit"). When content representations bear on purely operative processes, they are usually implicit; this is what Karmiloff-Smith (1992) might have in mind when she talked of representational level I (i.e., implicit). When content representations bear on complex figurative (or configural) patterning of the coordinations that operative processes and learning bring about, they function as early "conceptual" invariants that can be used in or out of context to categorize experience, as Spelke (Spelke, Breinlinger, Macomber, & Jacobson, 1992), Mandler (1992), Wynn (1992b), Baillargeon et al. (1995), and others have shown. We take the latter case to correspond to what Karmiloff-Smith called representations of level El (explicit-1).

DC2. After emergence of the symbolic function (an organismic function discussed later in terms of its mental-attentional demand) a new more complex form of representation appears, the only one that Piaget regarded as proper representation: the *executive* (or operational) *representation.* Executive representations use symbols (as defined later) and are based on reductive and causal abstraction (Pascual-Leone, 1984; Pascual-Leone & Irwin, 1994, 1998); they are driven *by executive/operational strategies* or scripts; and they monitor performance with reference to future or possible outcomes. These executive representations can be explicitly conscious or not. They can be verbal-conceptual (logological) or purely experiential (mereological—Johnson, 1991; Pascual-Leone, 1995;

Pascual-Leone & Irwin, 1994). These are the sorts of representation that Karmiloff-Smith (1992) classified, respectively, as levels E3 and E2. Note that executive representation turns into content representation with repeated practice and automatization.

DC3. Although reflective abstraction, under different names and formulations, has come to be recognized as referring to the causal processes of cognitive development, the Piagetian concept must be explicated (and deconstructed!) by positing a number of innate general-purpose mechanisms that in their dialectical interactions bring about, constructively, children's development and learning (Pascual-Leone, 1995). Most important, and yet missing not only in Piaget's but in other recent theories of representation, is the formulation of innate mechanisms for mental attention. Later, we summarize this model of attention.

DC4. The fundamental distinction between operative/efferent and figurative/afferent processes stems epistemologically from the need for biological organisms to adapt to their immediate environment (or context/world). The dynamic nature of these adaptive exchanges, and their urgency, create the need for codes that represent environmental (or organismic) contingencies; these are what Peirce (1955) called (external and/or internal) signs (i.e., Piaget's signifiers). The *figurative/afferent processes* are the brain's innate mechanisms for generating and processing signs. Dialectically complementing the figurative schemes, and developing concurrently with them, humans store blueprints for external and/or internal (mental) action, often conditional to signs, that are behavioral interventions on the environment and/or *processual transformations* of mental signs (i.e., Piaget's actions or transformations). These are the *operative/efferent processes* of the brains's machinery for producing interventions or transformations.

DC5. We believe that it is necessary to distinguish explicitly between two distinct but non-exclusive dimensions of variation, which together produce four different modes of representation. The first dimension is constituted by the dialectical pair operative/ efferent schemes (processes) versus figurative/ afferent schemes, which we have described previously. The second dimension is the dialectical pair conceptual/logological/generic schemes versus experiential / mereological /particular schemes (Johnson, 1991; Pascual-Leone, 1995; Pascual-Leone & Irwin, 1994). This second dimension of variation is the one that informed Piaget's conception of cognitive development. Stages of cognitive development, as conceived by Piaget and others, can be located along the structural continuum created by these polar attributes of information-bearing processes (i.e., schemes).

The second dimension can be clarified by explaining the labels we have used. Conceptual/logological corresponds to what Piaget called logical and cognitive scientists often call propositional/declarative networks. These are generic schemes because they stand for kinds rather than particulars, that is, types rather than token instances of experience; and because they are generic, we should see them as the processes of which concepts are made. Reductive abstraction, that is, the disregarding of unessential (noninvariant) aspects of experience, is the act of obtaining these generic representations that are concepts (in the broad sense of the word, used earlier). Experiential/mereological (*mereo is* Greek for "part," i.e., "part–whole relations") are the schemes that stand for particular objects of experience and their parts—the processes that encode real, nonreduced, pure and rich, experiences. That the two dimensions (i.e., operative/figurative vs. conceptual/experiential) are distinct is shown by the fact that their likely cortical projection in the brain is different (Pascual-Leone, 1987, 1995; Pascual-Leone & Johnson, 1991).

DC6. Piaget's idea that operative schemes literally derive from the coordination of actions can be regarded only as a suggestive analogy. Neural networks illustrate better construals, based on innate learning mechanisms that can increase the activation weights of neuronal connections as a result of experience and/or affect or mental attention (which is regulated, roughly speaking, in the prefrontal lobe).

DC7. For Piaget (and the French developmentalist Wallon) figurative schemes derive from internalized imitation, driven in part by innate sensoritonic and affective /social dispositions. This is, again, a suggestive analogy. It is more plausible to think (with Hebb, Luria, and many others) that both figurative and operative schemes are genetically prepared in humans by two distinct and dialectically complementary networks. The same principles of neural networks, suggested previously, when operating in the posterior cortical (i.e., figurative /afferent) nets, should produce figurative schemes. Imitation simply refers to operative processes that can help in the abstraction of configural afferent, that is, figurative, scheme coordinations.

A BRIEF ON OUR THEORY OF REPRESENTATION

Because the theory we propose has been discussed elsewhere (e.g., Johnson, Fabian, & Pascual-Leone, 1989; Pascual-Leone, 1984, 1987, 1989, 1995; Pascual-Leone & Goodman, 1979; Pascual-Leone & Johnson, 1991), we restrict discussion here to a few important aspects. The organism synthesizes performance dynamically—using all activated schemes in the subject's repertoire (or brain!)—at the moment when performance is produced. Thus performance is often truly novel (i.e., not solely determined by any single scheme stored in the brain's repertoire) and is always *overdetermined* by all compatible schemes currently activated. This principle of *schematic overdetermination of performance* (SOP principle) can be seen as a generalization of Piaget's principle of scheme assimilation or, neuropsychologically, as manifestation at the level of schemes—that is, cofunctional collections of neurons—of the spreading of activation in the brain's neural network. As happens in competitive neural networks (e.g., Hinton, Dayan, Frey, & Neal, 1995; Shultz, Schmidt, Buckingham, & Mareschal, 1995; Smolensky, 1988), schemes in the present theory compete for the codetermination of actual performance. One simple way of representing this codetermination is as follows: Schemes that are compatible in their application sum their activation levels/weights to form a dynamic cluster of compatible schemes, and the cluster of activated schemes that at any given moment applies to produce a part of the performance is the one that in this moment is dominant (i.e., has the highest total activation weight, irrespective of the source of this activation). Other incompatible clusters of schemes are (often momentarily) inhibited. Because this is a dynamic system, in which both activatory and inhibitory processes interact, and competition among schemes or clusters of schemes is common, one can usefully describe this theory as modeling a dialectical-constructivist organism.

In this theory there are four complementary sorts of dialectics, which together promote development: (a) a natural *external* dialectics between the individual and his or her life context—mediated by the releasing component or "cue" system of the schemes, which the features or "resistances" of the external context-situation can activate, (b) an *external* intersubjective dialectics, from each person to other persons, (c) an internal dialectics interrelating psychological processing components (schemes) within the individual, and (d) an *internal* dialectics interrelating, within the individual, schemes of action or representation with the resource capacities of the brain (e.g., attention's activatory or inhibitory mechanisms) via monitoring by executive scheme processes. These four sorts of dialectics together constitute situations as subjectively/objectively experienced. In this respect we mention the distinction between facilitating situations and misleading situations (Pascual-Leone, 1987); this distinction is not found in Piaget or in other theories of representation, but it is fundamental.

A situation is facilitating when all the schemes it activates are compatible with the task at hand. A situation is misleading when it elicits schemes that interfere with the task at hand. For instance, in Piaget's substance conservation task the situation elicits perceptual-global schemes of quantity that make the "sausage" appear to have more substance than the "ball" of clay. This is a misleading Gestaltist (S-R compatibility) "field effect" that supermarkets use very effectively in their packaging. Facilitating situations, because the schemes they elicit contribute to (or do not interfere with) the subject's task, are optimal for examining learning abilities, and have been traditionally so used by learning theoreticians, from behaviorist to Vygotskian to neo-nativist infancy researchers. When development is studied using facilitating situations, it appears as continuous, with a linear growth function being its characteristic curve.

Misleading situations, in contrast, are characteristic of problem-solving paradigms and have been used unwittingly by Piaget and others to investigate cognitive development. In these situations development often appears as discontinuous, in the sense of exhibiting a nonlinearly growing, at times stepwise, characteristic growth curve as a function of chronological age. This is found predominantly in cross-sectional studies, where there is no contamination with learning due to repeated testing (Johnson et al., 1989; Pascual-Leone, 1987).

From the perspective of the four sorts of dialectics mentioned previously, misleading situations (but not facilitating ones) are a source of internal conflicts —dialectical contradictions—between or among alternative processing strategies (not just overt motor responses or habits) elicited by the task, and these strategies usually draw on different processing resources (schemes or capacities) of the organism. Stages of development appear in misleading situations (and often not in facilitating ones), because learned habits (or innate automatisms), and their corresponding strategies, become obstacles to good performances. Thus in misleading situations subjects must use problem solving—that is, nonautomatized methods (invention; creatively synthesized, truly novel performances)—to cope with task demands, and do so by way of *dynamic syntheses.* Dynamic syntheses are brought about by the tendency (this is Piaget's "assimilation") of dominant compatible schemes to apply together, and *overdetermine* (Freud—Rappaport, 1960; see also Pascual-Leone & Johnson, 1991; Pascual-Leone & Morra, 1991) representations and other mentations, or performances, of subjects. In these syntheses, task-relevant schemes not activated by the situation are internally activated by the subject's *mental attention* (Case, 1985; Houde, 1992; Luria, 1973; Pascual-Leone, 1970, 1987; Pascual-Leone & Baillargeon, 1994).

Unlike orthodox Piagetians and many other theoreticians, we believe that organismic resources other than information-bearing units (schemes in our terminology) intervene in the emergence (i.e., generative construction) of novel representations, particularly in the context of misleading situations. Some of these innate but general-purpose organismic resources constitute in their dynamic interactions a function of mental attention, which is distinctly different from the informational units (schemes) on which it is normally applied to increase/decrease the level of activation.

Nonschematic Organismic Resources for Dynamic Representation

"Regulations" is Piaget's name for unexplicated (e.g., Garcia, 1980; Pascual-Leone, 1970, 1987, 1988) processes that overcome the limits of simple associative learning. Associative learning is a basic, "low-road" way of thinking and knowing (Pascual-Leone & Irwin, 1994, 1998) that is very powerful—as research on connectionist/neural networks has shown (e.g., McClelland, 1995; Shultz et al., 1995). But this "bottom-up" learning has its own severe limitations: Whenever the paradigm is a problem-solving one (i.e., a truly novel, misleading situation, particularly when subjects have had few exposures to the task), the powerful cue-driven bottom-up process of associative learning (whether in humans or in computers!) may become a hindrance, because it may activate schemes not relevant to the task. As a result, highly activated schemes, even if they are misleading, tend to dominate and determine performance. This is why purely associative organisms or machines are so limited in truly novel, creative problem solving. Associative learning models, not having "top-down" processing mechanisms, fall under the learning paradox (i.e., the paradox of not explaining where newly learned schemes come from—Bereiter, 1985; Jukes, 1991; Pascual-Leone, 1991a) and cannot solve Plato's problems (Pascual-Leone, 1987).

To solve these problems we need theories that have *more* than *one* learning mechanism and that can account for generation of dynamic syntheses (Pascual-Leone, 1987, 1991a, 1995; Pascual-Leone & Goodman, 1979). One of the learning mechanisms must deal with content/associative learning; we call this content or C learning. With repetition and automatization C learning produces an "effortless" but slow-to-acquire structural learning, which we call *LC (i.e.,* Logical Content) learning. This is the sort of learning that behaviorists, perceptionists, Gibsonians, connectionist simulators, and so on, have emphasized. *LC* is a very efficient learning in facilitating situations, because it is then driven by salient "cues." What Vygotsky (1986; see also Kozulin, 1990) called "complexes" and "everyday" concepts (as distinct from proper or "scientific" concepts) are most likely products of *LC* learning in facilitating situations, created via human mediation—external intersubjective dialectics. In misleading situations, however, *LC* learning cannot be applied effectively by itself, because in that case salient cues can lead to error.

Another learning mechanism, which is driven by the executive processes of mental attention (Pascual-Leone, 1987; Pascual-Leone & Baillargeon, 1994) and leads to rapid Logical-structural learning is, therefore, needed; we call it *LM* learning. ("Logical" is used here in the sense of Piaget—functional structures—and does not refer to formal logic.) *LM* learning uses endogenous mental *(M)* attention, a content-free (noninformational, nonschematic) organismic resource or capacity that, monitored by executive (planning) schemes, can be used to hyperactivate ("with mental energy") task-relevant schemes—in particular, schemes that are not highly activated by the situation. This mental "energy" or M-capacity is a brain utility, controlled top-down by the prefrontal lobe (Pascual-Leone, 1989, *1995;* Pascual-Leone & Johnson, 1991). Mental attention can also be used to centrally inhibit or "mentally interrupt" schemes that are task irrelevant (this is the I-interruption capacity, also controlled top-down by the prefrontal lobe). Schemes that are cofunctional (i.e., compatible in their function) and often coactivated (i.e., activated simultaneously or in immediate serial order) tend to become structured together—Piaget would say "coordinated"---into a common superordinate logical structure. The speed of this structural learning process is proportional to the activation level of the schemes involved.

From these learning assumptions three important consequences follow:

LM1. In LM learning, because M-capacity is hyperactivating task-relevant schemes while I-capacity is inhibiting task-irrelevant schemes, only schemes that are tagged as relevant by the dominant executive schemes will become part of the LM structure in question. Thus ordinary contextual schemes will be excluded and, so purified, the resulting *LM* scheme can function as a concept—a central conceptual structure (Case & Okamoto, 1996) or a Piagetian operational structure.

LM2. Because the growth of *M* is constrained by a maturational process that runs from the second month of life till adolescence (Johnson et al., 1989; Pascual-Leone, 1970, 1987; Pascual-Leone & Johnson, 1991), the level of complexity that the subject can generate in *LM* schemes will be, within misleading situations, bound by his or her (hidden) *M* capacity growth, a growth whose spurts (levels) correspond to Piagetian and neo-Piagetian (sub)stages. It follows that in misleading situations the processual complexity level, or M demand, of a given conceptual structure (I,M scheme) cannot be greater than the subject's own M-capacity, if it is learned by a subject without the help of an external human mediator (who, *by creating a facilitating* situation, may lower the M demand). This is the reason why stages of development may become manifest only in misleading situations.

LM3. High cognitive functions, as well as Vygotsky's proper or "scientific" concepts (Kozulin, 1990; Vygotsky, 1986) emerge, from experience and historico-cultural interactions, by means of *LM* learning and often in misleading situations.

Because the processual complexity of the LM schemes available to a subject is a function of his or her mental capacity (i.e., M- and I-capacities), which increases with age and maturation, this model of *LM/LC* learning offers an explanation of one of Plato's problems—the one concerning distinctiveness and common origin of two modes of processing: properly "conceptual" (analytical—including what Mandler called perceptual analysis) versus experiential (automatized or global everyday notions). The key difference between these two modes of processing is the requirement for mental attentional capacity. In the top-down "conceptual" mode, that is, *LM,* the mental-attention demand is high, and so progress in this mode can easily be defeated by a limitation of mental attentional capacity (due, e.g., to young age of the subject). Thus developmental stages may be manifested in this mode. In the bottom-up experiential mode, that is, LC, the demand of mental attention is relatively low and developmental stages are usually not manifested within it. LM learning as processual mechanism corresponds to what cognitive science calls "effortful" or "controlled" processes, LC learning to what it calls "automatic" processes. Our theory contributes, to a cognitive science formulation, a developmental perspective and rational methods for estimating the attentional-effort demands of tasks. We also distinguish other kinds of learning such as "effortless" learning driven by affective schemes (LA learning—Pascual-Leone, 1991b).

Explanation of the "continuous representation" problem, and resolution of other representational problems (such as the learning paradox), necessitates, in addition to multiple types of learning, the acceptance of four other mechanisms, which neuroscience and connectionist/neuronal modeling have investigated under other names. I refer to the SOP principle, the Gestaltist internal "field" factor (S-R compatibility, minimum principle), the space structuration factor, and the time structuration factor.

The SOP principle was discussed earlier. It states that performance is synthesized by the dominant (most activated) *cluster of compatible schemes* available in the brain at the time of responding. The probability of this performance is proportional to the relative dominance of the cluster of schemes generating it (Pascual-Leone & Baillargeon, 1994; Pascual-Leone & Johnson, 1991; Pascual-Leone & Morra, 1991).

The "field" factor, which we call *F* operator, is an internal-field and performance closure mechanism akin to the neo-Gestaltist principles of "minimum" and "S-R compatibility" (Pascual-Leone, 1989; Pascual-Leone & Morra, 1991; Proctor & Reeve, 1990). *This F operator is a sort of minimax function* generated in the brain by neuronal "lateral inhibition" mechanisms in conjunction with the SOP principle. In process analytical terms this minimax function can be formulated as follows: The performance produced will tend to be such that it minimizes the number of schemes that directly apply to inform the performance (including perception or representation); and it does so while maximizing the set of distinct, salient features of experience (activated low-level schemes) that, directly or indirectly, inform this experience (Pascual-Leone, 1987, 1995; Pascual-Leone & Johnson, 1991). For example, errors in the Wechsler picture completion subtest, such as failing to see the missing doorknob in the picture of a door, are caused by this F minimax mechanism, which prevents the application of low-level (local-perceptual) schemes, like the simple doorknob scheme, because automatized higher order schemes, like the superscheme of a standard door with its own doorknob, can also be applied and incorporate the lower scheme's representation.

Because they are likely to be important in enabling or disabling easy representations, we also wish to mention the space and time structuration factors—the space (S) and time (T) operators of the brain. What we call the space operator includes the known (Farah, 1995; Maunsell & Ferrera, 1995) specific neural circuitry that carries space-relational information suitable to answer questions about the "where" of objects, but not about the "what" of objects. We speculate that this space operator helps to bring about some degree of dynamic, automatic but ephemeral, structuration of interobject relations given in actual experience, that is, objects as experientially coexistent and localized entities--a temporary "space" structuration that facilitates learning. This is, we think, an explication of Kant's (1929/1965) profound idea of a transcendental category of space.

Likewise, a "time operator" must exist in the organism to permit some degree of dynamic, automatic but temporary, structuring of evolving states or appearances. These states facilitate dynamic construction of new objects, and so the answer to questions about "what" they are. The time operator (Kant's transcendental time, i.e., the brain's general-purpose temporal-structuring processes) is crucial not only for the synthesis and construction of self (as Kant, Husserl, and other philosophers emphasized) and language acquisition (as Petitto's research, 1996, 1997, suggests), but also for the synthesis and construction of objects. The space and time operators are (together with learning) the "glue" that permits, via dynamic syntheses brought up by the SOP-F mechanism, the emergence of objects, scenes, sequences of events, and so on, out of the manifold of sensuous experience (Plato's world of appearances).

As a result of nonlinear dynamic interaction among all these mechanisms, a heuristic implicit "choice" and synthesis of performance (whether in action, perception, representation, or mentation) takes place, which is brought about by the *F* and SOP mechanisms. It is within such a nonlinear dynamics for constructing actual performance that the significance of mental attention, as major developmental mechanism, becomes fully clear. From this perspective endogenous attention appears (Pascual-Leone, *1987;* Pascual-Leone & Baillargeon, *1994)* as the organismic functional system (or modular "function" < ... >) constituted by three resource capacities and a special subrepertoire of schemes—the executive schemes of mental attention—in their interaction as attentional *operators: <E, M, I, F>.* The attention component *E* is the set of currently dominant attentional executives, usually called by the collective name "the executive"; the component M is mental "energy" or capacity; the component I is top-down (central) inhibition of task-irrelevant schemes; the component F is the neo-Gestaltist minimax field factor just mentioned. By boosting (with M operator) the activation of, and/or deactivating (I operator), schemes in the field of activation, mental attention (monitored by affects via the *E* operator) can effectively change the "choice" of performance that F and SOP will together synthesize in a given situation. These are the effortful top-down mental equilibration processes that generate Piagetian operations—whether these operations are described with Piagetian models or otherwise.

Language and conceptual thinking emerge in the organism in this manner: via both an external intersubjective dialectics and two internal dialectics, which in their interactions, serve to internalize historico-cultural processes used by and created within society. The historico-cultural processes become internalized in terms of executive schemes, general attentional executives, task executives, and executive controls for the capacity resources *(M, I, F, LC, S, T,* etc.) These various sorts of executives, acquired via human mediation, permit the learner to keep a mental distance from misleading factors in the situations, and thus enable freedom of will. This chain of transitions is illuminated by Vygotsky's "one-sentence" formula: "If *at* the beginning of development there stands the act, independent of the word, then at the end of it there stands the word which becomes the act, the word that makes man's action free" (Vygotsky & Luria, 1994, p. 170).

In the next section we illustrate applications of our theory to four tasks studied by other researchers. The tasks we discuss are all for young children, because data on such tasks can contribute most to the problems of representation, including Plato's problems. Given the wealth of new paradigms and tasks to choose from, our choice of tasks is somewhat arbitrary.

TASK ANALYSES OF REPRESENTATIONAL PERFORMANCE

Mental-Attentional Constraints in the Language Learning of Native Signers

Reilly and Bellugi's (1996) recent study of acquisition of American Sign Language (ASL) can serve to illustrate, when interpreted from our theoretical viewpoint, how mental attention intervenes in language acquisition, via the dialectics of sociocultural mediation that relate babies to mothers. We begin with a selective summary of the Reilly and Bellugi article. By the age of 7 months "infants can reliably discriminate between angry, happy and surprised faces" (Reilly & Bellugi, 1996, p. 221), and "by the end of their first year, both receptively and productively, infants consistently associate specific facial behaviours with affective states" (Reilly & Bellugi, 1996, p. 222). Note that the ability to make these discriminations is related to the child's capacity to process simultaneously the analytical perception of the other's face, and/or the child's own facial behavior, with the affective state for which the facial expression stands as a sign or symbol (e.g., Pascual-Leone, 1991h). Usually, in particular in misleading situations, this simultaneous processing is possible only with the help of mental attention.

Linguistic form patterns (figurative forms from all levels of grammar: phonology, morphology, and syntax) are often obtained in ASL by using co-occurring manual and facial features suitably structured in space and time. "[Slpecific facial behaviours . . . function as obligatory grammatical markers" in, for example, conditionals, relative clauses, and questions (Reilly & Bellugi, 1996, p. 219). It happens at times that obligatory facial expressions convey emotional states that are incongruous or conflicting with their morphological significance in ASL. This is the case for Wh-questions. The linguistic form pattern demands the manual signing of the appropriate Wh-sign (WHERE, WHY, WHO, etc.) accompanied by a nonmanual marker: "continuous eye contact with the addressee, furrowed brows, and a possible head tilt" (Reilly & Bellugi, 1996, p. 225), all produced in temporal coexistence with the manual signing.

This nonmanual marker closely resembles the affective expression of anger and puzzlement. Thus when the mother signs to the baby a Wh-sentence, the nonmanual component should constitute a misleading situation for the baby. This is because by itself the nonmanual component signals anger/puzzlement, although in conjunction with the signed Wh-sentence it marks the presence of a Wh-question.

Positive affective contact during communication with deaf infants, conveyed by means of positive facial expressions, is even more important than for hearing children (Reilly & Bellugi, 1996). Thus learning the nonmanual marker of Wh-questions should provoke a strong affective-cognitive meaning conflict (dialectical contradiction) among the baby's activated semantic schemes, a contradiction that can be resolved only if the baby can, using his or her mental attention, simultaneously interrelate the various manual and nonmanual cues that together constitute the Wh-question. Should the baby be unable to keep track simultaneously of all these (figurative) cue-schemes he or she will fail to reductively abstract into a linguistic scheme the semantic-pragmatic functional "invariant" that carries the meaning of the Wh-question. This is because by itself the nonmanual component of the Wh-question is interpreted by the child as a negative affective expression, which preempts the chances of positive communication.

Babies who cannot keep track simultaneously of both manual and facial information may end up feeling sad and crying when mother furrows her brows. This negative reaction should not occur, however, when the child perceives the mother's furrowed brows as an integral part of a different, cognitive rather than affective, scheme: the ASL sign. Because this is a misleading situation, babies must have enough power of mental attention to boost simultaneously with mental energy (this is the M-operator) all the sign constituents, thus bringing about their coordination, while at the same time actively inhibiting (this is the Interruption operator) the facial "anger" scheme. We can use our theory and method of task analysis (e.g., Alp, 1994; Benson & Pascual-Leone, 1997; Pascual-Leone & Johnson, 1991) to formulate a mental-attention dimensional complexity estimate for this coordination of the ASL Wh-question scheme. This model estimate appears in Formula 1.

$$\mathrm{COORD}_3(\mathrm{COORD}_2(\mathrm{face}^*), \mathrm{COORD},(\mathrm{hand},{}^*, \mathrm{hand}_z{}^*)) \qquad (1)$$

Because ASL uses simultaneous motions with both hands (or else several sequential signs with one hand), to sign a sentence, the first coordination of information (schemes) needed is that of the motions produced by each hand. We symbolize these figurative schemes by hand,* and handz*. The semantic-pragmatic (experiential and linguistic) operative scheme that perceptually analyzes, assigns a meaning, and coordinates both hand motions we call COORD,. When this operative applies upon (assimilates, Piaget would say) the two hand schemes, the result is a meaningful symbolic structure for the total configuration. We call "face*" the figurative scheme that stands for the patterned nonmanual gesture once it has been integrated as a perceptual totality, and we call

$COORD_2$ the semantic-pragmatic scheme that applying on "face*" produces its ASL meaning as a component. Finally, $COORD_3$ is the semantic-pragmatic operative that applying on both semantic components produces the meaning of the overall Wh-sentence form. A baby whose mental-attentional capacity permits the boosting with activation of each of these six schemes (and who at the same time can inhibit the misleading "anger" schemes) should be in a good position to represent, via *LM* learning, the meaning of the Wh-sentence that mother attempts to teach, and would thus easily learn the linguistic form. A child whose *M* capacity cannot handle simultaneously six schemes, however, would be prone to be distressed if the facial gesture corresponding to $COORD_2$(face*) accompanies the mother's manual sign, because this would cue in the child the negative affective scheme of "anger."

Our theory stipulates that M capacity grows throughout the sensorimotor period according to the schedule indicated in Table 9.1. Essentially, at the end of each Piagetian substage of the sensorimotor period there is an increment in mental capacity corresponding to one additional sensorimotor (or simple conceptual) scheme that can be boosted with mental capacity. Thus at about 1 month (the end of first Piagetian stage and beginning of second) the baby's mental attention can boost one scheme; at about 3 or 4 months (end of Stage 2 and beginning of 3) the baby can boost with mental attention up to two schemes, and so forth. Three experimental PhD theses from our laboratory

TABLE *9.1*
The Sensorimotor Period *(Six* Substages)

1.	Me = *0*	THE USE OF REFLEXES (0-I nlo.)
2.	Me = 1	ACQUIRED ADAPTATIONS & PRIMARY CIRCULAR REACTIONS (1-4 *mos.)*
3.	Me = *2*	BEGINNING OF SECONDARY CIRCULAR REACTIONS & PROCEDURES FOR MAKING INTERESTING SIGHTS LAST (4-8 mos.)
4.	Me= *3*	COORDINATION OF SECONDARY SCIIF.MES & APPLICATION OF SCIIEMES TO NFW SITUATIONS (8-12 *mos.)*
5.	Me = 4	BEGINNING OF TERTIARY CIRCULAR REACTIONS & DISCOVERY OF NEW MEANS BY ACTIVE EXPERIMENTATION (12-18 mos.)
6.	Me = *5*	INVENTION OF NEW MEANS THROUGH MENTAL COMBINATIONS *(18-26* mos.). Executive performance representation is not possible until this stage. Five or four units are needed to spontaneously construct an executive.
7.	Me= *6*	TRANSITION TO MENTAL **PROCESSES** *(26-34* mos.)
8.	Me = 7	EARLY PREOPERATIONAL PERIOD *(34-59* mos.). The child is able to mobilize an executive and relate one symbolic scheme to another. The child has an M-capacity *of* Me = 7,orM=e+1.

Note. Me is the executive mental (M) capacity available during the sensorimotor period. The mental capacity added after this sensorimotor period we call Mk, and in rnany *of* our articles we have stated that the total M *of* an older child or adult is equal toe + k (i.e., the M-capacity that emerges during the sensorimotor period, later used in the processing *of* executives, plus the M-capacity that matures afterwards).

have upheld these mental capacity estimates originally proposed by Pascual-Leone on the basis of Piagetian data (Alp, 1994; Benson & Pascual-Leone, 1997; Holloway, Blake, Pascual-Leone, & Middaugh, 1987; Pascual-Leone & Johnson, 1991). As Table 9.1 shows, the baby cannot boost simultaneously, with mental attention, six schemes until after the second year (26 months). Our theory of representation would thus predict that difficulties in coping with a task such as that symbolized in Formula 1 will last until after the second year.

Reilly and Bellugi (1996) presented naturalistic data very clearly supportive of this prediction. Their data come from two studies, one cross-sectional and one longitudinal, of deaf mother—infant dyads. Their findings can be summarized in three points:

1. Deaf children at about 18 months can spontaneously sign their own Wh-questions, but they do so without using the facial grammatical components; that is, they sign showing neutral faces.

2. Prior to the baby's second year, deaf mothers do not use the facial grammatical component when signing Wh-questions to their babies. This unusual pattern of signing before the babies' second year is produced by mothers unconsciously, even though they exhibited it in both cross-sectional and longitudinal studies.

3. When the baby is beyond the second year of age, both deaf babies and mothers begin to sign Wh-sentences using the appropriate grammatical facial morphology.

Using the model just outlined to explain the performance of both deaf mothers and babies, and assuming the M-capacity maturational schedule given in Table 9.1, these data become clear. The distress of babies is caused, as Reilly and Bellugi (1996) intimated, by the facial anger scheme that they cannot control, and this distress shapes mothers' communicative praxis vis-a-vis babies, without mothers becoming aware. It induces mothers (operant conditioning?) to exclude from Wh-questions the grammatically obligatory facial component. This unconscious, linguistically abnormal pattern is abandoned as soon as babies have enough mental capacity to dynamically synthesize the full (manual and facial) grammatical configuration. Possibly mothers can recognize unconsciously when the baby may he ready to develop the mature adult representation of a signed Wh-question.

Our theory contributes to Reilly and Bellugi's (1996) work in that it predicts approximately at what age the baby should be ready to handle the adult, mature form of signed Wh-questions. The theory achieves this predictive power by way of a process analysis of the dynamic syntheses that in the organism produce representations. This example may serve to clarify the nontrivial sense of the last part of the Mandler epigraph: how attentive processing is used in perceptual analysis. The example also shows that innate general-purpose maturational factors such as the growth of M (working memory, if you will), interruption (i.e., active inhibition of task-irrelevant schemes), and the *SOP-F* mechanisms can bring about the learning of specific linguistic /grammatical patterns of representation—patterns that may not be acquired consciously.

Attentional Executive Controls and Infants' "Enumeration" of Actions

In a series of studies, Karen Wynn (1992a, 1992b, 1996) has demonstrated that infants can discriminate between small numerical differences within the context of facilitating situations. A recent study by Wynn (1996) implicitly illustrates a point we wish to make: The general-purpose innate attentional system constituted by executives (E operator) and the hidden ("silent") organismic hardware operators M, *I*, *F (i.e.,* the complex substantive *function* of mental attention < E, *M, I,* F>) serves as an internal mediator permitting the subject to make specific, principled, and rule-governed discriminations, which are conceptual in the broad sense, even though they are learned as a result of experience.

In Wynn's (1996) task, 6-month-old infants were habituated to a puppet jumping either two or three times (in two different treatment conditions). Following habituation, six test trials were presented in which the puppet alternately jumped two and three times. The main finding from our perspective, replicated in a second control study, was that infants looked significantly longer on novel-number trials relative to old-number trials; and when the perceptual salience of these jumps was maximized by keeping the puppet still when it did not jump (so a more facilitating situation is created) the difference in looking time between novel- versus old-number trials was enhanced.

As Wynn (1996) indicated, there are two questions of particular theoretical interest in these results, questions that she did not answer:

1. What is the mechanism of "individuation" or segmentation into *units of the experience?* Because the discriminant stimulus is clearly the number of jumps, babies must be segregating every jump as a unit. How does this happen? In our theory this is done by means of *figurative schemes* synthesized via the space and time operators and the *SOP-F* mechanism described earlier. Each of these schemes stands for a jump.

2. What is the mechanism of "enumeration" whereby the *relative numerosity,* or relative perceptual quantity of "jump" experiences, is evaluated for each trial as a relational characteristic (a distal-relation scheme or dynamic feature) found in the puppet—the distal object in question? Wynn inferred that this mechanism is some form of primitive enumeration, because it is found in infants across all sorts of experiential units, whether objects or relations of many different kinds. This conclusion is premature, because one can explain the generality and rule-governed character of these content representations without having to appeal to the number concept in the proper sense. This is possible by making the following dialectical constructivist (DC) assumptions that one of us

has long held (Pascual-Leone, 1970, 1984; Pascual-Leone & Goodman, 1979; Pascual-Leone & Johnson, 1991).

(DC8) The attentional executives of the mechanism of mental attention can, in an innate manner, evaluate the amount of mental attentional energy that a certain cognitive act has consumed. This amount can be evaluated by an observer analyst, in terms of the number of separate schemes that mental attention has had to boost in order to generate the intended performance. One such intended performance might be, for instance, to perceive analytically the salient (or the task-relevant!) units of experience (schemes) available in the present situation. For instance, the experimenter produces three jumps of the puppet and the child attempts to analytically (i.e., discretely) perceive the three jumps. Each jump might be a new instantiation or concretization of the same distal-relation scheme, that is, a jump-scheme image. These various instantiations can simultaneously be perceived analytically (and thus can be subitized—i.e., perceived in their numerosity) with the help of mental attention and/or L-learning, as illustrated later.

(DC9) The maximum numerosity that this analytical perception can discriminate should be a function of the child's power of mental attention (M power), which in its "working memory" span of capacity ("slots" for schemes) has a naturally given and ready small-set measuring grid (or *psycho-set)* that can be used to appraise numerosity over sets of highly activated schemes in the internal field of activation, even if this set of schemes is arbitrarily chosen from any content domain. We talk of a psycho-set to emphasize this important idea (Pascual-Leone & Johnson, 1991). The largest set of schemes that a subject of a given age can boost simultaneously with mental attention serves as an innately given set-theoretical measure of complexity used in perceptual analysis. For instance, assume that a child can keep within mental attention only two sensorimotor schemes, that is, $Me = 2$. A model of how such a child could at first perceive analytically the sequences of jumps presented in Wynn's (1996) paradigm appears in Formulas 2 and 3, which represent respectively the child's experience in a two-jump trial and a three-jump trial.

$$\{M(jump_{,}*, jump_{z}*) \ldots\} \tag{2}$$
$$\{M(jump_{,}{}^{*}, jump_{s}*)\ jump_{,}* \ldots\} \tag{3}$$

In these formulas we have represented symbolically the theoretical field of activated schemes in the child's brain (i.e., his or her *field of activation)* when he or she is in the critical moments of Wynn's (1996) task. The words found inside {...} stand for schemes in the field of activation; M( ) stands for the M-operator applying on the schemes found inside the parentheses, so as to boost maximally their activation level. Finally, the ellipsis mark indicates other schemes actually in the field of activation that we do not wish to represent explicitly. Among the schemes not explicitly represented are, for instance, affective/motivational schemes (Pascual-Leone, 1991b), such as curiosity vis-a-vis novel events (i.e., novel schemes appearing in the field of activation). Such affective schemes compel the baby to spend more time looking at the situation that contains (i.e., induces the activation of) novel schemes relative to situations that contain only old (habituated) schemes.[1]

Let us apply these models to explain the result of Wynn's (1996) experiment. Our theory proposes that 6-month-olds (the age of Wynn's subjects) can boost simultaneously with mental-attentional energy at most two simple schemes (see Table 9.1). In the treatment condition where infants are habituated to the two jump trials, Formula *2* represents the analytical perception of the old stimulus: The puppet produces two jumps, and the respective jump-schemes become hyperactivated by mental attention (M-operator). In this treatment condition, Formula *3* represents, then, the analytical perception of the novel stimulus: Two jumps are hyperactivated but a third jump is also found, less activated, outside M but in the field of activation (outside M, because the infant has the capacity to boost with mental energy only two jump-schemes). Notice that in the other treatment condition, in which infants are habituated to three jumps, the reverse will apply: Formula *2* would then stand for the novel stimulus and Formula 3 for the old stimulus.

For the sake of simplicity, assume that the infants have been habituated to two-jump trials. Then due to the curiosity/novelty affect they should look significantly longer at the situation represented by Formula 3, but only if they can discriminate between the two fields of activation represented in Formulas *2* and 3. Wynn (1996) found that 6-month-olds could make this discrimination. What our theoretical analysis contributes is an explanation for why such results should be obtained at 6 months and never before 3 or 4 months (see Table 9.1).

Notice that our model makes unique testable (although as yet untested) predictions. Consider, for example, a model for a situation in which the number of puppet-jumps produced by the experimenter is either three or four. If the infant's mental attentional capacity is $Me = 2$ (which occurs within the stage between 3 or 4 months and 8 months—see Table 9.1), then the models in question will be as in Formulas 4 and *5:*

$$\{M(jump_1^*, jump_2^*)\ jump_3^* \ \ldots\} \tag{4}$$

$$\{M(jump_1^*, jump_2^*)\ jump_3^*, jump_4^* \ \ldots\} \tag{5}$$

Now theoretical predictions change, because in our theory the perceptual analysis that produces significantly longer looking to the novel stimulus is made possible by mental attention. Further fine discriminations, and thus content representation of the difference between the numerosities of old and novel stimuli, may not be possible or be very global when it bears on similar elements (e.g.,

[1]To show how Formula 1 and Formulas 2 and 3 in fact model the same mental-attentional mechanisms, we rewrite Formula 1 using the symbolic conventions used in the latter formulas:

$$\{M|COORD_3(COORD_2(face^*), COORD_1(hand1^*, hand2^*)))\ldots\} \tag{1a}$$

jumps*) that are found in the field of activation but *outside* mental attention. This is because gestaltist factors—F-operator—allow only simple processing of schemes placed outside attention. Because this is the case for the comparison depicted by Formulas 4 and 5, we would predict that the baby's tendency to look longer at the novel stimuli will be reduced, and so the difference in looking time may no longer be significant.

If the subjects chosen were older, however, so that they belonged to the next developmental stage (i.e., 8–12 months, Me = 3—see Table 9.1), the appropriate models for the three- and four-jump trials would be those represented in Formulas 4a and 5a. We predict that a child of 8–12 months would have the M-capacity to distinguish between the two situations and thus a statistically significant difference in looking times would again be expected.

$$\{M(jump_1{*}, jump_2{*}, jump_3{*})...\} \quad \textbf{(4a)}$$

$$\{M(jump_1{*}, jump_2{*}, jump_3{*})\ jump_4{*}\ ...\} \quad \textbf{(5a)}$$

What Symbols and the Symbolic Function Add to Representations

Symbols and signals are *signs* (Johansson, 1993; Peirce, 1955). As such they have a triadic structure: (a) the token *sign* itself or signifier (Peirce's "representamen"), (b) the "object" that it represents, that is, its significate or *referent,* and (c) the *meaning* or signification that the token sign, as interpreted, attributes to the referent (Peirce's "interpretant"). One should talk of symbols when the mode of processing/learning is such that the token-sign appears *functionally detached* from its referent. This is possibly what Piaget (1975) meant by "differentiation of signifiers from significates" (see the first epigraph). We know that the token-sign is functionally detached from its referent when, for example, the meaning attributed to it changes with the context. For instance, when the infant first says "ma!" referring to his or her mother, the intended meaning is fixed for each child. In one child it might mean "(hug me!)," if it was learned in the context of playing-with-mother. In another child, however, it might mean "(give me more food)" if it was learned in the context of feeding. Children draw their own initial meaning from the context of learning, and for as long as this concrete meaning remains fixed, the scheme is only a signal. It becomes a symbol when the child can change the intended meaning of "ma!" to signify "(hug me!)" in the playing context, or "(feed me!)" in the context of feeding, and so on. Thus defined, symbolic schemes do not usually appear until after 12 months of age, and are not common until after 19 or 20 months. In contrast, adults who when hearing the word "fire!" stand up and begin to run out of the theater as if they were about to be burned, are functioning with the signalic mode. Signals indicate the here-and-now actuality of their referent, but symbols indicate only the actual *possibility* of their referent (e.g., "the theater may, but only may, be on fire").

Consider how the functional difference between signalic and symbolic processing could be incorporated into schemes. In signalic processing sign and meaning are functionally attached. Thus the sign-token function can be carried by the *releasing conditions of* the scheme (Pascual-Leone & Johnson, 1991), and these conditions become cues when the scheme assimilates the situation (i.e., applies to it). The meaning function *of* the signal can then be carried by the same scheme: the scheme's *effects* that become actions, images, or mentations when it applies. Because schemes are indivisible units (e.g., Pascual-Leone & Johnson, 1991), the meaning *of* a sign should indeed be fixed *if* the meaning is carried by the same scheme that carries the sign-token; this prescription fits well with the definition *of* a signal.

Using the same line *of* argument we conclude that the constituents of a proper symbol (i.e., token-sign, meaning, referent, context indicators) must be carried by different schemes, to allow the context-sensitive character of meaning—the functional detachment of meaning in symbols—to appear in mental processing. The consequence is that the learning of symbols, but not learning of signals, requires that a number of distinct schemes be activated simultaneously and coordinated into a functionally unitized new totality or structure—as our analysis of the Reilly and Bellugi (1996) data illustrated. Such learning necessitates mental attention and effort (Pascual-Leone, 1987; Pascual-Leone & Baillargeon, 1994; Pascual-Leone & Irwin, 1994)—what experimental psychologists often call controlled processes. We (e.g., Pascual-Leone & Goodman, 1979; Pascual-Leone & Irwin, 1994, 1998) refer to such learning as LM learning, because mental attentional capacity (M "energy") must be used to boost into hyperactivation the symbol's constituent schemes. The learning of signals, in contrast, does not need to be effortful. It can take place by simple conditioning or *LC* learning (learning of automatic, effortless, habitual schemes). The neuropsychological literature, which we cannot summarize here, suggests to us that LM/symbolic learning takes place in the left hemisphere for most people (e.g., right-handers), whereas LC/signalic learning occurs in the right hemisphere, a claim that has received empirical support (Pascual-Leone, 1987).

Figure 9.1 summarizes what we have just said about these two semiotic functions, symbolic and signalic (Cassirer, 1929/1957, 1944).[2] The diagram also illustrates, using an operator-logic notation, the types of schemes that a subject must coordinate to form symbolic versus signalic schemes. In this notation the Greek letter `I' stands for an operative scheme—the type of schemes represented in Formulas 2 through 5 with words written in capitals; and the Greek letter e) stands for figurative schemes (represented in Formulas 2–5 by words written in lowercase with a postfixed asterisk). The formula for a symbol (Fig. 9.1) indicates that it emerges from the coordination (dynamic synthesis) of figurative schemes that encode the context (**0,** $_{x}$), the sign token (t $_{g}$), and the referent

[2] In his later years, Piaget changed to call semiotic function what we are here calling (with Cassirer and the early Piaget) symbolic function. This was an unhappy change, which we reject, because the signalic function is also semiotic.

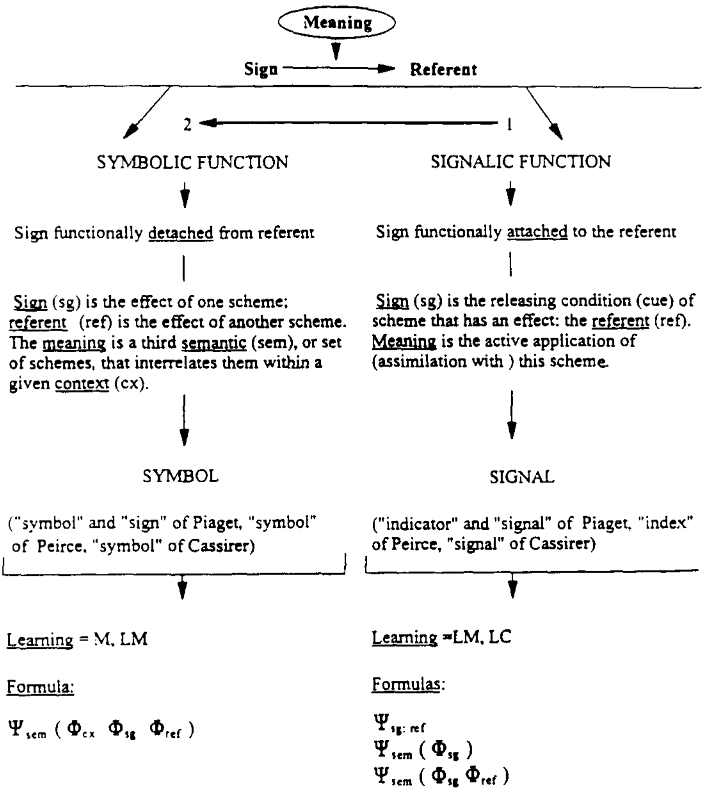

FIG 9.1. Classification of signs.

(fi$_{re}$r). This coordination is brought about by a semantic-pragmatic operative scheme ("1- ,) which represents the functional system or unit of praxis (intentional activity) within which the sign stands for the referent in the stipulated context. This operative scheme can be conceived as the system of semantic-pragmatic relations that exist, or are predicated, among the cognitive elements on which the operative in question applies.

When the baby uses the term "ma" as a holophrastic name for his or her mother, and this is a symbol. the component $_{Ysem}$ of this symbol might be the operant/ request "give me more food!", the fi$_0$, might be the situation of "feeding time," and <U$_{sg}$ and $_{firef}$ would be, respectively, the utterance "ma" and the food being used. Notice that in the symbol, as opposed to a signal, the meaning of the operative scheme can change with the context, for a given sign and referent, and the alternative meanings represented by alternative schemes easily become misleading factors that could interfere with the intended meaning—

as happened with the facial anger scheme in the deaf infant's signing of Wh-sentences.

Thus the four schemes needed to generate the simplest symbol cannot be directly "chunked" (automatized) as happens with schemes in facilitating situations (which generate signals), but have to be coordinated using mental attention. Symbol-generating situations are typically misleading situations that demand representations that are context sensitive in their meaning, but otherwise detached from other schemes in the situation. The symbolic function (i.e., the active effortful coordination of the four semiotic schemes just mentioned) serves to make representations detached, and this situational detachment makes possible executive/operational representations as defined earlier.

Figure 9.1 also presents formulas for coordinations of schemes that generate signals. Because in a signal the meaning of the operative scheme is unconditional, the context (which with symbols serves as condition) need not be coordinated with the operative meaning scheme, the sign, or the referent: The most complex signal has at most to coordinate three semiotic schemes.

Figure *9.2* summarizes an observation made by Fogel (Reinecke & Fogel, *1994)* on the emergence of an instance of symbolic play, as well as our analysis of the representational process underlying the child's plan (executive) for this behavior. In the days prior to the occasion summarized in Fig. *9.2,* Hannah's mother had tried unsuccessfully to engage her in the pretend game of talking by telephone. Fogel described the first time that Hannah spontaneously enacted the game. According to our analysis, Hannah can acquire the general idea of the game—the plan or general executive of the task—in a single mental act of dynamic synthesis, given that she has sufficient mental attentional capacity. Figure *9.2* shows how this semantic synthesis maps onto the previously defined formula for a symbol. The resulting symbolic operative, an early executive scheme, is $_{\text{'pretend-talk-to-people.}}$ Our claim is that when an infant's mental energy (Me) is

At **about** 12 months (Re = 4l Hannah picks up the **phone** and offers it to mother. **Mother** takes the phone, puts it to her ear and says: "Hi, grandma!" Hannah smiles and reaches **for the phone; she puts** it **to** her **ear** (first time **she does** this) **and** says: "Ha-o!" **Hannah looks and again** offers **the phone to** mother **for** more **pretend** talk.

LEARNING TIIE SYMBOI.IC'1'ELEMlONE GAME

sem (cx, sg, ref)

M 1 **,alk- to-people** **'F Playing with Mom** **'F VISUAl. On1ECL'V icicphone** **nISrAI. OBJECT: calking telephone** I **Pretend talk-tn - people**

FIG 9.2. Summary of observation by Fogel (Reinecke & Fogel, 1994) and task analysis of the emergence of the telephone game.

sufficient to boost simultaneously the activation of four different schemes—corresponding to semantic meaning (sem), context (cx), sign (sg), and referent (ref)—the executive representation will take place, if occasions/experiences socioculturally propitiate this learning. Thus the sociocultural operative "talk-to-people," is dynamically coordinated with the figurative of the situational context "playing with Mom," the figurative of the familiar visual object "telephone," and the figurative of the distal-intellective object (which she has seen Mom use) "telephone-for-talking." This coordination (symbolized by the arrow) brings about the emergence of the symbolic operative scheme (i.e., the executive) of pretending to talk to people by phone.

Hannah was about 12 months old at the time of Fogel's (Reinecke & Fogel, 1994) observation. According to our theory, this would give her a mental capacity of Me = 4, sufficient to boost simultaneously the requisite schemes. Note that what makes the situation just described misleading is the existence of a previously acquired LC-structure (i.e., habit) that would bias the child to interpret telephones as purely physical (not sociocultural) objects to be explored. This misleading habit makes difficult the access to symbolic play, unless (a) there is a human mediator who encourages symbolic play, and (b) the baby has an Me capacity of at least 4.

The Spatial-Mapping Representation Task

Judy DeLoache (e.g., 1987, 1995) discovered and has studied thoroughly a new paradigm in which executive-operational representation can be investigated in a complete yet simple form. In DeLoache's task the child is shown a miniature ("small scale") model of a room with all its furnishings, and then a separate full-size room of which the miniature is a model. The child is told that with the two rooms there are two toys: a very small "Little Snoopy" and a full-size "Big Snoopy." The two toys "like to do the same things in their rooms. Wherever Little Snoopy hides in his little room, Big Snoopy likes to hide in the same place in his big room" (DeLoache, 1995, p. 70). The child then observes the experimenter hide the miniature toy somewhere in the model, for example, behind the couch. Next, the experimenter tells the child that she is going to hide the big toy in the same place in the big room, and she does so without the child seeing. The experimenter then asks the child to find the big toy inside the big room, repeating that the two toys are hiding in the same place. At this point the child is brought to the big room to try to find the big toy. Only errorless retrievals are scored as correct. Finally, the child returns to the small room and is asked to retrieve the small toy; this serves as a memory and motivation check.

As DeLoache (1995) and other researchers (e.g., Halford, 1993) emphasized, to solve this problem a child must be able to coordinate, by way of a semantic–pragmatic mapping, his or her knowledge of the small-room model and small toy hidden in it, with his or her analytical perception of the full-size room **and**

the big toy to-be-found in it. This is a misleading situation, because the great difference in scale between the two rooms makes mapping by simple perceptual generalization very difficult or impossible (unless facilitating circumstances, e.g., photographs [DeLoache, 1987, 1995] are introduced). Thus symbolic processing, as just described, becomes necessary and with it the need to use mental attention. The structure of this mapping and the amount of M capacity needed are clarified by our task analysis, which is symbolized in Formula 6.

$$\text{MAP}[(\text{SEM} = \text{hidden}, \text{CX} = \text{s-room}^{*}, \text{SG} = \text{s-couch}^{*}, \text{REF} = \text{s-toy}^{*}\text{`"})\ (\text{SEM} = \text{find}', \text{CX} = \text{b-room}^{*}\{\text{REF} = \text{b-toy}^{*}\}_{\text{L},\text{L2}})] \rightarrow \text{SG} = \text{b-couch}^{*} \quad (6)$$

In this process—analytical formula, there are two basic ideas: *(1)* The act of remembering where the small toy (s-toy) was hidden is encoded by means of a semantic operative (which embodies the functional "game" of hiding/finding an object), represented in this formula under two different instantiations: SEM = hidden and SEM = find. Then under this routine "game," and in the context of the small room (CX = s-room*—the asterisk indicates a figurative scheme), the object-screen (small couch) behind which the target-object is hidden and/or found becomes the symbolic sign (SG = s-couch*) of the hidden/found target-object, which functions as its referent (REF = s-toy*).

(2) We interpret the act of inference serving to mediate the distal transfer or cognitive transposition from small room to big room as a dynamic synthesis or coordination between the symbolic representations of the small-room task and the big-room task. This is our interpretation of what DeLoache (1995) and Halford (1993) very properly call a mapping—a semantic mapping from one task-situation to the other. Notice that in the symbolic representation of the big room, the sign is missing. This is the unknown of the problem to be found by analogy to the task situation of the small room; this analogy constitutes the mapping. Further, notice that the big-room task's referent (REF = b-toy*) is not being boosted by M-capacity but instead is being activated by the same L-structures (LC learning) that subtend the operative SEM = find and the figurative REF = s-toy*. The child's familiarity with this task ensures that b-toy* and s-toy* already are chunked into the same L-structure.

According to this model, the minimum number of separate sensorimotor schemes that must be boosted by M is 7, as Formula 6 indicates. As shown in Table 9.1, the power of M capacity does not reach the number 7 for sensorimotor schemes until 3 years of age. This developmental schedule explains the well-documented finding that children cannot solve this cognitive distal-transfer or mapping task until they have reached 3 years of age (DeLoache, 1987, 1995). Also supporting this mental-capacity interpretation of DeLoache's paradigm is Marzolf's (cited in DeLoache, 1995) finding that one can make the task too difficult for 3-year-olds by using as sign four identical white boxes, small and big, placed in a certain configuration; "so the child must encode which box contains the hidden toy. The only way to identify the relevant box is to encode its *relation*

[REL] to available landmarks in the model" (i.e., the small-room situation; De-Loache, 1995, p. 107). The modified Formula 6a represents this new task.

MAP[(SEM = hidden, CX = s-room*, SG = (REL(s-boxes*)), REF = s-toy* L')
(SEM = find ¨, CX = b-room*{REF = b-toy*} LIL2)] SG = b-box* (6a)

In this new formula the number of schemes that must be coordinated with the use of mental attention is 8—a number that according to our theory can only be integrated spontaneously at the approximate age of 5 (Johnson et al., 1989; Pascual-Leone, 1970; in these articles we talk about "e + 1," where "e" is equal to 6 sensorimotor schemes, and "2" is equal to 2 mental schemes).

GENERAL CONCLUSIONS

To evaluate the predictive power of our theoretical model, examples of representational tasks were chosen to cover a wide range of neo-Piagetian sensorimotor stages and a wide range of semantic contents. In each case—and we were able to discuss only four examples here—our theory-based task analyses accounted for developmental landmarks and showed habitual schemes or other factors that make these situations misleading for the child. Because they are misleading, mental attention *(M* capacity and *active inhibition—I* interruption) is needed to bring about the truly novel dynamic syntheses of performance that each task exhibits in the child when it is solved for the first time. This detailed demonstration of how mental attention participates in the genesis of representations is a contribution of our theory, for this aspect is usually ignored or glossed over by other theories. Mental attention alone is not sufficient, however. As the example from Reilly and Bellugi (1996) illustrates so well, representation and language are much enriched by sociocultural mediation, that is, by suitable mentors, who, via affective bonding and careful monitoring, guide the child's attention—thus making up for some of the baby's initial executive deficiency. Equally important, although not emphasized in our task analytical summaries, is the role of innate organismic factors—such as C, *LC, LM, S, T, SOP, F,* and so on—that effectively produce the dynamic synthesis (Piaget's equilibration) of a truly novel performance. In this synthesis, all activated compatible schemes summate their forces and tacitly collaborate to bring closure to a constructed performance that is simple and *yet* informed by all compatible schemes that are activated at the time when the performance is produced. The most decisive of these performance production mechanisms, often ignored in spite of the fact that modern connectionism has highlighted them, we have conceptualized as the principle of Schematic Overdetermination of Performance (SOP) and as the neo-Gestaltist field (i.e., F) factor. Although these important mechanisms were not emphasized in the analyses, the attentive reader may be able to see how they tacitly intervene in the analysis if he or she reviews the theory presented. More detailed discussions of these mechanisms in the context of task analyses have been offered elsewhere (e.g., deRibaupierre & Pascual-Leone, 1979; Johnson et al., *1989;* Pascual-Leone, 1987, *1989;* Pascual-Leone & Johnson, 1991; Pascual-Leone & Morra, 1991).

Notice that ours is a middle position relative to nativism and empiricist constructivism. Like modern neo-nativists we believe that human learning is not possible unless the child is born with a rich repertoire of mechanisms (such as innate schemes and powerful general-purpose "silent"—i.e., tacit—organismic "hardware operators"), which constitute mental attention, the space and time mechanisms, and various kinds of learning. These brain operators bring about the dynamic/dialectical syntheses that create truly novel performances. Yet as dialectical constructivists, we also wish to emphasize that innate factors in humans are likely to be general purpose vis-a-vis the content of experience, albeit processually very specific. This wide-content generality of our innate endowment, which promotes adaptability, is the mark of our species. Elman et al. (1996) adopt a similar stance.

We began the chapter with a formulation of Plato's problems. The first problem—the common origin (but irreducibility) of concepts/representations and experiences—we have been discussing all along in different terms. The same general-purpose hardware operators and partly different manifolds of schemes intervene in both, although the innate repertoire of schemes may already distinguish between "conceptual" and "experiential" kinds (this is currently a controversial issue).The second problem of Plato—to explain the genesis of *continuous* representations (i.e., the fact that humans never cease to perceive or represent something irrespective of the situation)—can be solved in principle by appealing to the mechanisms of dynamic synthesis, in particular, the *SOP* and the F operator, which together continuously resolve conflicts among schemes by tacitly or explicitly creating, again and again, new overdetermined configurations of life experience and/or conceptualization. Concept/representation and experience are both intertwined and distinct. As Ortega, the great philosopher of "vital reason" (i.e., life's rationality), said: "Never will the concept give us what we get from immediate experience, i.e., the flesh of things. But this is not a deficiency of the concept, because the concept does not aim to do this job. Never will immediate experience give us what we get from a concept, i.e., the form, the physical and the moral [i.e., practical—JPL] meaning of things" (Ortega y Gasset, 1914/1981, p. *63;* translated from the original Spanish by JPL).

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