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ABSTRACT

A cognitive or internal representation refers to an organized system of information which reflects certain, but not all, of the information about reality being represented. This paper considers various opinions, controversies, and debates about what representation is, how it comes about, and what forms of representation can be distinguished. The article is divided into seven sections. Section 1 introduces basic concepts related to mental representation. Section 2 analyzes and compares several types of representation: iconic, propositional, and non-propositional. Section 3 describes how and under what circumstances young children develop representation, and discusses recent research on the development of representational thinking in young children. Sections 4 and 5 examine the relationship between "referent" and the mental process of "sense," suggesting that the accuracy of a representation can be evaluated on the basis of interaction and reflection. Section 6 proposes and distinguishes various levels of representational thinking. Section 7 considers the following important functions of representation: organization, control, elaboration of levels of representations, communication, and reflection on one's own mental activity. Finally, the article recommends investigating the unconscious construction of representation. Contains 52 references. (AA)

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Representation and Cognition

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Abstract

The concept of representation is based on different theoretical points of view, some of which the authors question. What is a representation, what is being represented, and how? Several types of representation are analyzed and compared: iconic, propositional and non-propositional representations. Recent research on the development of representational thinking in young children is discussed. Representation refers to a "referent" and a mental process, the "sense"; the relationship between these two aspects is also discussed. The statement is made that the accuracy of a representation can be evaluated on the basis of interaction and reflection. Various levels of representational thinking are proposed and distinguished, and the following important functions of representation are considered: organizing, controlling, elaborating levels of representations, communication and reflection on one's own mental activity. Finally, the authors recommend investigating the unconscious construction of representations.

Representation and Cognition

According to DeLoache (1989), "the topic of representation lies at the heart of cognitive psychology" (p. 2). It is indeed true that we can hardly imagine the recent literature on cognitive psychology without the concept of representation. The more frequently the concept is used, the more interpretations we can expect. As Von Glazersfeld (1987) has remarked, "...the word is used with a rather wide range of meanings" (p. 215).

The definition of representation is often closely linked to the scholarly context within which the word is being developed and used. Some authors use representation as a synonym for thinking, imagining and visualizing -- in short, as a general term for knowledge (Butterfield & Nelson, 1989; Finke, 1989). Others see it within a specific, theoretical context. Some examples are "cognitive representation" (Palmer, 1978), "connectionistic representation" (Bechtel & Abrahamsen, 1991), "misrepresentation" (Perner, 1991), "accessible knowledge representation" (Mandler, 1988), "imagistic representation" (Kaput, 1988), "representational control system" (Dretske, 1986), "spatial representation" (Kosslyn, 1978), "symbolic representation" (DeLoache, 1989), "internal representation" (Fodor, 1981), "einzelnen Repräsentationen" (Vygotsky, 1977), "semiotic models" (Davydov, 1972), "psychisch Abbild" (Leont'ev, 1982b).

This article considers various opinions, controversies and debates about what representation is, how it comes about and which forms of representation can be distinguished (section 2). It also describes how and under which circumstances young

children develop representations (section 3). Section 4 discusses the relationship between "referent" and "sense" and section 5 how representations can be evaluated for accuracy. The article goes on to address the various levels of representation which have been identified in the literature (section 6) and ends by considering the functions of representations (section 7).

Representation: Opinions, Controversies and Forms

What Is Represented and How?

For the sake of clarity, we will begin by giving a working definition of representation. Following in the footsteps of DeLoache (1989), we will use the following definition: a cognitive or internal representation refers to an organized system of information which reflects certain -- but not all -- of the information about the reality being represented.

Like many other authors (see Fodor, 1981; Perner, 1991; Kaput, 1988, Janvier, 1987), Dretske (1986) agrees with the logician G. Frege (1848-1925) in distinguishing between referent and sense. Identifying the referent means identifying what is being represented, while sense indicates how the system represents. A thermometer measures the temperature (referent) and does so by means of a scale (sense). According to Dretske (1986), a representational system is "any system whose function it is to indicate, by its various states, how things stand with respect to some other object, condition or magnitude" (p. 102).

Palmer (1978) also distinguishes between referent and sense, using the terms "represented world" to refer to the first and "representing world" to the second. In his view, a single referent or represented world can represent a variety of aspects;

imagine the various types of map, for example. But it is also possible to represent the same aspect in a variety of ways (representing world); the mineral deposits in a particular region can be shown numerically or by lines of different thicknesses. These are multiple representations of the same reality. It is therefore possible to represent ("non-equivalent representation") multiple aspects (relationships) or to represent the same aspect in different ways ("equivalent representation").

The distinction made by the mathematician Vergnaud (1987) is similar to Palmer's (1978). Vergnaud (1987) sees the referent as the "real world," "signified" as the level at which cognitive processes (predicting, drawing conclusions, reflecting) and therefore representation take place and the "signifier" as the symbols (schemas, diagrams) which convey meaning.

Iconic and Propositional Representations

Several researchers (Kosslyn, 1978; Anderson, 1990; Sinha, 1988) emphasize the importance of distinguishing between iconic and propositional representations. Iconic representation exist in a variety of forms and are constructed in different ways depending on the degree to which they are linked to and determined by perceived reality. An iconic representation can take the form of an "icon," i.e. an image which is perceived for a very brief space of time (Anderson, 1990). An icon can be considered a "photographic representation."

Such representations also take the form of an "image." There are two types of images. The first is still associated with perception, but not as closely as an "icon" is. It is also not as ephemeral and subject to time constraints. Perner (1991) calls

such images "primary representations," while Palmer (1978) characterizes them as "analog representations." He calls the simplest analog representations "first-order isomorphisms." Analog representations of images have the same structure as reality, according to Palmer (1978), (for example a map).

The second type of image is also influenced by perception and reality, but the process of constructing such images is more closely tied with propositional knowledge (Kosslyn, 1978). Anderson (1990) speaks of "perception-based knowledge," which includes Kosslyn's "spatial representations." Kosslyn emphasizes that fundamental cognitive, non-perceptive processes (such as conceptual thinking) guide the construction of iconic representations or images. Perner (1991) describes these images as "secondary representations," whose construction, according to Perner, is much further removed from reality and the present moment. Palmer (1978) distinguishes between simple "first-order" and more functional "second-order isomorphisms"; the latter are images of the second type. These "second-order images" do not reflect reality to the same degree; rather, they add something to reality. For example, they clarify relationships which cannot be perceived at first glance. This was one of the conclusions reached by Dörr, Seel and Strittmaier (1986), who argue that teaching (physics) should make use of what they call "mental models," in particular visualizations which make the relational structure of systems transparent. Remarkably, as found in a study conducted by Dwyer (1978), students gained more understanding from abstract representations than from realistic ones, because the former were better able to clarify structures which could not

be perceived directly (in this case various functions of the heart). Johnson-Laird (1983) and Davydov (1972) both describe iconic representation, i.e. images of the second order, as mental models and ideal models respectively. According to Johnson-Laird (1983) mental models are always analogous to reality, and Davydov (1972) believes that constructing ideal models (images) leads to a greater understanding of reality.

Propositional representations consist of symbols, structures, networks and propositions, termed "meaning-based knowledge" by Anderson (1990). In Palmer's (1978) view, the structure of propositional representations is not the same as the referent. Structure is constructed (for example rules of grammar) and that means that propositional representations are interpretive.

For Davydov (1972), ideal models include not only iconic models but also semiotic ones. These (propositional representations) reflect theoretical relationships, for example (see Minskaja, 1977) the mathematical relationship between quantity, size and number. According to Johnson-Laird (1983), propositional representations are distinct from mental models in that the first are "freer" and refer to hypothetical realities.

Non-Propositional Representations

The distinction between iconic and propositional representations has also given rise to critical questions. For example, Bechtel and Abrahamson (1990) defend the use of what they call non-propositional representations, i.e. "imagistic representations" or iconic representations. Their critique of propositional representations is epistemological and based on the

decision to apply what the authors see as a new paradigm in cognitive studies, which they call the connectionistic paradigm, following Rumelhart and McClelland (1986). Connectionists believe that the learning process does not proceed by means of symbols but that it is based on schemas, scripts, and so on in which the relationship between the elements provides the desired information. This paradigm is presented as the epistemological alternative to the "symbolic" paradigm. Connectionistic representations consist of networks which are built up out of elementary units, "each of which has some degree of activation" (p. 3). Units in a network can be "connected" and activated in various ways, so that networks are always flexible and dynamic (think, for example, of a network in which different relevant characteristics of wine can be connected at will: type of grape, acidity, storage life and region). Propositional representations are connected to complex and, in the view of the authors, rigid "rule systems," which are inflexible, difficult and domain-specific. Connectionistic representations do not have these drawbacks. That is because they consist of recognizable patterns, and this very recognizability takes away the arbitrary nature of the representation. They are, however, symbolic because they are formal: "That is, they are to be operated upon by rules in virtue of their syntactic form without any consideration given to their reference" (p. 124). The authors seem to be exaggerating this contrast, however. After all, symbolic representations gain meaning through interaction and cannot therefore be seen as pure, "context-free" symbols, characterized by formal, syntactic rules. On the other hand, their description of "images" as specific,

analogous and iconic in nature, rendering them suitable for specific fields of knowledge (visual and spatial knowledge), seems correct.

How Representations Develop

Various researchers have recently tried to formulate a theory of how representational skills develop in young children (Perner, 1991; Mandler, 1988; DeLoache, 1989; Wellman, 1990). Perner (1991) and Wellman (1990) are particularly interested in how children learn to understand the "mind" in its representational function (for a more detailed discussion, see Nelissen, in press). They show that the thinking of children up to the age of three or four is still strongly influenced by the situation they find themselves in, i.e. by reality. In Perner's study, children were asked to show a drawing which lay on the bottom of a box (Perner, 1991). The children under the age of four held the box in such a position that they could still see the drawing themselves. For them, seeing is believing; seeing is direct contact with reality (another example is that children of this age "hide" during a game of hide-and-seek by holding their hands in front of their eyes). The older children (from four years on) held the box so that they could no longer see the drawing. They understood that they could represent the drawing in their minds. According to Perner (1991), full-fledged representations develop as follows: at 6 months, children can already recognize the resemblance between a person and his/her photograph. At 18 months they begin to interpret images (their own reflection in a mirror, for example). At approximately two years they can think in two different "models" and acquire their

first understanding of representation: daddy in the photograph and the real daddy. From about their fourth year on, they interpret the photographs as a representation; the photograph refers to daddy (the child understands that daddy is making funny faces in the photograph). The child also understands by now that misrepresentations are possible, and that is what Perner (1991) calls an essential feature of the ability to represent. Misrepresentation means that either the image does not correspond with reality or that it does not represent anything real. At four years, children are already capable of understanding misrepresentation in simple terms. Perner (1991) demonstrated this in the following experiment. The children were shown a box of chocolate, but the box actually contained a ball. The children were asked to say what was in the box and all of them replied "chocolate." The box was then opened, and to the children's surprise it contained a ball. The following question was: what did you answer when I asked you what was in the box? Children below the age of four replied "a ball." They were therefore unable to distinguish between "sense," i.e. their own misrepresentation (after the fact) and "referent," i.e. the actual situation. Children of four years and older were able to make this distinction, implying that they understood the concept of metarepresentation. In other words, they understood that the situation had been interpreted and represented incorrectly ("sense") and they recognized that their representation did not correspond with reality ("referent"). Perner (1991) believes that all internal processes can in fact be interpreted as "representational" (see Fodor, 1981; Sterelny, 1990).

Wellman (1990) showed that at the age of three children already understand that human behavior is a consequence of "internal states": because I want something, I am happy when I get it (compare Fodor's "propositional attitudes"). They therefore understand the difference between "mental entities" and "physical objects." Mama is thinking about a piece of candy. I can't have that, but I can have a real piece of candy. According to Wellman (1990), representation develops in the following way. Until their third year, thinking is determined by reality to a large extent. In an experiment, children were told that the boy in a picture thinks that the ball is under the cupboard, but that in fact the ball is under the table. Where will he look for the ball? Children up to the age of three replied "under the table." Their thinking was a copy of reality. The older children saw belief as the "mind's" representation and understood that the boy in the picture would look for the ball under the cupboard: they were able to interpret reality. Wellman (1990) speaks of children moving from a "container concept" of the mind (my mind can contain all kinds of thoughts) to a homunculus approach (I can do all kinds of things in my mind). After six or seven years, there is another development towards an interpretive theory of the mind.

Mandler (1988) is particularly interested in when children are able to construct higher (symbolic) forms of representation. According to Piaget (1972), children are exclusively sensorimotor until the age of three or four; in other words, they represent reality in the form of perceptual and motor schemas (hence "images"), while higher, conceptual types of representation

evolve later. Mandler (1988) sees sensorimotor representations as procedural knowledge which is often strictly mechanical and therefore unconscious (for example, reaching for an object). Conceptual representations are linked with declarative knowledge, which is conscious and accessible (a concept is after all formed consciously). The most important conclusion that Mandler (1988) reaches in his study is that children under the age of four are capable of constructing conceptual representations. His conclusion was supported by Keil (1989), who found that young children under the age of four already allowed themselves to be guided more by basic (intuitive) theories than by perceived characteristics. Such theoretical notions develop and become domain-specific. Mandler (1988) points out that children understand at an early age what gestures mean, and gestures refer to concepts, not only to visual recognition. Children are furthermore capable of "recall," indicating that they have an "accessible conceptual system" or "knowledge representation": in essence, that is a symbolic process in which perceptions are compared and which leads to categorization. Mandler (1988) believes that only cognitive -- and not sensorimotor -- representations are accessible for this type of operation.

In a study by DeLoache (1989), children were shown to have an "accurate and accessible memory presentation" at approximately three years (p. 4). DeLoache subsequently wondered which skills were required to be able to use such representations flexibly. In her experiment, a child watched as an object was hidden in a playroom. The child was then asked to indicate on a scale model where a similar object might be hidden. Children between 30-32

months were not capable of doing so, but children between 36-39 months were, for three reasons: they were able to locate objects spatially ("spatial cognition"), could think in analogies (what is important in one room may be important in another) and were able to construct symbolic representations (they understood that the model was a symbol for playroom.

In all of the studies discussed above, the younger children were capable of performing at a higher level of cognition than is often assumed.

Referent and Sense

As we have seen, while some theories of representation are based on Frege's relationship between the referent and sense, others question this relationship. Sinha (1988) wonders how simple this relationship actually is, while Von Glazersfeld (1987) casts doubt upon the correspondence between representation and reality as such.

Even if the truth conditions for the current referent, i.e. that determined by sense, are wrong, according to Sinha (1988), a successful co-referent is still possible. Suppose that R. is known as the artist who painted Composition 1, even though T. is the real painter. This would be a case of referential intersubjectivity: the referent is successful and still untrue. It is important that people agree on the referent, but that is no guarantee of truth: the referent and its "denotation" do not correspond. Even in the case of simpler, successful references, it is by no means certain that people "mean" the same thing (the word school may have totally different meanings for different children).

Von Glazersfeld (1987) goes even further, arguing that there is no correspondence whatsoever between referent and reality. In his view, it is not the correspondence between internal representation and reality which is important, but rather that between internal and external representations. External representations are indeed the "real world," but that world is something that we conceptualize ourselves. People construct the world and its facts, Von Grazersfeld (1987) believes; there are no "originals" on which we can pattern ourselves. He makes an interesting distinction in this connection between "Darstellen" (a photograph or drawing refers to an object) and "Vorstellen" (the construction of a mental representation). For him, a "Vorstellung" is a relatively independent conceptual structure "in its own right and does not 'refer to' or 'stand for' something else" (p. 220). Representations therefore do not refer to reality but to internal activity. One wonders whether what goes on in the mind isn't after all the real world, at least for that particular person. Why then should we speak of the world? What we represent is based directly on our inner experiences and images. The answer to this question depends on how one defines the concept of "reality." Reality may for example also encompass mental reality, which is constructed by people and which may include such elements of consciousness as ideas, theories and hypotheses. In the field of physics, quarks were accepted as real before their existence had been observed empirically (the last of the six, the top quark, has yet to be pinned down).

Evaluating Internal, Cognitive Representations

How do we know whether internal, cognitive representations

are correct? Upon which criteria can we base our evaluation? Palmer (1978) has listed a number of evaluation criteria: prototypes ("templates"), isomorphisms and "similarity of corresponding representing objects." Each person evaluates a cognitive, in particular perceptual, representation on the basis of categorial representations stored in memory as "images." The new constructed perceptual representations reflect the existing categorial representations, although this is not always a conscious process. That is what Harth (1993) means when he says that "'internal logicians' will see to it that the imaged and imagined are not wildly at odds with the rules of logic and the laws of the world of objects" (p. 87). The following criteria discussed by Palmer (1978), following Shepard and Metzler (1971), is an isomorphism "that might hold between the real world and people's internal representations" (p. 290). Palmer (1978) arrives at the following definition: "A representation is a second-order isomorphic to its referent world if the similarity of represented objects is functionally reflected by the similarity of corresponding representing objects" (p. 292). We may of course wonder what he means precisely by similarity and correspondence and which criteria should be used to evaluate their accuracy. How can one evaluate whether internal (perceptual) representations correspond with the "represented objects"? Palmer (1978) does not go into this problem. The precise neurological processes are not interesting, as long as the internal representation is consistent with external reality. But perhaps the question about correspondence can be reformulated to ask not how one can evaluate whether a representation

ultimately corresponds with a "referent" or "original" but whether and to what degree a representation approximates a "referent."

Kosslyn (1978) and Kosslyn and König (1992), who analyzed the same set of problems as did Palmer (1978) - the construction of iconic, perceptual representations - offer more concrete tools with which to explore the latter question (although Kosslyn does not discuss this question explicitly). Like in other cognitive processes, the functional components of "imagery," according to Kosslyn (1978), are abstract propositional structures. Images ("spatial representations") are usually stored in long-term memory. The question, however, is how such images are called up out of memory. An image is not stored as a single, complete unit, but neither is it broken down into ready-made parts which are then conjured up and re-assembled in a flash. Images are constantly being re-generated and reconstructed, with both perceptive memory and language (concepts) playing a role in this process. Kosslyn (1978) speaks in this connection of "internal speech" which ensures "verbal coordination." How can we evaluate whether and if so to what degree an (iconic) representation approximates the "referent"? One possible answer is by reflecting on the cognitive, specifically the verbal processes underlying the construction of images. Language appears to be the basis for comparison between the images that people construct. Pimm (1991) believes that "language can be used to conjure and control mental images" (p. 23). Sinha (1988) even went so far as to base his representation theory explicitly on this hypothesis of communication. A child's "environment" is not neutral, but set up

intentionally by previous generations. The physical environment is significant in its material structure and represents human intentions. The idea that people (must) constantly compare their own representations with those of others is derived from the fact that they want to know whether they understand one another's intentions and motives.

One of the most fundamental and enduring principles of the cultural-historical tradition (Daniels, 1993) is that people want to understand one another's intentions and motives because they arise from social activity and subsequently form the basis for such activity. According to Leont'ev (1982a, 1982b) and Vygotsky (1978), representation systems (language, symbols, art, mathematics, gestures, rituals, and so on) are developed within this social context. Children internalize the "objective" symbols (representations) which have evolved throughout the history of the culture, and social intercourse constantly explores whether these representations -- including the iconic, which Leont'ev (1982a, 1982b) calls "Psychisch Abbild" or "Sinnesvorstellungen" -- correspond with the current accepted representations.

Sinha (1988) points out that according to Piaget (1977), the motor which drives the development of representations is not interaction and the attribution of meaning, but "actions." That is why Van Oers (1987) interprets Piaget's (1977) ideas on internalization as the process in which internal representations are constructed from external actions. External objects and individual actions in particular are reflected and represented schematically in an internalized plan. Mathematicians such as Goldin (1987) and Vergnaud (1987) have also argued that

discussions should be used to evaluate representations on their correctness (and use) (see Nelissen & Tomic, 1993).

Levels of Representation

Every human activity, including the process of representation, can be divided into levels which we can describe in terms of its different sources. The most familiar are Bruner's representational levels, which, like those of Piaget (1977), are divided into enactive, iconic and symbolic forms of representation.

According to Piaget (1977), cognitive development moves from "abstraction empirique" to "abstraction réfléchissante." The first comes about by manipulating objects, giving rise to what Mandler (1988) calls sensorimotor representations. The second arises when coordination moves to a higher plane, leading to Mandler's (1988) conceptual representations. Simple versions of conceptual representations evolve at a younger age than Piaget (1977) assumed.

In Vygotsky's (1977) view, the development of representations cannot be separated from communicative processes. In his representational theory, children first develop "syncretic images," i.e. iconic representations in which an unorganized "multitude" of unconnected objects are merged into a single "image." The child subsequently selects a single relevant (for him) meaning to represent the various objects, which Vygotsky calls "einzelnen Repräsentationen" (1977, p. 122). In this way the child represents the world as a series of concepts (including "pseudoconcepts") called "complexes" by Vygotsky (1977). All these concepts are spontaneous and non-reflective. It is only

when they begin to deal with adults, specifically in an educational context which focuses on the "zone of proximal development," that children develop what Vygotsky (1977) calls "scientific concepts." These represent the world on a conscious, general, systematic and reflective level. Davydov (1972), like Vygotsky (1977), speaks of empirical concepts in which material models are formed. Education then gives rise to "theoretical concepts," so that the child learns to construct ideal models (iconic and semiotic representations).

Freudenthal's (1991) "realistic" theory of math teaching methodology can be considered a domain-specific theory in which levels of representation are distinguished. Freudenthal (1991) sees development as moving from intentional (child-defined) to extensional (more formal) concepts. In other words, the child uses concepts (representations) which are initially closely associated with its own meaningful context, and these are subsequently raised to a higher formal level by means of model-like representations. Freudenthal (1991) emphasizes the importance of "common sense" in this connection, which begins in "means of common language" (such as counting algorithms). Kaput (1988) has also pointed out the interdependence of "natural language" on the one hand and "imagistic representations and symbol systems" on the other. According to Freudenthal (1991), however, common sense is not enough; the representations are propelled to a higher level through reflection, transformation and formalization in the form of models. At each higher level, they once again become common sense.

Dufour-Janvier et al. (1987) and Cobb, Yaeckel and Wood

(1992) have distinguished between internal and external representations within the context of math teaching. External representations are all "external symbolic organization" (schemas, diagrams, symbols, and so on). Cobb et al., (1992) see external representations as "instructional representations" and they criticize the "top-down" practice of teaching in which children are made to learn math from "external instructional materials" devised by adults without any input from the children themselves (emphasis is authors'). Cobb et al., (1992) call this approach the "instructional representation approach." In essence these authors are challenging an opinion that no representation theoretician defends, but which one does come across in information-processing theory. Their criticism is justified in the latter context, and the constructivists Cobb et al., (1992) argue that children must be allowed to construct their own representations in what he calls a process of "negotiation." The constructivists believe that knowledge of mathematics develops through "mathematical discourse," an essential part of which is the discussion, explanation and justification of ideas.

A theory of representational levels has also been proposed for physics teaching, based on "images" which are the result of experience. Unlike in math, however, representations (images) in physics which are based on experience and intuition can be in direct contradiction to what the science of physics actually tells us. According to Redeker (1990), physics contradicts what we observe every day (concrete perception, common sense) by stating that all bodies fall at the same speed, regardless of their shape and weight. A study by Bouwens and Verkerk (1988)

showed that a large percentage of the students involved (aged 15 to 18) did not consider it necessary for beams of light to hit the eye of the observer in the dark in order for him or her to see them. Lagerwerf and Korthagen (1993) argue for a theory of levels in which the first phase consists of the construction of images, the second phase of the construction of schemas and the third of the construction of theories. Dörr et al., (1988) also propose basing physics teaching on the development of "images." Lagerwerf and Korthagen (1993) point out in this connection that the construction of images is often intuitive and implicit; they are constructed "from experience in reality" (p. 151). This proposition is not very accurate, however. The construction of images is not based directly on the (perception of) concrete reality. Concrete reality is always subject to interpretation, i.e. assigned a meaning, and that process is always based on representations which have already been formed (that is why Davydov (1972) speaks of "mental concrete"). Phenomena -- in particular, but not exclusively, physical ones -- are assigned meanings based on already existing representations and that certainly does not make the task of physics teaching any easier. To evaporate is to disappear; energy means eating a Mars Bar; the molecules that make up a block of cement are motionless; heat can disappear; air exists when I blow into a glass; iron is colder than wood.

As we saw, the various teaching methodologies also make use of levels of representation. The way in which representations are generated in the first place may differ quite dramatically from one domain to the next, however.

Function and Construction of Representations

The first, important function of representations is to organize reality and control cognitive processes. Various authors believe that representations are connected with systems. Dretske (1986), Sterelny (1990) and Hofdstadter and Dennett (1981) speak of "representational systems." The latter authors, who base their perspective on computer science, view such systems as an "active, self-updating collection of structures organized 'to mirror' the world as it evolves" (p. 192). A representational system actively organizes and reorganizes information. Through organization, we gain knowledge about and control over reality, prompting Dretske (1986) to call this "the representational-control mode." But above all we gain control of our own cognitive functioning, in the sense that our internal representations of knowledge (both "images" and propositional representations; see section 2.2) -- consciously but likely more often unconsciously -- direct our cognitive processes. We must make our observations and concepts compatible with theory, as it were, comparing and linking them with the internal knowledge stored (we hope flexibly) in long-term memory. That is what Janvier (1987) means by the "categorial representation of space" upon which perception and the construction of concepts is based in geometrical analysis.

The second important function of representation is not only to organize but also to organize at succeedingly higher levels of thinking. Freudenthal (1991), Janvier (1987) and Kaput (1988) are among those who have discussed representational systems in mathematics. It is considered highly important in math teaching to focus in on translation processes, in other words the

transition between one representational system and another. For example, Kaput (1988) mentions the translation of a non-mathematical representation into a mathematical one based on "natural representation systems of natural language and pictures." Janvier (1987) mentions the conversion from an "equation to a graph." Representations serve as mediators in generating concepts, then, and research has shown that they also have a supportive function. Symons, Goldrick, Snijder and Pressley (1990) recommend encouraging children to construct "representational imagery" in reading comprehension exercises, because this appears to stimulate both comprehension and memory.

The third function of representations is the communicative function. Vygotsky (1977) believes that a (propositional) representational system such as language arises during psychic development as a consequence of interactions with adults. Representations first regulate the interaction, and afterwards the child's own behavior. They are "mediational means," according to Wertsch (1993), and become the "psychological tools" that the child learns to wield.

But acquiring those "tools" requires "negotiation." The meaning of the symbols must be accepted. That is why Sinha (1988) focuses on such concepts as intention and recognition in his linguistic representational theories. What is meant and what must be recognized? "Sense" (the representative meaning), semantic value (the relationship to other "senses" or concepts), denotation (the relationship to the world), "referent" (the thing being represented), "signification" (the contextual meaning). As we can see, Sinha (1988) bases this line of thought on the socio-

communicative function of representation ("organized social practices," p. 58).

The fourth function of representation can be called the psychological function. A person must learn to realize that a. a representation (image) of reality is not necessarily itself reality; b. his/her representation can differ from that of another person; c. his/her own representations can be subject to reconstruction; d. representations are always an approximation of reality and no more than that; e. misrepresentations are always possible; f. in many cases only a few aspects of reality can be represented (see Palmer, 1978); and g. representations are not only constructed consciously but in many instances unconsciously (under the influence of one's peer group, television, ethnicity, age, character, and so on).

An understanding of these aspects of the process of representation forces the person to reflect on the way representations are constructed and can result in a critical detachment from reality and one's own mental functioning.

There is another interesting question which can be raised with respect to the construction of representations, namely whether the process of representation has a neurological basis. Both Palmer (1978) and Fodor (1981) are inclined to reject neurological explanations for the functioning of representation. However, other theoreticians are not so quick to repudiate the idea that representations have a neurological or material-biological basis, and indeed some of them defend this notion (Bechtel & Abrahamsen, 1991; Kosslyn & König, 1992; Sterelny, 1990; Sinha, 1988). Bechtel and Abrahamsen (1991) believe that

the nervous system -- i.e. "a network of elementary units or modes, each of which has some degree of activation" -- lies at the foundation of cognition (p. 3). Sterelny (1990) sees a particular connection between the construction of representations and thinking as a "nonsemantic process" on the one hand and the central nervous system on the other. For example, our brains may have functions which specialize in recognizing faces, just as they are also supposed to have "color vision receptions" (p. 138) (the subject is still "images"). Sterelny (1990) warns that this explanation for the "representational theory of mind" is not in any way" committed to any vulgar reductionism" (p. 111). It is a last-ditch effort to wrench representational qualities away from the environment of "unexplained primitives."

Concluding Remarks

With the possible exception of (neo)behaviorism, many psychological theories characterize the human psyche as representational. Human beings construct representations not only of the world outside -- including existing iconic ("images") and propositional representations -- but also of their inner world (hypotheses, ideas). To an important extent such representations are unconscious (depending on intelligence, age, social background, and so on) -- think, for example, of preconceptions. That means that "referent" and "sense" are considered as one and the same thing, so that the representation of reality -- in the form of "images" or propositional representations -- are considered reality. There should be more attention given to such cognitive processes, both in research but also in the practice of teaching. Representations may also be constructed consciously,

however. For example in education they can support the construction of concepts and raise the student's level of thinking. The literature has shown, however, that researchers and teachers are not adequately aware of the fact that children process the information being provided to them (representations) on the basis of representations which they have already constructed, sometimes in a highly intuitive fashion, although this can differ from one domain to the next (Keil, 1989; 1991). While prior knowledge is generally considered to support the learning process (Tomic, 1989; Dochy, 1993), in such cases prior knowledge based on idiosyncratic representations may actually obstruct the process of generating concepts. On the other hand, in other cases the construction of "images" can make it easier to understand information.

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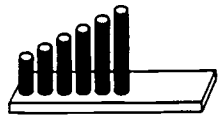
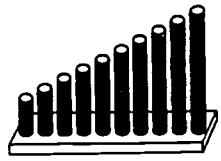
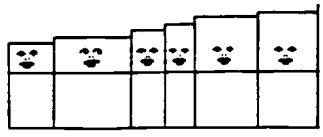
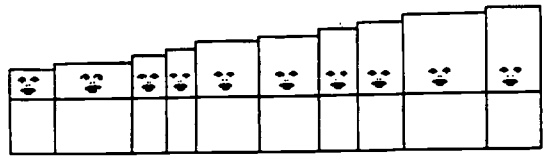
A 

A¹ 

B 

B¹ 

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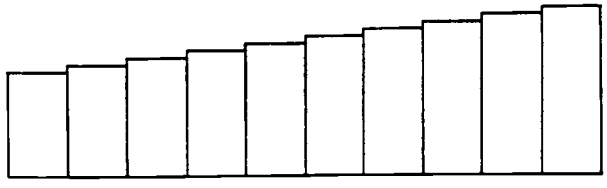
C¹ 

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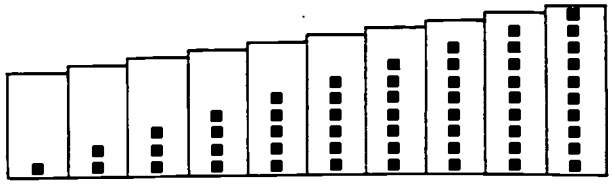
D¹ 

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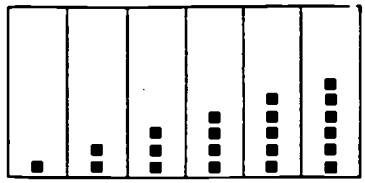

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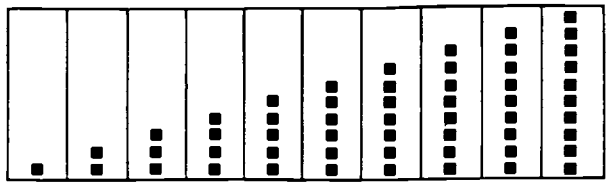

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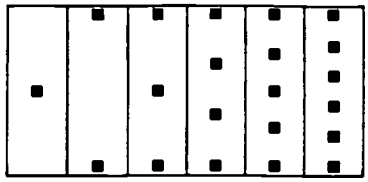

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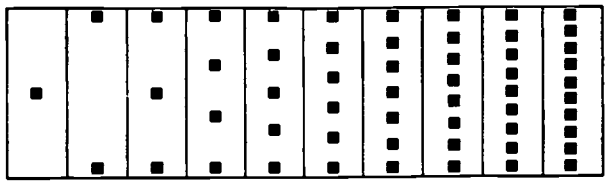

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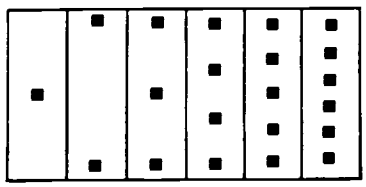

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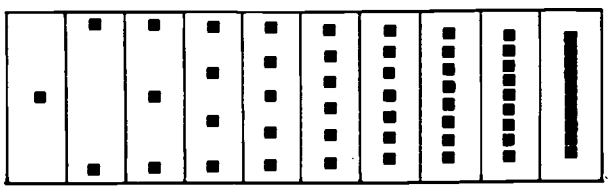

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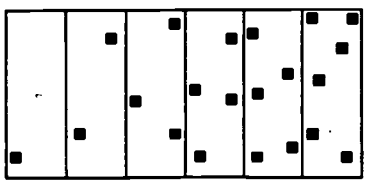

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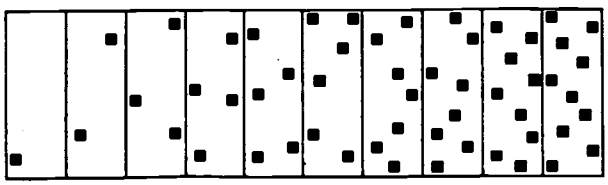

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