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Review Article

Cognitive Science - the Question of Knowledge Representation and the Propositional Mental Representations

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Received date: March 03, 2025; Accepted date: March 17, 2025; Published date: March 28, 2025

Citation: Theofilidis Antonis, (2025), Cognitive Science - the Question of Knowledge Representation and the Propositional Mental Representations, *Psychology and Mental Health Care,* 9(3): **DOI**:10.31579/2637-8892/326

Abstract

In cognitive psychology, the term representation refers to the way information is mentally represented through coded symbols (Eysenk & Keane, 2000). It is a construction of the mind that results from the processing of external stimuli and is of primary importance in problem solving, communication and education. Piaget introduced the concept of representation in 1936 to explain the child's ability to control the invisible movements of an object. The child must have a mental representation of the object, which guarantees its permanence in space and time (Mounoud & Vinter, 1985). Starting, as psychology has historically done, from an empiricist model that sees the mental as arising from representations of the real through the senses, we can identify an important point for research into the types of representations, even if this is defined as a subject mainly for external representations.

If we accept that the mental consists of representations, then it is natural to ask the question "what kinds of representations?" The Cognitive Revolution told us that we know what the mental is: they are internal representations, analogous to symbolic representations (Haugeland, 1985). But we need to better understand how different elements are involved in the mental process that leads to the creation of representations (Moser, et. al.,2015).

Keywords: mental representations; cognitive psychology; propositional mental representations

Introduction

The need for psychology to deal with the mental.

A major revolution in linguistics was made by Chomsky (1956) who recognized in language, not primarily the communicative character, but the mathematical/logical structure in the representation of information. The opposition to behaviorism is completed with Chomsky's (1956) attack on Verbal Behavior proposed as an explanation of language by Skinner. On the one hand, Chomsky tells us that behaviorism is unable to explain language, therefore it is unable to explain thought, to the extent that thought is based on language, therefore it is unable to explain behavior to the extent that behavior is based on thought (Kargopoulos, 2008). On the other hand, the analysis of the relationships between the inflow of meager linguistic experiences, and the outflow of a complete system of linguistic competence, shows us language as a window to scientifically explore the mind, and to connect it with the brain. he above supported the need for psychology to deal with the mental, despite the behavioral prohibition. However, what allowed the scientific turn to be completed in a research program (Lakatos, 1970), was the invention by Alan Turing (1951a) of Turing machines and in particular the Universal Machine which was able to imitate any process that was sufficiently specified to be recorded as a computer program consisting of algorithmically specified procedures. The reason that the computer managed to bring the mind back into scientific study was precisely that it showed us that the problem of psychophysical causality could be solved. The mind is not some mysterious entity, but a large set of diverse activities performed by the brain, so 'studying the mind' means analyzing, recomposing and thus simulating its functions. In this way I have a complete way to study the mind with scientific rigor (Stilling, et al, 1987; Thagard, 2005). The result of these was the Cognitive Revolution in psychology which, in defiance of behavioral theory, brought the study of the mental back to the center of psychology. A trend that from the beginning began to extend even into application in clinical practice, because every manifestation of inner life has the relevant cognitive content, and therefore emotion is recognized as a carrier of cognitive content and, consequently, any emotional disorder can be considered a cognitive error and corrected, and not just 'unlearned' with behavioral

methods. From an epistemological point of view, the greatest achievement of the Cognitive Revolution must be considered to be the genesis of Cognitive Science, the interdisciplinary effort to analyze intelligence, because this created a general program of new research with clear criteria for success and recognized areas of specialization. Artificial Intelligence occupied a central position in the first phase of Cognitive Science because it provided the basic ontology and the accompanying methodology. If mental processes are considered as algorithmic routines executed by the biological computer called the 'brain', then the task of Cognitive Science is clear. Cognitive scientists must record all mental abilities and analyze each one into individual processes. These individual processes must be analyzed into other 'more individual' ones and so on until they arrive at the processes that can be executed mechanically. Starting from these, they then recompose (by 'reverse engineering') the processes with a final product that can be tested with absolute certainty: the simulation of the corresponding human ability by the computer. If the machine is able to do what our biological computer (brain) does, then the analysis of this particular mental capacity has succeeded, even if we are not sure that the brain does the same activity in the same way (Stilling, et al, 1987).From a theoretical point of view, the important thing is that, despite the differences we recognize between a computer and a brain, there are at least two fundamental similarities in which there is no way that there is no correspondence. A computer is a mechanism that executes instructions (i.e., any series of instructions can be executed), and it is able to do this because it manipulates symbolic representations. From these two fundamental properties of the computer, two corresponding properties for the mind arise: Since the computer is an executor of instructions, then all mental activities must be analyzed into a series of algorithmic instructions, which are executed 'serially' (i.e., one action at a time with a strict time order between actions). But given that to do so, the computer must manipulate symbolic representations, it follows that a significant part of the nature of the mind is captured by the concept of representation. Finally, the Cognitive Revolution told us that we know what the mind is: it is internal representations, analogous to symbolic representations (Haugeland, 1985). But we need to better understand how different elements are involved in the mental process that leads to the creation of representations (Moser, et. al.,2015).

The issue of mental representations.

He idea that the mind can be considered as consisting of internal representations is not a new idea in the history of ideas. What is new is the model of the computer that is strictly mechanical, but by manipulating symbolic representations it is able to perform in principle any calculation, and then can be extended to any activity that can be analyzed into algorithmic rules. Given that computers without representations do not exist, representations are and will remain at the center of cognitive science research, which is also concerned with the type of representations that the mind manipulates in each mental task. Cognitive science is interested not only in the ontological depth of the concept of representation (whether it is an object, property, or relation and how many parts the relation consists of) but also in the breadth of the application of representations (how many and what types of representations there are and how they are combined with each other in mental tasks). The very concept of representation is problematic. In principle, there is no objection to assuming that events and objects in the world correspond to activities in the brain of which they are considered as representations. So far we have two elements 'what happens in the world', which is subject to the laws of the natural sciences, and 'what happens simultaneously or almost simultaneously in the brain' which is subject to the laws of the biological sciences, and therefore, ultimately, again of the natural sciences. When we add to the above naturalistic relationship a third factor, the mental one which is subject to the laws of semantics, we have a complicated relationship between A, B, C:

A. Represented (object, quality, relation, property, event in the world)

B. Representation I (Brain event corresponding to the represented)

C. Representation II (Mental event corresponding to the two above)

In the whole concept of representation, there is, therefore, in principle the difficulty regarding the question of which of the three possible relations (represented -to- representation I, represented -to- representation II, representation I -to- representation II) actually corresponds to the representation that cognitive science theoretically requires. Of the three relations in the preceding parenthesis, the first can be considered as a given: the basic function of the brain is the manipulation of information from the environment, but in order for this manipulation to take place, it is necessary for there to be some process in the brain that corresponds (or is equivalent) to the event in the environment, and this equivalent can of course be considered as a 'representation'. The reason why we consider it as a 'representation' can be attributed to the knowledge we have about the anatomy and physiology of vision. What is visible in the environment is initially recorded as an inverted image (a type of representation) in the retina, which is already part of the brain, but in turn causes a series of changes in the geniculate body and the occipital lobe, which are followed by other changes in various parts of the brain. This part of the process can be considered as scientifically documented in its entirety. If we limit the concept of representation to this, there is no problem, but why call it 'representation' and not 'covariation', or 'causal chain process', or 'final causation'? The term 'representation' refers mainly to entities with a semantic dimension that 'refer' to other entities. A description of the interior of an office, as well as a photograph of the interior of the same office, are representations of the office that must be governed by rules in order to be understood. The rules to be followed in the case of verbal description require first syntactic rules and conventions and then semantic and pragmatic rules. Photography requires a different kind of rules (such as being held at a certain distance, being pointed upwards, identifying the point from which it was photographed, usually from the eye level of an average person standing and surveying the scene).Of the two types of representation, the virtual (the photograph) can be considered as the more naturalistically primary, we have seen it on the retina of living beings, but we can imagine that even those that do not have language, such as animals and babies, have it. However, the system that cognitive science took as an example, that of the computer, posits the linguistic system as the most primary given that a computer is basically a syntactic machine: it manipulates symbols (0, 1) based on their syntactic form. For the rest (semantics, pragmatics) to the extent that they depend on the syntax, or to the extent that they have the same structure as the syntax, we can hope that when they are fully deciphered, they will be simulated. We already see here the basis for the controversy: are thoughts words that, connected in sentences, refer to situations or images that resemble the situations to which they refer? The above difficulties have led some researchers to abandon the concept of representation. According to Rodney Brooks (2002), the concept of representation does not solve the problems of cognition, but rather doubles them. Before we accept this and turn to the so-called 'embodied intelligence' (Gallagher & Karin, 2005. Gibbs, 2006. Pfeifer & Bongard 2007. Schwoebel & Coslett 2005) we must exhaust the

classical line in the cognitive approach that advocates that the concept of representation is the basic element of explanation of the mental. To the extent that representations can be the object of systematic processing, the path to considering them as the basic mental explanans of the mental explanandum remains open. The difficulties are not limited to the ontological question of the relations of real-cerebral-mental, but often revolve around the systematic ambiguity that follows the term 'representation', called 'process - product ambiguity': The same word 'representation' can refer to the process of 'representing' or to the product/result, that is, to the symbol it represents. For example, in the sentence "Da Vinci's representation of the Last Supper depicts 13 faces" the term 'representation' refers to the product of a process. On the contrary, in the sentence "The representation that a camera makes is an inverted impression of a three-dimensional scene on two-dimensional photographic film" the term 'representation' refers to the process by which we end up (or even not end up) with a product. In the symbolic external representations that we encounter in language and art, the process usually results in a product, precisely because the product is made to be used by others who will be led in their own (representational) way to the represented. However, it is obvious that the process is the surest and perhaps the only legitimate concern in Cognitive Science, given that there is serious doubt about the final product: Is it simply brain activation of neuronal cells or is it the combination of concepts involved in a conscious thought? It is certainly not an image, since there are no eyes in the brain to see it, nor a sentence to hear or read it for the same reason. The representations about which we know most are the external representations, which are generally products of the processes of representation. For these we know that although they are objects, calling them "representations" suggests that they are at least four-way relationships (Kargopoulos, 2008). Specifically: A (symbol) represents B (symbolized) according to convention C in symbolic situation D (which includes the symbolizer and the possible recipients). Thus, for example, the abstract drawing of a fish (A) symbolizes Christ (B) according to the secret acronym code "Jesus Christ of God Son of God Savior" (C) so that a Christian can secretly declare his identity to another Christian (D) and hide it from another non-Christian (D).It is obvious that we have a wealth of knowledge about external representations, given that a science (Linguistics) and a group of studies (humanities) deal exclusively with this wealth of symbols, texts, works and interpretations. On the other hand, however, about internal (mental and/or cerebral) representations, our knowledge is strictly limited. The barking A of a dog in the environment is "represented" (corresponds as a counterpart) to some cerebral change E (which occurs – as neuroimaging shows – even when the person is sleeping) but, under the condition of consciousness, it is represented as recognition of the presence of a dog (concept Z) in the environment by the person, if the person specifically pays attention to this sound and distinguishes it from other sounds in the environment. The relationship seems to be at least three-fold: real – cerebral – mental, Things get more difficult when we recognize that external representations are ontologically parasitic on internal ones, since they presuppose internal representations in the user of the symbol and in those to whom it is addressed. Consequently, using external representations as a guide to explain internal representations is an explanatory prior that leads dangerously close to explanatory circularity. This position is in full agreement with Searle's distinction between real intentionality, which characterizes internal mental representations, and as if intentionality, which characterizes external representations (Searle, 1992, 1998). The problem, however, becomes more complicated when we recognize that even the above position on the parasitic nature of externals on internal representations is precarious, when we ask ourselves whether language belongs to internal or external representations. Whether as sounds in space, or as signs on paper, on a blackboard, on a wall, or even on the ground, language is certainly external and relies on the internal representations of the writer or speaker and the readers or listeners, in order to be distinguished from other accidental signs or sounds. However, language is at the same time a 'natural' system of symbols despite the conventions that govern the diversity of spoken languages. Cognitive science was early involved in this controversy that it inherited from philosophy. Whether there is a language of thought that is universal but not identical with the spoken language of the thinker is an unconfirmed hypothesis. Unanswered questions remain whether we can think without a spoken language (Wittgenstein, 1953), whether different languages lead to different kinds of thinking (Whorf-Shapere Hypothesis) (Whorf, 1966), and whether language learning itself presupposes thinking (Fodor, 1981, 1998). Close to these questions are the basic questions of whether the human mind uses only propositional representations or whether it also uses figurative representations that are not parasitic on the propositional knowledge we have of these images. Despite all these unanswered questions, however, starting, as psychology historically did, from an empiricist model that sees the mental as originating from representations of the real through the senses, we can identify an important point for research into the kinds of representations, even if this is defined as a topic mainly for external representations. If we accept that the mind consists of representations, then it is natural to ask the question "what kind of representations?"

Types of representations

Mental representation is the way in which the external world of objects and events is depicted in the human mind. By abusing this metaphor, we say that something that exists or happens outside is represented within the mind (Denis, 1989). In cognitive psychology, the term representation refers to the way of mentally representing information through coded symbols (Eysenk & Keane, 2000). It refers to a construction of the mind that is the result of the processing of external stimuli and is of primary importance in problem solving, communication and education. Piaget introduced the concept of representation in 1936 to explain the child's ability to control the invisible movements of an object. The child must have a mental representation of the object, which guarantees its permanence in space and time (Mounoud & Vinter, 1985). The symbolic nature of the representation concerns the highest stage of cognitive development. Up to the age of 2, the representation of the world is directly linked to the senses and motor action, the child represents the world according to the way in which he himself acts in it. This type of representation is called active representation, while the storage of information in the form of visual images is called figurative representation (Bruner, 1957). The figurative representation of childhood is partly symbolic in nature (use of language and numbers) but children generally use the figurative type, while adults use the symbolic type of representation (Bruner, 1957). Knowledge from the external world leads to the formation of mental representations of things, ideas and events. The representations can be figurative (a dog, a tree, etc.) or verbal (for linguistic information - e.g., graphic codes). Bruner (1957) mentions three ways of representation:

Active representation: Which depends on human activities and the functioning of the senses (from birth to the age of 2 years), and includes physical skills such as: standing, sitting, moving, walking, tying a knot,

swimming, and riding a bicycle. That is, it includes representations of events through movement and corresponds, essentially, to "knowing how to do something".

Pictorial representation:

This (from two years to six/seven years), depends on images (visual, auditory, gustatory, tactile, olfactory) that 'look' like the object. However, they are personal images of the individual, images of his own, which differ from person to person.

Symbolic representation:

This depends on symbols (from the age of seven onwards), where the connection between the symbol and the object it represents is arbitrary, e.g., the word "a book". Symbols can represent people's abstract thinking through their ability to formulate propositions about the world using symbols instead of tangible objects. This is the case in Logic, Physics and Mathematics.

Bruner (1957) argued that once we have acquired all three modes of representation we can use any mode that is appropriate for what we want to represent.

During children's cognitive development, the above types obviously become more complex as toddlers learn to reproduce the barks of dogs before learning to say the word 'dog' while they recognize the dogs they encounter on their walks and willingly imitate the barks when their parents ask "how is the dog doing?".

The above views on representation preceded cognitive science. According to newer approaches, according to Eysenck and Keane (2000), representations are distinguished into: a) External representations such as images, maps, diagrams and all verbal descriptions, oral or written, and

b) Internal or mental representations which mainly concern the way information is organized in the mind.

External representations are either of a figurative or verbal form, while internal representations are symbolic. Symbolic internal representations are divided into analogical and propositional. An example of an analogical representation is the visual image of a stimulus which is imprinted in our cognitive system. While propositional representation has an abstract form and concerns the basic concepts of the content of an information, i.e. concepts that constitute the core of a state.

Mental analogical representations

As we explained earlier, while we know a lot about external representations, what we know about internal ones is the result of conjecture and theoretical arguments with frequent recourse to this highly ambiguous field of evidence, that of introspection. For this reason, the distinction between analogical and propositional representations will be made with references to the corresponding distinction of external representations, that is, to the distinction between virtual and verbal representations, because the two different external representations, virtual and verbal, are cases of analogical and digital representations respectively.

At the heart of scientific research is the question of whether the mind contains propositional (digital) representations only, or whether it also contains virtual (analog) ones. Analogical representation is the equivalent of the virtual-external representation, while propositional (not sentential) representation approaches the verbal, because the logical proposition is of abstract form and independent of any specific sensory characteristic, that is, sounds of oral speech, the ink of written communication, or the gestures of the sign language of the deaf. The basic form of analogical representations are mental images, which either come from a sensory stimulation immediately after it ceases, or are creations of the mind, i.e. of our imagination. Analogical representations are elements whose experience is analogous to that of the perception of the relevant object in the real world, e.g. I see a tree, this experience is translated into a representation that allows me to store some information about this tree (Kosslyn, 1990). Using analogical representation means that I bring to mind an image of the tree as I had seen it. Based on this image, I compare, process the relevant information and thus answer. To the question whether the green of the tree was more or less dark than the green of another tree that I see, in order to answer, I try to imagine the tree as I had seen it and thus I try to "see" how much its color differs from the color of the tree that I have in front of me. An analogical representation can be transformed or changed in the same way that the corresponding image or the corresponding object would change, e.g. I have a book in front of me, I rotate it and thus the visual stimulus that corresponds to the book changes. While I rotate it, the sequence of stimuli that I perceive follow a specific causal order. If I am asked to close my eyes and imagine the process of rotation, the changes in my analog representation of the book should exactly correspond to the actual changes in the visual stimulus that corresponds to reality as I rotate it. Analog representations usually correspond to objects and actions (see rotation process). The structural relationships between the elements of an analog representation correspond exactly to the relationships between the elements of the object being depicted. For example, in a tree the relationship of branches and trunk usually has a specific form. In the corresponding analog representation the relationship between the elements depicting the branches and the elements depicting the trunk will be the same. In short, analog representations are images in the mind. The process that produces the analog representation generally follows the causal chain that usually leads from the symbolized to the symbolizer. A classic example is photography, other analogies apply to other virtual representations, but also to mental representations in other senses. The frequency and intensity of a musical sound is transferred through the air to the microphone membrane to end up after other causal stages imprinted either in the magnetic fields of a tape or in grooves on the vinyl of a record. Analogies apply to tastes, smells, tactile experiences. In contrast, in the case of the digital representation of a sound, such as on CDs, DVDs, the process is different because what is recorded is a conventional numerical signal (in 0 and 1) which the laser head 'reads' to convert it into music. The numerical signal contains much more detail than what a musician does when reading a score (also a digital representation) containing notes and rests on the staff. Naturally, analog representations even when they are virtual can be given at various degrees of abstraction (Kosslyn, 1994; Tatler, & Melcher, 2007). A map can be a satellite photograph of an area, it can contain a lot of detail or very little detail. A straight line on a piece of paper extending from a point called 'Berlin' to another point called 'Athens' with intermediate points placed analogically can be an analog route map that corresponds to the drivers' thinking in a mental route map that preserves the relationships 'before', 'after', 'between'. If we think only of the order of cities as words, it is a verbal representation (like a poem), if we think of it as stations on a path, then it is a verbal representation of an analogical representation. Certainly there are also conventional elements on a map: The border line everyone knows does not exist although it is depicted on every political map. It certainly has

political meaning, but it has no physical meaning. Like the so-called 'center of gravity' as a point that despite its practical usefulness does not exist as a fixed point but only as a component of gravity forces.

Conceptual representations

Just as there was a dispute about the existence of mental images (analogous internal representations), a corresponding and more intense dispute had previously been expressed and supported against the idea of a 'logical' proposition which assigns the meaning of a verbal proposition (sentence) which in turn is expressed during the use of speech to make a statement. The 'logical' proposition according to this approach, either does not belong to any language, or belongs to the universal language of thought and is the ultimate bearer of truth, that is, what is or is not true. The dispute against 'logical propositions', as against meanings, comes from the behavioral camp. J. Watson (1930) considered thought as 'inaudible speech,' that is, our speech that we cannot hear. Wittgenstein (1953) argued strongly against any private language of thought, claiming that the meaning of an expression is exhausted in its observable use in some communicative context. Finally, Quine (1975) argued against meanings and logical propositions by showing that meaning is empirically undetermined. These positions are of particular importance both for the philosophy of language and for the philosophy of psychology, regarding whether reference to mental entities is scientifically acceptable. In this thesis we accept, at least as a central position or working hypothesis, that reference to the mental is acceptable and we bypass the problem of meaning in linguistics by focusing our search on the basic kinds of mental representations and not on whether mental representations exist. Within the framework of Cognitive Science, there is an important problem that is directly related to the above concerns, the so-called LOT or LOTH (Language of Thought Hypothesis), that is, the problem of the Language of Thought (the well-known 'Mentalese') which is not identified with any language, but is language-like and a prerequisite for learning any language, as Fodor (1983) says, who also considers Mentalese to be an innate language and universal to the human species. It is obvious that the above positions are particularly problematic (questionable) and it is not necessary to have a solution to the problems (such as, for example, the innateness of LOT or its universality or, possibly, its private character) in order to continue the present research. Besides, what may arise from similar research could perhaps be used in the controversy regarding LOT. What is necessary to do is to explain the two basic types of internal representations in order to understand the distinction between analog / virtual, and digital / conceptual representations. We present here the conceptual representations, by analogy with the verbal representations of language, because this is the closest we have to them as theoretical entities. Besides, the analogical representations (mental images) for the same reason developed by analogy with the external iconic ones. However, the difference between the verbal and the propositional representations must be taken into account, because what is being opposed in the dispute is the propositional versus the analogical representations.

Key differences between propositional and virtual representations.

Propositional representations consist of mental symbols, are abstract, and independent of the nature of any specific sensory feature. This position comes from linguistics and uses the system and rules of logic, based on the view that the abstract sentence (or propositional unit) is the basic unit of semantic representation, that is, it is what can express a verbal sentence, in other words its content, regardless of any spoken language or the medium of expression in which it is expressed. Their advantage is the ability to express meanings in a relatively abstract way, while their disadvantage is the fact that they cannot be applied to structures that go beyond the propositional level (Anderson, 2011). As we have said, the closest example to propositional representations is verbal representations as language, either in written form or in the primary oral form. A sentence in written language consists of words connected according to syntactic and semantic rules, with spaces or punctuation marks between them, while the words themselves consist of letters in a (conventional) order from left to right. A sentence in spoken language has a similar syntactic arrangement of words which consist of sounds / phonemes which almost correspond to the letters of written language.Furthermore, in spoken language the tone of voice gives additional information.The symbols of verbal representations are abstract, that is, the form of the symbol has no causal relationship with the meaning it represents. For example, the analogical representation for a dog is the image of a dog. Some visual representations, such as photographic ones, contain complete information about the symbolized dog seen from a certain point of view. Obviously, not all visual representations of a dog include all the elements of the normal stimulus, we do not process or store all the information that constitutes a visual or auditory stimulus. The verbal symbol for a dog in Greek is 'σκύλος' or 'κύων', in other languages 'dog', 'chien', 'hund', 'kjopek'. We conclude, therefore, that there is nothing in the form of the verbal symbol that indicates its meaning. The meaning is imposed on the basis of an arbitrary (conventional) correspondence.In verbal representations, symbols are distinct (either as sounds, letters, or as meanings for the deaf) in contrast to figurative representations where the elements are not distinct. Also, while the part of a verbal symbol does not represent (the first part of the word 'cauliflower' does not refer to the known insects), each part of a figurative symbol represents the corresponding part of the depicted (Kargopoulos, 2008). Directly dependent on the above difference is the fact that in verbal representations all transmitted information must be described explicitly, while in a figurative representation of a book on a table the relation "on" is visible, we do not need to specifically state that the book is on the table. On the contrary, if we want to represent the same information propositionally then we should explicitly use the qualifier "on". The definition of analogical representations is clearly different from the definition of propositional representations (Anderson, 2011. Nanay, 2013).In order to contrast the two types of internal (mental) representations, i.e. mental images with logical (mental) propositions, we used the corresponding external representations, i.e. images and language, and all the differences we recorded apply to the corresponding mental representations we are studying. Going a step deeper, we must attribute these differences to the fact that these two types of representations arise in a different way.The virtual representations are also called analogical and arise initially from the processes of the senses. In this way, the basic mechanisms that lead from the symbolized to the symbolizer are of a causal nature. The initial cause, as a whole, causes the causal symbol after various stages of transition. For this reason, similarity plays a dominant role in the relationship between representation and represented object. A scene or an event is imprinted in memory or on film or tape directly (without being translated into symbols) and the trace it leaves in each case is somewhat similar to the represented scene or event (Kargopoulos, 2008).

In contrast to the above analog representations that are bottom-up, digital representations are top-down because they categorize and select the representation of information based on rules of meaning, syntax and phonology, where symbols are conventional and not causally connected

to the symbolized (Raftopoulos, 2009). In place of causality, the basic characteristic of verbal representation that allows the above function of language is compositionality, which is analyzed into two properties:

1) productivity, that is, the fact that from finite elements based on finite rules, infinite composites arise (which are understood by analogous procedures), and 2) systematicity (what is produced is logically related to other productions: it is compatible with others, it implies others, it excludes others) (Kargopoulos, 2008).

These two properties are based on the morphologically syntactic nature of language. The cognitive science bias in favor of digital representation comes from the fact that the main model of mind, the Electronic Computer, is a syntactic machine because it operates exclusively with morphologically processing symbols (Haugeland, 1997).

For virtual analog representations (in the broad sense that includes representations in all senses) there is no corresponding property of syntheticity. We do not have a logic of images until after translation into propositional knowledge. For example, to consider an image of the book 'above' the desk as less probable than an image of the book 'on' the desk is a matter of cognitive permeability from the propositional knowledge that heavy objects do not float above surfaces without some form of support. In contrast, an image with a cloud 'above' the mountain is just as likely as an image with the cloud 'on' the mountain based on propositional knowledge about the nature of clouds. Knowing that cognitive processes such as language are possible only with propositional representations and that the direct perception of a visual stimulus is analogical, the question arises: "in what form do we represent knowledge?" Is it an analogical, propositional representation, or some form that includes elements from both categories? The research continues.

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DOI:10.31579/2637-8892/327