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Perception, Representation, and Epistemic Reference

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Abstract

In this essay, I argue that our perception of the phenomenal world can be epistemically related to what exists without corresponding to it, since the human brain did not evolve to deliver a "true" image of reality but primarily to serve survival of the species. Perception is not a mere response to environmental stimuli but is a higher-level cognitive experience that provides indirect knowledge of objects and events. From this perspective, I defend a non-correspondentist, realist, and representational account of perception and language.

Keywords: epistemic reference, language, indirect realism, mental representation, perception, phenomenal world, vision.

1. Living and survival

Any living organism can be regarded as a particular organisation of matter (or energy), a particular structure of the elements composing inorganic matter (such as carbon, oxygen, nitrogen, and hydrogen atoms). As such, any living organism is an open system, in unstable state, with the capacity to reproduce itself; in other words, a dissipative structure able to maintain itself far from thermodynamic equilibrium.[1] To do so it may exploit mechanisms of adaptation to stimuli from its environment.

All living organisms are therefore "thermodynamically" open systems in a state of non-equilibrium, characterised by self-organisation.[2] They

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1. See Grégoire Nicolis and Ilya Prigogine, *Self-Organization in Nonequilibrium Systems: From Dissipative Structures to Order through Fluctuations* (New York: Wiley, 1977); Ilya Prigogine and Isabelle Stengers, *Order out of Chaos: Man's New Dialogue with Nature* (New York: Bantam, 1984); Grégoire Nicolis and Ilya Prigogine, *Exploring Complexity: An Introduction* (New York: W. H. Freeman, 1989).
2. The term "self-organization" means the capacity of living organisms to coordinate all the mechanisms of the biological reactions necessary for their existence. In the 1960s, Ilya Prigogine developed non-linear thermodynamics to describe the phenomenon of self-organization in open, far-from-equilibrium systems. In classical thermodynamics, the dissipation of energy as heat was always associated with a loss. According to the

draw energy, i.e. matter, from the environment and transform it into structure, conservation of which is the principal purpose of their existence. This conservation relies on regulatory mechanisms that exist at all levels of living matter, from simple particles to human behaviour.

According to a systemic view, the essential properties of an organism or living system are properties of the whole that no single part possesses, because they arise from interactions and relations between the parts. Although it is possible to distinguish single parts of any system, these are not isolated. In any case, the nature of the system cannot be reduced to the sum of its parts.[3]

In this framework, the human brain evolved to achieve a fundamental purpose: to perceive the change, the movement, the evolution that permits life on planet Earth. Its evolution would have been different in a fixed, unchanging, eternal world. In biological-evolutionary terms, *the ultimate purpose of any organism, from the most elementary, like bacteria, to Homo, is not to live but to survive, i.e. to act and fight for life, in the case of species, to avoid partial or total extinction*.[4]

It is therefore appropriate to distinguish mere existence, the condition of simply being alive (being a living organism), from survival, the condition of staying alive in the midst of continuous competition between living organisms (the number of which is significantly greater than those that could live with the resources available) through a process of adaptation that extends in two directions: inward, to favour the regular development and physiology of living organisms; outward, to respond to changes in the environment.

In a world with unlimited energy resources, or where all organisms are autotrophs, competition would presumably have no place. Survival of the fittest would not be a fundamental biological law, which among humans often regulates inter-species relations with great cruelty despite laws,

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theory of Prigogine (see Ilya Prigogine and Isabelle Stengers, *La nouvelle alliance*, Paris: Gallimard, 1979), dissipative structures not only maintain themselves in a stable state, far from equilibrium, but can even evolve: when the flow of energy and matter through them increases, they can enter new phases of instability and transform themselves into more complex new structures.

3. See Ludwig von Bertalanffy, *General System Theory* (New York: George Braziller, 1968), and Mario Bunge, *Emergence and Convergence: Qualitative Novelty and the Unity of Knowledge* (Toronto: University of Toronto Press, 2003).

4. See Charles Darwin, *On the Origin of Species* (New York: Simon & Schuster, 2008 [1859]); John Maynard Smith, *Evolutionary Genetics* (Oxford: Oxford University Press, 1989); Daniel C. Dennett, *Darwin's Dangerous Idea* (New York: Simon & Schuster, 1995).

ethical principles, and religious beliefs. As their cell complexity increased, animals had to face new challenges to conserve their structure as self-sufficient units, the parts of which give up their individuality for survival of the whole system of cells. This required evolution of the nervous system – a sensorimotor integration device – made up of specialised cells (neurons) that enable the rapid, long-distance transmission of information and the connection of sensory receptors to motor effectors.[5] Neurons, moreover, can be modified during interaction of the organism with its environment, showing a characteristic known as *synaptic plasticity* essential for learning. The advent of synaptic plasticity was probably a determinant factor in the Cambrian explosion of animal phyla.[6]

Naturally, the advent of nervous systems and their evolution in animals provided many mechanisms and strategies for moving towards and away from things, beyond the simple taxic reactions of unicellular organisms. Specifically, neuronal control made it possible to approach and withdraw more effectively for the objective of survival, though in humans there does not seem to be a close causal relation between mental states (e.g. emotions) and survival behaviours. It is legitimate to sustain that we flee from danger because we fear what could happen, but in our species approach, flight and other behaviours related to survival are mediated by brain circuits different from those determining fear, pleasure, disappointment and so forth.[7]

In *Homo,* brain structure is enormously complex: about 85 billion neurons (16 billion in the cerebral cortex alone) make up a vast network with thousands of billions (10^{13}-10^{15}) of synapses forming intricate interwoven patterns.[8] Sub-networks communicate with each other as elements of a network, the fundamental feature of which is their *non-linearity*: every network or sub-network extends in all directions.

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5. See Eric R. Kandel et al., *Principles of Neural Science*, 5th ed. (New York: McGraw-Hill, 2013); Michael S. Gazzaniga, Richard B. Ivry, and George R. Mangun, *Cognitive Neuroscience: The Biology of the Mind*, 5th ed. (New York: Norton, 2019).
6. See Eric R. Kandel, "The Molecular Biology of Memory Storage: A Dialogue between Genes and Synapses," *Science* 294 (2001): 1030-1038; Gerald M. Edelman, *Neural Darwinism: The Theory of Neuronal Group Selection* (New York: Basic Books, 1987).
7. See Joseph LeDoux, *The Deep History of Ourselves: The Four-Billion-Year Story of How We Got Conscious Brains* (New York: Viking, 2019).
8. See Suzana Herculano-Houzel, "The Human Brain in Numbers: A Linearly Scaled-Up Primate Brain," *Frontiers in Human Neuroscience* 3 (2009): 31.

2. Perception and perceptual experience

To conserve their structure, living organisms seek energy in the environment through 'sensors'; hence the need to have locomotor systems that enable them to move physically in space to find and reach energy sources; more precisely, to acquire biological knowledge, i.e. knowledge of the environment that can ensure the survival of individuals and species.

Considerations on its biological purposes suggest that perception is a simple process, whereas it is in fact extremely complex due to the variety of systems involved and their great diversity in living organisms.[9] The innate perceptual and cognitive instruments that formed during phylogenesis are our first tools for "reading" and "interpreting" the world. They enable us to establish causes and to formulate choices and predictions, but always in the ambit of the environment in which our species evolved, because the structure of the phenomenal world[10] determined the properties of our perceptual-cognitive instruments via the Darwinian mechanism of selective pressure.

Two fundamental functions of perceptual experience can be distinguished: 1) collection of information from the environment via sensory organs and receptors (*sensation*); 2) analysis and interpretation of this information by the nervous system, contributing to experience of the mental states of perceptual awareness (*perception*).

Sensation consists in an initial activation of the nervous system, i.e. in the transduction of information on the environment into patterns of neural activity. The mental representation of the original stimulus, derived from processing and interpretation of the modifications that the proximal stimulus determined in the sensory organs, is known as the *percept*. Perception can therefore be understood as the process of construction of the percept.[11]

Sensations enable us to formulate an immediate and adequate representation of the world and of the position we occupy in the world, and to provide rapid responses to three questions we continuously pose: Is

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9. Cf. Hermann von Helmholtz, *Treatise on Physiological Optics*, trans. J. P. C. Southall (New York: Dover, 1962 [1867]); Richard L. Gregory, *Eye and Brain: The Psychology of Seeing* (Princeton: Princeton University Press, 1966).

10. With this term I refer to the world accessible epistemically through perceptual experience, distinct from the physical world.

11. See Gazzaniga, Ivry, and Mangun, *Cognitive Neuroscience: The Biology of the Mind*. More in the next section on the problems associated with recourse to the concept of mental representation.

there something? What is it? What has changed? The answer to these questions is possible because all sensory systems play two basic functions: *detection*, or the cognitive response to presentation of a sensory stimulus, and *discrimination*, which consists in differentiating stimuli by selecting those considered more important than others.[12]

So, when we consider sensory experiences, we must not forget that our sensations are qualitatively different from the physical properties of stimuli because, as Kant forecast, the nervous system extracts only certain informative elements from every stimulus, ignoring others. It is then up to the brain to interpret this information according to the limits imposed by its structure and by previous experience. We therefore receive electromagnetic waves of different frequencies, but we "see" them as colours; we receive pressure waves from objects vibrating at different frequencies, but we hear sounds and words, and so forth. In fact, colours, sounds, words etc are mental representations constructed by the brain that do not exist as such outside the brain but are related to specific physical properties of the stimuli.

Perception begins with reception of sensory information by the receptors of sensory organs. The organ transduces the energy of the stimulus into an electrical signal, which is then transmitted to the brain for processing. The first phase of processing of sensory information consists in a breakdown of the stimulus into its components, each coded by a single receptor or projection neuron. To build a representation of an object or event, these components are integrated by nerve networks that favour certain characteristics rather than others. This means that our perceptions do not simply reflect objects or events but are a refined product of our brain.

Each sensory mode has its cluster of central neurons (the sensory system) connected to specific classes of receptor.[13] Most of the neurons of the retransmission nuclei receive converging excitatory input from many presynaptic neurons, integrating and combining them with inhibitory and top-down signals prior to transmitting the processed information to higher brain areas. Inhibitory mechanisms are useful to remove irrelevant information during objective-driven behaviours, thus helping focus the attention on aspects relevant to the objective.

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12. See Kandel et al., *Principles of Neural Science*.
13. Ibid.

Perceptual activity is therefore not only to do with the initial codification of information detected by receptor cells, but also interprets stimuli received from the environment by sensory receptors. Perception can be better explained using the psychophysical chain concept, that gives a schematic but reliable/description of the subjective experience arising from the processing and interpretation of the changes that proximal stimuli cause in sensory organs:

Distal Stimulus → Proximal Stimulus → Percept

where distal stimulus is the object or event in the phenomenal world (e.g. a body that emits and/or reflects light), proximal stimulus is what impinges on sensory receptors and is transmitted to the brain cortex (e.g. the retinal image of visual perception) and the percept is the stimulus as perceived by the perceiver (e.g. the set of size, form, colour etc. attributes I recognise as 'cat').

In the first phase of the perceptual experience, our sensory systems transmit simple filtered representations of sensory stimuli that are rough, ambiguous, and incomplete, and above all, without meaning. The brain activities involved in the perceptual process encode the sensory information as objects or events. In this way perception resolves gaps in the sensory evidence and formulates hypotheses or inferences on the causes of the sensations, drawing on already acquired knowledge.[14] For example, the taste of a dish (or the aroma of an object) extends single experiences into the domains of memory/recollection and imagination. Indeed, what we perceive is always the result of an association of sensory stimuli with the memories they evoke and utilise.[15]

We know that the relationships between perception and memory were initially studied by empiricists, in particular William James and John Stuart Mill, according to whom, sensory and perceptual experiences happening simultaneously or in rapid succession or repeatedly become associated with each other. Association is a powerful mechanism: learning consists largely in formulating associations through repetition.

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14. See Andy Clark, *Surfing Uncertainty: Prediction, Action, and the Embodied Mind* (Oxford: Oxford University Press, 2016); Floris P. de Lange, Micha Heilbron, and Peter Kok, "How Do Expectations Shape Perception?" *Trends in Cognitive Sciences* 22, no. 9 (2018): 764-779.

15. See Wilfrid Sellars, "Empiricism and the Philosophy of Mind," in *Science, Perception and Reality* (London: Routledge, 1963), 127-196, and Fred I. Dretske, *Knowledge and the Flow of Information* (Cambridge, MA: MIT Press, 1981).

What can we observe in the case of *Homo?* If for example we examine a simple visual perception, such as that of a book on a table, we observe that the perceptual content does not consist solely of visual information from the object to the eyes and visual cortical structures, but also of other information already present in the CNS. We therefore do not perceive solely an object with certain physical attributes, but rather we visually perceive a book, considered such because it is recognised cognitively. In other words, the book has been assigned attributes that cannot be derived directly from photonic reception, such as ‘an object useful for learning’, ‘an object consisting of printed sheets’, ‘my book on my desk’, etc. Non-phenomenal factors, such as the concept ‘book’, the concept ‘sheet’ etc., are therefore involved in the formation of this perception.

The fundamental task of the eye is to inform the brain through a nerve-signal code, i.e. a series of electrical impulses that are interpreted by brain centres and transduced into the representations of objects. We look at an object and our brain obtains the information to reconstruct the image from the nerve input. Proponents of the theory of form (*Gestalttheorie*) sustain direct formation of images in the brain, explaining the process of perception as the result of modifications in the brain’s electrical fields, which are said to reproduce the form of perceived objects. This notion, known as isomorphism, has been deleterious to the interpretation of perceptual phenomena, because it introduced a tendency to attribute certain properties that enabled explanations of visual function deformation and other optical phenomena to these hypothetical fields, unsupported by experimental evidence. However, certain important aspects of the problem of perception and the difficulty of fully explaining the process leading from retinal stimulation to the perception of objects, did not escape the gestaltists. They identified the tendency of the visual system to group single elements into simple units, building objects that embody the sensory data acquired and transmitted by peripheral receptors in direct relation with the phenomenal world.

The vision of objects involves various sources of information besides the visual source. Specifically, previous knowledge of the object through sight or other sensory organs becomes necessary. Objects are not just a source of stimuli but are distinguished by having a past and a future, which makes it impossible to reduce them to the sensory experience alone. Perception is never determined exclusively by sensory stimuli but is the result of a dynamic research process directed at proposing the most likely interpretation of the available data, i.e. of the sensory experience and the information otherwise obtained about the perceived object. Over-stepping the immediate evidence of the senses, perception exploits other information content to formulate an interpretation of objects in the outside world, an interpretation that is reliable, namely in line with perceived reality.[16]

The eyes receive energy but see objects. The energy does not contain exact meaning, whereas the objects show a set of attributes that transcend the capacity to stimulate the eyes, have a duration, may change, and do not explicitly show properties except under certain conditions. For a perception of a real entity to be truthful, it must meet certain criteria. The visual system is often at odds with the brain cortex. For example, we know that the moon is 380,000 km from Earth, though for the visual areas it is at hand; the striate cortex is indifferent to cortical content. It almost seems that the brain uses the same deductive method that astrophysicists use to assess the distance and composition of stars to process the raw information provided by the sensory organs. Were the brain unable to fill gaps and formulate hypotheses to complete the scanty information received, our activity would cease, in the absence of external stimuli. This means that perception is never the result of sensory stimuli but is a dynamic search process for the most satisfactory interpretation of the available data, i.e. of the sensory experience and information on the perceived object acquired by other means.

3. The problem of mental representations

Representation is probably the key concept of any theory of the mind and the crux of the difficulties of reducing the latter, even in conceptual terms, to a product of brain activity. Behaviourism, which above all in North America dominated the field of experimental psychology for almost all the first half of last century, banned mental representations and any mention of internal mental states, sustaining that it was more important to analyse the stimulus that gave rise to a given action in any circumstance and hence the corresponding response. This aversion of behavourists was above all due to the vagueness of the concept of representation formulated in psychology and to the fact that mental representations cannot be directly observed.[17]

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16. See James J. Gibson, *The Ecological Approach to Visual Perception* (Boston: Houghton Mifflin, 1979), and Alva Noë, *Action in Perception* (Cambridge, MA: MIT Press, 2004).
17. See John B. Watson, *Behaviorism* (New York: W. W. Norton, 1924) and Burrhus F.

As we know, mental representations were rehabilitated by the cognitive revolution.[18] Taking the level of internal representations into consideration, if not on an ontological, at least on a methodological plane, leads the scholar of cognitive sciences to embrace more or less abstract mental entities, like symbols, images, schemes, ideas, rules and beliefs, assuming that in our mind there is a level of representation of concepts and images which is immediately pictorial (*iconic representations*)[19] or only indirectly visualisable but always subject to elaboration and manipulation (*mental representations*).

In truth there have been many cognitivist studies that testify the existence and functional dynamics of mental representations. In first place, certain experiments have shown the importance of expectation and overall context in interpretation: different people interpret a story in different ways according to how the story is presented to the interpretative keys available to them, thus revealing the powerful influence of mental frames on the perception and interpretation of narrative passages. This suggests that our mind does not work in *bottom-up* mode, i.e. from perceptual elements to mental schemes, but in *top-down* mode, because mental representations and schemes exercise a significant role in the organisation of percepts. Another clue to the existence of mental representations derives from the manipulation of mental images: when a person is asked to decide whether two images, one of which is shown rotated with respect to the other, are identical, one observes that the time taken to respond is a function of the difference in angle of the two images. If the two images are rotated by 80°, the time needed to process the response is greater than if they are rotated

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Skinner, *Science and Human Behavior* (New York: Macmillan, 1953).

18. See Charles R. Gallistel, in "Psychology of mental representations," in *International Encyclopaedia of the Social and Behavioral Sciences*, ed. Neil J. Smelser and Paul B. Baltes (New York: Elsevier: 2001), 9691-9695; Mauricio Suárez, "Scientific representation: against similarity and isomorphism," in *International Studies in the Philosophy of Science* 17, no. 3 (2003): 225-244; Steven Piantadosi, "The computational origin of representation". *Mind and Machines* 31 (2020): 1-58; Joulia Smortchkova, Krzysztof Dołęga, and Tobias Schlicht (eds.). *What are Mental Representations* (Oxford: Oxford University Press, 2020).

19. The term 'icon' indicates a model useful for pictorially reproducing and classifying an object. Studies on "mental rotation" and image scanning have led to what is known as *depictive theory*, according to which mental images are not simple internal representations that provide visuo-spatial information, but "depict such information" because the format of such images is almost pictorial. See Stephen. M. Kosslyn, William L. Thompson, Giorgio Ganis, *The Case for Mental Imagery* (New York: Oxford University Press, 2006); Joel Pearson and Stephen M. Kosslyn, "The heterogeneity of mental representation: Ending the imagery debate." *PNAS* 112, no. 33 (2015), 10089-10092.

at 50°. This means that people do a mental rotation at a relatively constant speed of one of the figures, of which they have evidently made a mental image.

It is worth recalling that in rigorous terms, 'representation' is a mathematical and computational concept: a mental or other representation is a system of symbols. Such a system is isomorphic[20] with respect to another system (the system represented), i.e. it has the same form as the other system, so that conclusions obtained by processing symbols in the representative system are valid inferences about the represented system. The form in question is mathematical, being the form of the equations that specify the relations between the symbols and between the things the symbols represent. For example, Ohm's law, I=V/R, the equation for the relation between current (I), voltage (V) and resistance (R) in an electric circuit, has the same form as the equation for the relation between velocity (V), force (F) and viscous resistance (R) in a mechanical system such as a shock absorber: V = F/R. Since the equations describing the two systems are identical, apart from the symbols used, it is possible to represent a mechanical system with an electrical one and vice versa.[21]

Systems X and Y are therefore isomorphic if operations in X "do the same thing" as the corresponding operations in Y, and vice versa. For example, the ticking of the second hand is isomorphic with the ticking of the minute hand: both make 60 movements and then begin a new cycle. The way one state leads to the next is 'the same', even if the details are different because one hand beats seconds and the other minutes.

In any case, modern cognitive science rests on the concept of mental representation, and in some cases on the conviction that the brain does "computations". In fact, functional states that can be considered equivalent to the performance of algorithms do not exist, but rather a broad set

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20. The term *isomorphism*, in natural language, means identity of form. It is used in mathematics to indicate two structures that while differing in origin and formalism, have the same structural properties. In other words, one can speak of isomorphism when two formal structures can be mapped onto each other in such a way that for every part of one structure there is only one corresponding part in the other, where "corresponding" indicates that the two parts play similar roles in their respective structures. Applied to perceptual images, this notion means that the principal characteristics of the objects they refer to are coded in the images, thus establishing a semantic relation between the physical object and the mental representation, a relation that makes the mental representation a structure that *stands for* an object or a state of things in the phenomenal world.

21. See Gallistel, "Psychology of mental representations".

of selective repertoires of neuron clusters, the degenerate[22] responses of which can be open to environmental signals and to the richness of every individual's history. The neurosciences use the term 'representation' (or 'code') in a non-univocal manner to indicate the correlation or covariance between configurations of neuronal discharges and perceptual signals or memory states. A neurophysiologist can assert that a configuration of discharges correlated with an afferent signal constitutes a representation; however, his usage of the term reflects a third-person point of view[23].

A major development in the mathematical treatment of the computation and representation happened with the definition and quantification of information: signals are symbols that convey information from one place to another in space-time;[24] e.g. nerve signals that conduct information about the environment from sensory receptors to the brain. The quantity of information conveyed by a signal is a function of the quantity of information about the world already present in the place where the signal is received and processed. In other terms, in our information-processing structures, we must have incorporated implicit representations of the various environments that we could encounter i.e. we have to already know something about the world that we are about to experience.

The development of mathematical analysis of information processing and of the decisional process has favoured development of psychology centred on mental representations. There are many examples of human and other behaviour that seem to implicate mental representations: e.g. cases of learned behaviour in animals that depends on underlying repre-

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22. *Degeneracy* is the capacity of complex systems to serve the same function or produce the same result. Based on this capacity, brain networks are embodied by epigenetic processes to determine a high degree of inter-individual variability in anatomical structures and connections between groups of neurons. Thus, *degeneracy* emerges as a fundamental property of evolution, becoming a prerequisite for natural selection, enabling it to operate only in a population of genetically different organisms (Gerald M. Edelman and Joseph A Gally, "Degeneracy and complexity in biological systems,", in *PNAS,* 98 (2001): 13763-13768).
23. See Gerald M. Edelman, *Wider Than the Sky. The Phenomenal Gift of Consciousness* (New Haven: Yale University Press, 2004); Patricia Smith Churchland, *Neurophilosophy: Toward a Unified Science of the Mind-Brain* (Cambridge, MA: MIT Press, 1986); Fred I. Dretske, *Knowledge and the Flow of Information* (Cambridge, MA: MIT Press, 1981); Bence Nanay, *Between Perception and Action* (Oxford: Oxford University Press, 2014); Rafael Yuste, "From the Neuron Doctrine to Neural Networks," *Nature Reviews Neuroscience* 16 (2015): 487-497.
24. See Claude E. Shannon, "A mathematical theory of communication", in *Bell Systems Technical Journal*, 27 (1948): 379-423; 623-656.

sentations of fundamental abstract properties of the world, such as distance, direction, duration, and time of day.

If we consider the visual capacities of insects: their computational power is low compared to more complex organisms and elementary artificial systems, but they can fly, avoid obstacles and possible predators, reach destination, land correctly and so forth. Surprisingly, all this happens at the same speed as human sight. For example, when foraging bees return to the hive after discovering a nectar source, they perform a dance that symbolises the direction with respect to the sun and the distance of the source from the hive. Other foragers that observe the dance fly in the direction for the distance indicated before searching for the source. Thus, the dance directly "symbolises" or "represents" the direction and distance, since the other bees derive the direction to fly and the distance from the dance they observe. In other words, the direction and distance are represented in the nervous system that controls the bee brain. Wherever there is regularity and form in the world, animals represent that regularity and that form to use them for their own purposes.[25]

The causal factor underlying isomorphism is important for two reasons: a) because the representation cannot be current (and perceptual) unless it is constantly updated, which presupposes a causal chain from events in the outer to events in the inner world; b) because the representation cannot be reliable unless there is a structural link with the world it represents[26]. For example, cones are arranged on the retina like photoreceptors in a camera. The spatial pattern of excitation of the retina is projected through the lateral geniculate nucleus onto the primary visual cortex in a sequence of maps that preserve its structure. In every phase of the processing chain, the model of neural activation is a representation of the stimulus.[27] In particular, the visual mental representations or visual

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25. See Karl von Frisch, *The Dance Language and Orientation of Bees* (Cambridge, MA: Harvard University Press, 1967); Charles R. Gallistel, "Symbolic processes in the brain: The case of insect navigation", in *An Invitation to Cognitive Science: Methods, Models, and Conceptual Issues*, ed. Daniel N. Osherson *et al.*, Cambridge, MA: The MIT Press, 19982, 1-52. Charles R. Gallistel, *The Organization of Learning* (Cambridge, MA: MIT Press, 1990); Martin Giurfa, "Cognition with Few Neurons: Higher-Order Learning in Insects," *Trends in Neurosciences* 36, no. 5 (2013): 285-294.

26. See Stephen E. Palmer, E. *Vision Science: Photons to Phenomenology*. Cambridge, MA: The MIT Press, 1999; Alistair M.C. Isaac, "Objective similarity and mental representations," in *Australasian Journal of Philosophy* 91, no. 4 (2013): 683-704; Alex Morgan, "Representations gone mental," *Synthese* 191 (2014): 213-244.

27. See Roger N. Shepard and Jacqueline Metzler, "Mental Rotation of Three-Dimensional Objects," *Science* 171 (1971): 701-703, and Joel Pearson, "The Human Imagination:

mental images seem to play an important role in many daily activities, such as going into a shop, remembering the shopping list and putting the purchases in the boot of the car, and more generally in cognitive functions like learning, memory and reasoning.[28]

In the field of philosophy, the term 'representation' is used with different meanings. Two are more frequent. The first is when the object is imagined (*se représenter*) in its entirety together with any parts that may be missing or not perceivable – a subjective representation of a state of things considered to be objective. The second is etymological in the sense that it is re-presentation to memory (remembering), i.e. recognition or identification of an already experienced object. For Husserl any intentional *Erlebnis* is a representation (*Vorstellung*) or is based on a representation (*Repräsentation*), where *Vorstellung* is the complete act of "merely representing" i.e. the mental process by which a content appears to awareness (the act of bringing an object or concept to mind, without there necessarily being a judgement or a linguistic expression), whereas *Repräsentation* regards the content of an intentional act, i.e. what determines the specific reference to an object, the element that gives awareness the capacity to refer to a determined object in the world, thus giving the *Vorstellung* a content.

In much of contemporary philosophy of the mind, mental representations are understood either as structures of symbolic data or as levels of activation of sets of neural networks and/or as connection capacity between such networks. In any case 'mental representation' or 'cognitive representation' are terms used to refer generically to any state of a cognitive system identified by semantic content. Let us see some of the main interpretations:

1. *Symbolic structures or neural networks*: the representations may be seen as sets of symbolic data (as in the case of computational theories of the mind) or as neural network activation configurations, where the neural activation models represent cognitive information.
2. *Resemblance criterion*: Here it is underlined that the representations can take the form or reflect the structure or "logical form" of what they represent.
3. *Covariance or causality criterion*: In this case, the representations are linked to physical states of the brain that co-vary with objects or events in the

The Cognitive Neuroscience of Visual Mental Imagery," *Nature Reviews Neuroscience* 20 (2019): 624-634.

28. See Kosslyn, Thompson and Ganis, *The Case for Mental Imagery*.

external world. For example, in vision, activation of the visual cortex could co-vary with movement of the perceived objects.

4. *Adaptation*: The representations are also seen as symbolic activities that do not always establish a direct resemblance or covariance relationship with what they represent. For example, the dance of bees communicates information on food without directly imitating the object communicated.

5. *Functional or computational role*: the representations are analysed in relation to their role in the cognitive system.

6. *Reference and truth*: finally, mental representations are conceived based on their capacity to refer to something in the world and to be considered true or false, according to whether they match reality.

4. Perception and environment

As we move in the environment, we come into relation with many objects having stable properties: they have constant form and size, despite changes in perspective, because of the relations between the elements of the phenomenal field, i.e. the space where things and states of things that stimulate or can stimulate our perceptions are found. In all its presentations, an object conserves its properties because all its possible perspectives in relation to form and size are just modes of relation with context.[29]

When I observe my desk, which is built in a certain way, I do not establish an irreversible unchangeable relation with it: indeed, if I move away from the desk or change the visual angle, I expect an apparent change in its size and form, because I am aware that at a certain distance I can perceive the actual size and form of the desk. I am also able to identify objects irrespective of the position they occupy, because the multiplicity of possible perspectives does not invalidate the perceptual experience, I have from a certain observation point and a certain distance.[30]

My specific observation point determines what I can perceive visually of a physical object, i.e. my perception is always incomplete. It is impossible to see an object as a whole:, even if I visually perceive my desk to have a posterior part, not in my visual field. This is because I have implicit knowledge (cabled in my brain in the form of a generative model) of how

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29. See Gibson, *The Ecological Approach to Visual Perception*, and David Marr, *Vision: A Computational Investigation into the Human Representation and Processing of Visual Information* (San Francisco: W. H. Freeman, 1982).

30. See Maurice Merleau-Ponty, *Phénoménologie de la perception* (Paris: Gallimard, 1945).

rotation of the desk changes the incoming sensory signals.[31] I see my desk as mine because my perception draws on previous perceptual experience (different occurrences of the desk): I do not see object x, and later recognise it as my desk; I see the desk as mine. The content of what we perceive is not transmitted by sensory signals but emerges from the brain's implicit knowledge of the degree of correlation between actions and perception.

Awareness of the existence of an external world is the primary level of conscious experience, since experience of the phenomenal world is fundamental for any biological entity. We entrust ourselves to our senses, especially our eyes, to obtain reliable information about the external world. They provide us with the information necessary to act but transmit to the brain a raw product that must be processed, refined, and completed.

Our sensory receptors and those of other animals must solve adaptive problems already encountered by the first hominins at the dawn of the Palaeolithic. They evolved first to enable the australopithecines to escape the large mammals of the savanna and then to enable us not to be run over by cars when crossing the road. In any case, our brain did not evolve to give us direct access to the depths of reality but to favour our survival, i.e. to ensure our Darwinian fitness, which means that from a biological-evolutionary viewpoint, knowing what a thing really is does not matter, but we have to process received information in a way that serves our action in the world.[32] It is therefore not surprising that vision involves about a third of the cerebral cortex, because visual perception is not the same as passively recording objects and events but means generating interpretive models of reality.

We now know that subatomic particles, atoms, and molecules, i.e. the building blocks of everything that exists, do not obey Newtonian mechanics. The advent of quantum theory opened a new world to us. Once the veil of Maya was removed, the true nature of reality was disconcerting. It was not a rigidly deterministic world (the level of reality we are accustomed to living in, the one we experience daily) but a world inacces-

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31. See Karl Friston, "The Free-Energy Principle: A Unified Brain Theory?" *Nature Reviews Neuroscience* 11 (2010): 127-138; Grégoire Borst et al. "Representations in mental imagery and working memory: Evidence from different types of visual masks." *Memory & Cognition* 40 (2012): 204-217; Anil Seth, "The Cybernetic Bayesian Brain. From Interoceptive Inference to Sensorimotor Contingencies," *Open MIND*, eds. T. Metzinger & J. Windt, MIND: Frankfurt a.M., 2015; Anil Seth, *Being You. A New Science of Consciousness* (New York: Dutton, 2021).

32. See Clark, *Surfing Uncertainty: Prediction, Action, and the Embodied Mind*.

sible to our sensory organs, intuitive, statistical, indeterminate: the world of quantum mechanics.

From the point of view of quantum theory, the solid material objects of classical physics disappear at subatomic level, and we have wave patterns that do not represent the probability of things but rather probability of connections. In other words, subatomic particles have no meaning as isolated entities, but can only be apprehended as connections between different processes of observation and measurement. The world thus appears as a complicated tissue of events, in which connections of different kinds alternate or overlap or combine and thereby determine the texture of the whole.[33]

We therefore cannot decompose the world into elementary units, each of which exists independently of the others. When we see a network of connections between leaves, branches, and trunk, we call this network 'tree': the concept 'tree' in scientific terms depends on our methods of observation and measurement: we do not observe nature itself, but the nature exposed to our methods of investigation.

Thus, perception has a generative character, since our CNS produces our perceptions of objects in real time, and these are interpretative models of reality: we do not see apples and trees, but our brain generates the image of what we call 'apple' and 'tree'. It is therefore evident that perception cannot be considered a mere representation of external reality but must be understood as the constant creation of new connections within neural networks: our perceptual activity is what traces the borders, limits and outlines of the "objects" generated by our CNS from information received from our sensory organs.

For example, we know that cats and birds see trees differently from the way humans see them, since they perceive light in different frequency bands. When we see an entity that we indicate with the name 'tree' we are evidently not "constructing" a particular plant. In any case, the way we divide reality up into discrete units using received sensory stimuli depends on our perceptual system: so, the existence of trees is not ontologically objective, but subjective, in the sense that nothing exists independently of the observer (understood not as a subject but as any physical system). This does not imply subjective or idealistic points of view. Just as there is no such thing as velocity independent of the observer because velocity is

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33. See Werner Heisenberg, *Physics and Philosophy: The Revolution in Modern Science* (New York: Harper & B., 1958).

that of one body with respect to another, likewise there is no such thing as facts that exist independently of the observer because they are always facts of one system with respect to another.

Nevertheless, reality *is* in a specific way, and determining *what that way is* undoubtedly constitutes a significant ontological question. The perceptual experience of a thing dissolves epistemic doubts because it establishes a correspondence between the epistemic subject that sees and the entity experienced visually, or what is real and therefore "true". This is the so-called naive realism or common sense, which from a biological point of view is indispensable for adaptation and evolution.[34]

5. The visual system and the phenomenal world

Visual systems evolved by natural selection in close relationship with the structure of the phenomenal world, adapting to the ecological niches of the various species. They must therefore be coherent and reliably represent visual reality to obtain major adaptive benefits, as these depend largely on the state of the organism and on the success of its actions; otherwise, organisms with incoherent visual systems would soon become extinct.

We see an apple and immediately close our eyes: is there still trace of the apple we have just experienced visually in all its objectivity, independently of our representations? In fact, as we have already said, there is no objective apple, the existence of which is independent of the observer: rather, there is something composed of particles and chemical-physical processes to which we relate by various modes of reference. And it is worth adding that the perceptual images regarding the apple are always conditioned by the observer's perspective: thus, there will be as many images of the apple as there are observers on the scene.

In any case, when I see an apple, I do not infer its existence from my perceptual experience more than I deduce the validity of a logical inference from the fact that I cannot help believing the conclusion. However, as punctually observed by Thomas Nagel[35], when I see an apple, I can suppose I am mistaken, even if I am justified in believing the evidence of my sensory organs in most cases, because that is coherent with the hypothesis that a

34. See Mariano Bianca and Paolo Piccari (eds.), *Epistemology of Ordinary Knowledge* (Newcastle: Cambridge Scholars, 2015).

35. See Thomas Nagel, *Mind & Cosmos. Why the Materialist Neo-Darwinian Conception of Nature Is Almost Certainly False* (Oxford-New York: Oxford University Press, 2012).

reliable representation of the phenomenal world is the product of sensory organs modelled by evolution for that purpose. In the *Fourth Paralogism* of the first edition of the *Critique of Pure Reason*, Kant, too, convinced that transcendental idealism was compatible with empirical realism, sustained that "every outer perception therefore immediately proves something real in space, or rather is itself the real; to that extent, empirical realism is beyond doubt, i.e., to our outer intuitions there corresponds something real in space."[36] When I see an apple on the table, I see it because it is effectively there, but not *simply* because it is effectively there. I am aware of the apple because it stimulates my eyes that I know to be modelled by natural selection to respond to the stimulus of light reflected from physical objects. It follows that I see an apple effectively there in front of me only in a very complex and indirect manner.

People usually do not doubt what they see, because visual perception seems to open the main door of access to reality, the only reality possible that does not admit other eventual or possible realities not yet realised. It follows that people assign the attributes of reality and truth to the contents of visual experiences: what they see is real and therefore true. They therefore assume that "what is real is true", a sort of perceptual *a priori*. Thus, truth and reality are the epistemologically founding presuppositions of our trust in sensory organs, i.e. in naive realism and common sense.

Beyond the judgment one can make from a gnoseological viewpoint, so-called *naive* realism is biologically necessary. It is an attitude that humans share with many other animal species for biological, evolutionary, and adaptive reasons. Under selective pressure, visual systems adapted phylogenetically to perceive the external environment adequately and reliably to ensure the survival of living organisms.

We are certain that we see the world as it is because we believe we receive precise information about the world through our eyes, though they actually transmit an unrefined product to the brain. From the two-dimensional image on the retina, our brain obtains information on the three-dimensional organisation of the phenomenal world, transduced into electrical signals representing the forms and outlines of a face or an object, subsequently re-coded into various brain areas and processed into a perceptual image. No two-dimensional image projected on the retina could ever directly report the three-dimensions of the perceived object:

36. Immanuel Kant. *Critique of Pure Reason* [1781], ed. Paul Guyer and Allen W. Wood (New York: Cambridge University Press, 1998): 429.

this is the so-called *inverse optics problem*.[37] Indeed, since any image projected on the retina can be derived from objects of various sizes with different orientations and distances from the observer, the effective source of our perception of any three-dimensional object is by nature uncertain.[38]

Light from the centre of the visual field (i.e. what we see directly) is focused by the cornea, lens, and pupil on the photosensitive retina in the fundus of the eye bulb, where there is a high concentration of photoreceptor cells: the cones respond to high density light and the rods are also sensitive to minimal amounts of light. These features make the cones suited to day vision (photopic), i.e. with colours and high definition under conditions of good lighting, and the rods to night vision (scotopic), when forms can be seen in darkness but without colour or details.

Light energy that changes in intensity and wavelength in space and time is concentrated in the retinal image and absorbed by photoreceptor cells that transduce it into bioelectric signals, which through the intermediate stage of bipolar cells, give rise to nerve impulses in *ganglion cells*.[39] The axons of these cells unite in the optical papilla and project from the retina as the *optic nerve*, which leaves the eye at the *blind spot*, an area without photoreceptors, projecting to the visual centres of the brain. The two optic nerves cross (*decussation*) in the *optic chiasma*, after which they are referred to as *optic tracts*: axons from the right half of the two retinas form the left optic tract, while axons from the left half of the two retinas form the right optic tract. This means that the left half of the visual field is represented in the right side of the brain and vice versa (Fig. 1).

About 90% of the axons of the optic nerve project to the diencephalon and the lateral geniculate nucleus (LGN), the second station of visual processing. This subcortical structure, intermediate between the retina and the brain cortex, is situated in the dorsal thalamus of both hemispheres and regulates the flow of visual information, exposing it to

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37. See David D. Knill and Whitman A. Richards (eds.), *Perception as Bayesian Inference* (Cambridge: Cambridge University Press, 1996); Dale Purves and Beau Lotto, *Why We See What We Do: An Empirical Theory of Vision* (Sunderland, MA: Sinauer, 2003); Alan L. Yuille and Daniel Kersten, "Vision as Bayesian Inference: Analysis by Synthesis?" *Trends in Cognitive Sciences* 10, no. 7 (2006): 301-308; Wilson S. Geisler, "Contributions of Ideal Observer Theory to Vision Research," *Vision Research* 51 (2011): 771-781; Michael A. Webster, "Visual Adaptation," *Annual Review of Vision Science* 1 (2015): 547-567; Eric Kandel et al., *Principles of Neural Sciences*.

38. See Eric Kandel, *Reductionism in Art and Brain Science: Bridging the two Cultures* (New York: Columbia University Press, 2016).

39. See Thomas Albright, "Perceiving", in *Daedalus* 144, no 1 (2015): 22-41.

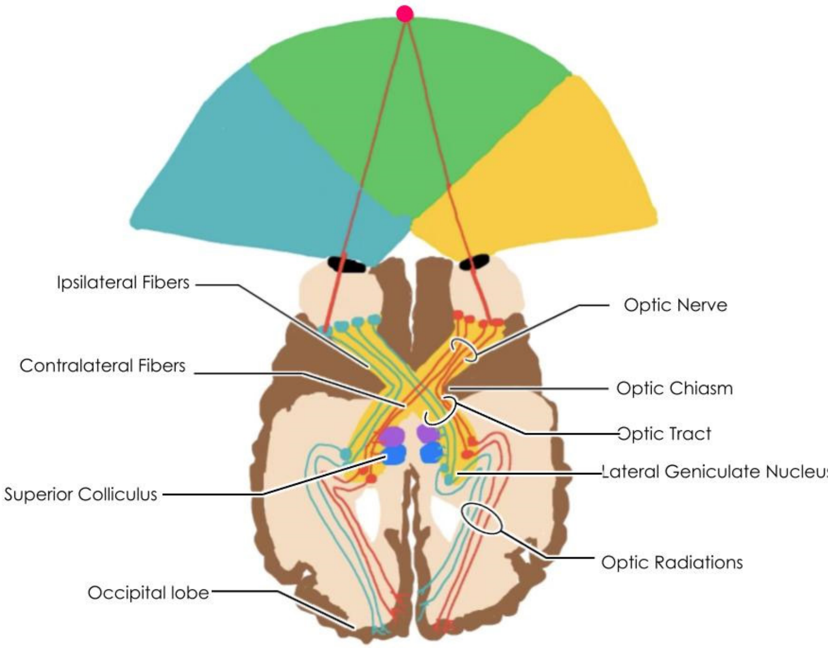

Fig. 1. The principal visual pathways.

cognitive and emotional influences. The axons that carry information from the right visual field project to the left LGN, whereas the axons carrying information from the left visual field project to the right LGN. Axons from the LGN are directed towards the posterior occipital lobe of the cortex where they establish synapses with cortical neurons. As with the LGN, the right occipital lobe receives information from the left visual field and the left occipital lobe receives information from the right visual field. This crossing of information from the environment (visual space) to the brain is known as *contralateral connectivity*.

Visual information from the LGN reaches the principal region of the primary visual cortex in the posterior occipital lobe, known as the *striate cortex* or visual area 1 (V1): this is a fundamental stage of an elaborate instrument for extracting essential information from the visual world.[40] Generally, the neurons of V1 respond to the margins of objects, i.e. they extract the overall form of an object, and the neurons of V4 respond to

40. See Semir Zeki, "Art and Brain," in *Daedalus* 127 (1998): 71-104.

specific colours and are less influenced by form and movement, whereas many V5 neurons respond to movement, velocity and direction without being particularly sensitive to form or colour. Each of these visual areas has a sort of map of visual space.[41]

The retino-genicular-striate projection (the principal visual pathway) is organized topographically, so that the central visual structures contain an accurate map of the contralateral visual field.[42] Objects that appear close to each other in visual space stimulate photoreceptor cells that are close to each other in the retina. This topographic relationship between objects in visual space is conserved to the end of the visual perceptual process, from the retina to the LGN and from there to the visual cortex. The cells of V1 are therefore organised in such a way that the receptor fields of cells in V1 respond to regions of visual space which are also close to each other. Although there are no cones or rods near the centre of the retina, where the optic nerve emerges, we do not see a dark spot near the centre of our visual fields because the brain fills in the gaps of the blind spot by analysis of context and use of mnestic content.

The output from V1 mostly travels in two bundles of fibres that transport visual information to regions of the parietal and temporal cortex involved in object recognition. The superior longitudinal fasciculus extends dorsally from the striate cortex and other visual areas, terminating mostly in posterior regions of the parietal lobe. The inferior longitudinal fasciculus runs ventrally from the occipital striate cortex into the temporal lobe.[43] These two pathways are known as the ventral occipitotemporal or *what pathway* and the dorsal occipitoparietal or *where pathway*.[44]

The *what pathway*, which begins in the V1 cortex and crosses visual areas V2 and V4 to the inferior temporal cortex, is associated with recog-

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41. See David H. Hubel and Torsten N. Wiesel, "Receptive Fields, Binocular Interaction and Functional Architecture in the Cat's Visual Cortex," *Journal of Physiology* 160 (1962): 106-154; Jonathan D. Victor, Michael M. Conte and Charles F. Chubb, "Textures as Probes of Visual Processing," *Annual Review of Vision Science* 3 (2017): 275-296; Kandel et al., *Principles of Neural Science*, chap. 26.
42. See Dale Purves et al., *Neuroscience*, 6th ed. (Oxford: Oxford University Press, 2018, and Mark Solms, *The Hidden Spring: A Journey to the Source of Consciousness*, New York: W.W. Norton & Co., 2021.
43. See Gazzaniga, Ivry and Mangun, *Cognitive Neuroscience: The Biology of the Mind*, and Kandel et al., *Principles of Neural Sciences*.
44. See A. David Milner Melvyn and A. Goodale, *The Visual Brain in Action* (Oxford: Oxford University Press, 1995); Melvyn A. Goodale and A. David Milner, *Sight Unseen: An Exploration of Conscious and Unconscious Vision* (Oxford: Oxford University Press, 2004); de Lange, Heilbron and Kok, "How Do Expectations Shape Perception?".

nition of forms and the representation of objects. It is also the only visual pathway leading to the hippocampus, which is concerned with explicit memory regarding persons, places, and objects, particularly useful for *top-down* processing. The *where pathway*, which runs from cortex V1 through visual area V2, the dorsomedial area and visual area V5 to the posterior parietal cortex, is associated with movement, spatial representation of the position of objects and control of the eyes and arms, especially when the visual information is necessary for grasping an object or for saccadic movements.[45]

Though distinct, the two pathways form a perceptual system of parallel processing, exchanging information along their courses. Indeed, together with the where pathway, the what pathway: a) does lower and intermediate level visual processing that enable the observer to distinguish objects from their backgrounds; b) does superior level processing that integrates information from the various brain areas to give sense to what the observer sees.

When the information has reached the highest level in either pathway, *top-down* processing takes place.[46]

It is worth recalling that two different images of the representations elaborated at retinal level reach our visual cortex, because the cells of the left half of both retinas project on the right occipital lobe and those of the right half on the left side. How are the two visual fields of the unified image we obtain recomposed? How are we able to perceive a stable and correctly orientated visual scenario? We know that our visual fields show images that are vertically and laterally inverted with respect to what we see and that our eyes move in jerks (about 3 per second) in various directions and are subject to head movements.

To understand how the properties of an image can be represented by populations of neurons that respond specifically to different orientations, it is possible to decompose the image into its frequency components by the Fourier method and filter it to generate a series of images, the spectral composition of which reflects the information transmitted by neurons tuned to different orientations.[47] Each class of neurons selectively sensitive to orientation transmits only a fraction of the information of

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45. See Joseph LeDoux, *Synaptic Self: How Our Brain Become Who We Are* (London: MacMillan, 2002), and Gazzaniga, Ivry and Mangun, *Cognitive Neuroscience: The Biology of the Mind*; Kandel et al., *Principles of Neural Sciences*.
46. See Kandel, *Reductionism in Art and Brain Science: Bridging the two Cultures*.
47. See Purves et al., *Neuroscience*.

a scene according to its filter properties, but the set of the partial information collected from these different neurons constitutes all the information necessary to generate an accurate representation of the original image.

Thus, the biological function of vision emerges clearly and enables *Homo* to act appropriately in the world, since there is a functional relation between images (which are obviously not photographs of the world although they "report" the figured attributes of the objects of the world through specific neural structures) and the world. A camera simply reproduces the intensity of light, point by point, in a plane of the visual field, while the visual system interprets the scene and reproduces it with all its components, separating the foreground from the background.

The visual system is certainly less accurate than a camera when it comes to determining absolute luminosity or identifying a spectral colour. However, it is formidable for identifying a charging animal or a speeding car, in full daylight or at dusk. It does this task rapidly to enable an adequate response to the stimulus: if necessary, flight. Vision is therefore a biological process that evolved to meet our ecological needs.[48] This explains the special efficiency of the visual system in extracting useful information, like the identity of objects, from the environment, attributing less importance to aspects like the exact nature of ambient light.

Inevitably there is an approximate correspondence between what we see and the sensory inputs that reach our cortex. This is borne out by the histories of neurological patients in whom the mechanisms that normally convert the information reaching the cortex into the scene we effectively see have been damaged. We can mention the case of a young woman with cortical dysgenesis of the occipital lobes: when she uses her visual memory (i.e. her predictive model), it sees two separate fields: one in which the image is vertically, and one in which it is laterally inverted. Her visual model of the world does not allow her to formulate the so-called corrective inferences necessary to orientate and integrate the visual fields. This condition involves wrong predictions and a latent conflict between visual experiences and those derived from other sensory organs.[49] The patient is therefore in great difficulty when she must establish the invariant charac-

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48. See Donald D. Hoffman, *The Case against Reality* (New York: Norton, 2019); Peter Godfrey-Smith, *Other Minds: The Octopus, the Sea, and the Deep Origins of Consciousness* (New York: Farrar, Straus and Giroux, 2016); Seth, *Being You. A New Science of Consciousness*.
49. See Purves et al., *Neuroscience*.

teristics of the form of objects, independently from her changing visual data (e.g. recognise a face from different perspectives or under variable lighting conditions). In other words, her visual cortex receives information normally but is unable to formulate generalisations by identifying the common properties of different perceptual moments of objects of a given class. Since her "associative" visual cortex does not automatically integrate the two visual fields and inverts the scene, she is forced to reconstruct her representations of the world by resorting to "forced" inferences: e.g. when she sees a geographical map of a place in the west, she knows that it is in the east.

The visual system exploits previously learned rules about the structure of the world. Some of these rules appear to be hard-wired into our neural circuits through evolution, whereas others remain plastic and support the interpretation of scenes in light of past experience.

Only in recent years have we understood the eminently generative nature of perception[50], because for a long time our conception of sensory perception was influenced by English empiricist thought (especially Locke, Hume, and Berkeley). These empiricists considered perception to be an atomistic process in which simple sensory elements (colour, form, luminosity) were put back together. Kant, on the other hand, understood that perception is an active creative process that goes beyond mere acquisition of information provided by sensory receptors. Subsequently, at the dawn of the 20th century, German psychologists Max Wertheimer, Kurt Kafka and Wolfgang Köhler developed Kant's intuition, founding the so-called Gestalt school of psychology that sustains that what we see is a stimulus, or the perceptual interpretation we formulate of any visual object does not depend solely on the properties of the stimulus, but also on other structures in the visual field.[51]

To understand the generative and auto-generative nature of perception, it is important to consider a phenomenon known as binocular rivalry, which was studied by Helmholtz during his research on unconscious inference.

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50. See Jakob Hohwy, *The Predictive Mind* (Oxford: Oxford University Press, 2013) and Clark, *Surfing Uncertainty: Prediction, Action, and the Embodied Mind*.
51. See Max Wertheimer, "Untersuchungen zur Lehre von der Gestalt," *Psychologische Forschung* 4 (1923): 301-350; Wolfgang Köhler, *Gestalt Psychology* (New York: Liveright, 1929); Johan Wagemans et al., "A Century of Gestalt Psychology in Visual Perception," *Psychological Bulletin* 138, no. 6 (2012): 1172-1217; Johan Wagemans, *The Oxford Handbook of Perceptual Organization* (Oxford: Oxford University Press, 2023).

When the right and left eyes are shown different images via a Wheatstone stereoscope, we observe that the visual experience is bistable, i.e. a composition of the two images is not seen but rather an alternation. For example, we see an apple then a table and not an apple-table. Clearly there is a distinction between the objective signal and the subjective perception it stimulates: while the retinal image does not change, interpretation of the visual signal changes, so that the observer has different experiences that do not concern sensory stimuli but rather inferences about them.[52]. In Bayesian terms, binocular rivalry means that if the most accurate hypothesis *a priori* (the high probability of seeing an apple-table) is not in line with our basic knowledge (the low probability that an apple-table exists), then it is discarded. Thus, we do not perceive sensory input, but inferences centred above all on our cortical predictive model which is derived from past memorised experiences (i.e. the most expected experiences).

Perceptual systems formed for this, not for other worlds (although they could operate suitably on another planet similar to ours), adapting phylogenetically to perceive the external world primarily in order to offer good chances of survival and to meet a double function: *qualitative,* insofar as they enable the content of our experience (percepts) to form, and *cognitive,* insofar as they provide information useful for exploring and acting in the environment.

We can recognise that perceptions provide reliable information about the world; more precisely, about its "appearance", not its structure or the laws that direct and regulate its processes.

6. Visual experience

The theatre of visual experience (as in any other type of perceptual experience) is not limited to the brain areas that process visual information but involves other mental content and body states, as well as objects of the world that stimulate the photoreceptors of the retina. It is therefore necessary to consider the *state of the subject and his/her relationship with the world*. Any visual experience is a relation between the subject and the world: *to perceive visually means establishing a relationship with the world that involves reception and processing of visual information*.

52. See von Helmholtz, *Treatise on Physiological Optics*.

Since its purpose is survival, perception first fulfils the task of permitting living organisms to move; movement is the response or reaction to a stimulus. Husserl was already aware of the close link between visual perception and motor capacity: in particular, visual perception seems affected by the kinaesthetic conditions of the observer's body, such that changes in his/her posture can change the system of images.[53] He sustained that the properties of the body of the perceiver are a condition of possibility of visual perception of an object. This thesis is confirmed by certain neuroscientific results.[54]

The physical constitution of the world directs us towards certain behaviours without dictating them: the objects of the phenomenal world do not tell us what to do with them, they do not have instructions for use. For example, a stick has no intrinsic function. It can be used to crush or break a bone, to strike prey, to mark a path or to burn in a fire. We are the ones to decide. So, our brain creates the meaning that stimulates the response: not a determined but a possible response because there can be many reactions to a stimulus and their efficacy can often only be assessed *a posteriori*. Every perception has a meaning, which however is not the resultant of the information received but rather the product of brain processing within an ecological domain by brain semiosis processes that enable interpretation of sensory signals by decoding them into symbolic representations compatible with our adaptive needs.

It is surprising to note the constant nature of brain operations in animals: deciding whether to move or stay still, approach or flee from something, taking the outcomes of similar past experiences into consideration. None of our perceptions have a univocal meaning because they are all carriers of overlapping meanings: white has a meaning, a white flag has an overlapping meaning and a white flag waved has a further superimposed meaning. Every perceptual experience is such, whether it concerns a physical object or an imaginary object: the image of a naked body can elicit a sexual stimulus equal to that of a naked body in the flesh, since in both circumstances the same brain areas are activated.[55]

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53. Cf. Edmund Husserl. *Ding und Raum. Vorlesungen 1907*, Hua 16, ed. Ulrich Claesges (Den Haag: M. Nijhoff, 1973).

54. Cf. Edmund Husserl, *Ideen zur einer reinen Phänomenologie und phänomenologischen Philosophie. Zweites Buch: Phänomenologische Untersuchungen zur Konstitution* [1913], Hua 4, ed. Walter Biemel (Den Haag: M. Nijhoff, 1952).

55. See Stephen M. Kosslyn, Giorgio Ganis, and William L. Thompson, "Neural Foundations of Imagery," *Nature Reviews Neuroscience* 2 (2001): 635-642, and Pearson,

During our perceptual experiences, automatic schemes form in the functional architecture of the brain, schemes that can determine what we think, assumptions that guide us in our daily activities. We sit on a stool because we believe it will hold our weight and not collapse; we take a step believing that the ground will not cave in under our feet, and so forth. In this way our brain is not forced to waste energy and cognition on continually analysing standard situations. Thus, the world projected on the screen of perception begins with the flow of information processed by our sensory organs, that impinges on the brain, spreading to cortical and non-cortical areas to activate a motor and/or perceptual response. In other terms, perception is an autonomous involuntary neural response. Our lives can also be considered a succession of innumerable sequential responses like those that make us move a knee tested with a doctor's rubber hammer.

All our perceptual experiences thus depend on active interpretation of sensory signals, i.e. on a generative act in which perceptual, cognitive, and socio-cultural expectations contribute to "the best hypothesis" of the brain about the causes of those signals: a widespread approach that gives priority to *top-down* processing, which enables us to go beyond unnecessary *bottom-up* computational work, saving energy resources, not only in the brain.[56] In any case, even if *top-down* predictions can be wrong, the system can correct the *bottom-up* prediction errors in an incessant process of error minimisation. The *bottom-up* information is supplied by computations implemented by our brain circuits and regulated by largely innate mechanisms that allow us to extract the salient elements of the images of the phenomenal world, such as outlines, intersections, the crossing of lines and junction points. These mechanisms are indispensable for distinguishing objects, individuals and faces, for identifying their position in space, for limiting the ambiguity of visual information and finally for representing very refined visual worlds of practical value. Thus, even babies recognise human faces from early life.[57]

Top-down processing of information depends above all on the low and intermediate levels of vision. The expression *top-down information* indicates the influence exercised by higher-order mental and cognitive functions such as attention, expectations and learned visual associations. Since bottom-up processing is unable to decipher all the uncertain information

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"The Human Imagination: The Cognitive Neuroscience of Visual Mental Imagery".

56. See Friston, "The Free-Energy Principle: A Unified Brain Theory?"; Hohwy, *The Predictive Mind*; Clark, *Surfing Uncertainty: Prediction, Action, and the Embodied*.

57. See Kandel, *Reductionism in Art and Brain Science: Bridging the two Cultures*.

received from the sensory organs, the brain must do *top-down* processing to resolve existing ambiguities. This involves apprehending the meaning of representations related to the state of things in the phenomenal world, by formulating and verifying hypotheses in light of previous experience[58].

When we have perceptual experience of a colour, our visual system responds to a small portion of the electromagnetic spectrum between low infra-red and high ultra-violet. We perceive a certain colour when the cones of the retina are activated in a certain proportion in the framework of a complex interaction between light reflected from a surface and the general illumination of the environment. In other terms, colour depends on inferences made by the brain on the way this interaction happens, and it is evident that colour is not an intrinsic property of the object itself, but an effective means exploited by the brain to recognise and memorise objects under certain light conditions.[59]

We can see a red cherry, but the cherry is not intrinsically red. Its redness depends on the way it reflects the light that the brain registers via its perceptual mechanisms. Thus "redness" is the ontologically subjective nature of this process: when I see a red cherry, the redness I experience depends as much on the cherry's properties as on those of my brain and corresponds to the content of a set of perceptual predictions on the ways a certain surface reflects light.

The aim of perception is to direct action and behaviour to favour the survival of living organisms. Our sensory organs thus evolved to perceive the phenomenal world not as it is in itself, but in a way that is useful for our species.[60]

Individuals can respond to an event in the world more rapidly and effectively if they consider it to objectively exist. It is therefore not surprising that a phenomenological property like colour appears to be an ontologically objective property of things.

But what happens when I no longer observe the red cherry? Does the red cherry still exist? An ontologically objective red cherry no longer exists; or rather, there is still something that can be called 'cherry' but *being a red cherry* is not a *mind-independent* property.

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58. Ibid.
59. See Webster, "Visual Adaptation," and Beau Lotto, *Deviate: The Science of Seeing Differently* (London: Weidenfeld & Nicolson, 2017).
60. See Zenon W. Pylyshyn, *Things and Places: How the Mind Connects with the World*. Cambridge, MA: The MIT Press, 2007.

It is a difficult problem for consciousness to explain how the physical matter of which neurons are made, the same as the matter of rocks, can determine a subjective experience. We know that Bohr, reflecting on the behaviour of electrons and photons, concluded that all quantum systems have a dual nature: they behave as waves and as particles.[61] In other words, all of matter shows an amphibious capacity: it can exist in two different states at the same time. According to the Principle of Complementarity, in a complementary system that has two simultaneous ways of being described, one cannot be reduced to the other since the system includes both at the same time. Seeing light as a particle or a wave depends on how we measure and observe it, not on its intrinsic nature (light and the measuring instrument belong to the same system).[62]

So, Bohr reformulated his conception of objectivity from what is exclusively intrinsic to a system of matter to what is inherent to the system-observer pair.

For example, if a tree in a forest falls, does it make a sound even if no animal is there to hear it? Is the existence of sound mind-independent? A tree falling certainly generates sound waves irrespective of the presence of an animal to hear it, and the eardrum is a measurement device that records it (sound waves and the eardrum are a system-observer pair). So, to explain these phenomena it is necessary to consider both subjective measurements and causal laws; the unity of the system is not in discussion.

Since we did not evolve to perceive reality as it really is, our experience of the phenomenal world does not match the deep structure of reality from a gnoseological viewpoint. Besides, our brain is not predisposed for this purpose, but evolved primarily to tackle the uncertainty and instability of the terrestrial environment. It is the physical result of perceptual automatisms as they formed through the process of natural selection and those of the culture we belong to, enabling our perceptions to report functionally adequate information on the phenomenal world. The sensory processes that permit perception do not allow direct access to the deep structure of reality, because it is not necessary for survival; indeed, it could be an obstacle.[63]

Rather, the "reality" reported by our perceptions is the meaning of the information received by the brain. This information does not have

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61. Cf. Bohr, *Atomic Physics and Human Knowledge*.
62. Cf. Heisenberg, *Physics and Philosophy*.
63. See Chris Frith, *Making Up the Mind. How the Brain Creates our Mental World* (Oxford: Balckwell, 2007).

meaning of its own, being energy or molecules, but must be interpreted and processed by different brain areas: we do not experience anything outside of ourselves except through the meaning attributed to it by our brain via the formulation of hypotheses regarding the causes of sensory signals.

Berkeley sustained that we do not perceive anything but our ideas and sensations: we do not see reality but what our brain selects from what interaction-space produces. However, he was wrong in sustaining that nothing could exist independently of the mind, since the world in its physical constitution exists independently of the experiencing subject. Underlining that different worlds do not exist but only different ways of referring to a single reality), albeit structured in very complex forms, we are nevertheless aware that reality is subject to continuous change that makes it instable, ephemeral and in constant transformation, a characteristic of living organisms. Organisms can only vary their thermodynamic equilibrium, i.e. their death, by extracting order from their environment and therefore reducing their own entropy and simultaneously increasing that outside themselves.

7. Representational realism

Common sense tells us that the world around us is real and solid, rich in objects, individuals, places with form, colour, consistency and so forth. Our sensory organs work in such a way as to give us direct access to this world by detecting physical objects and their properties and transmitting specific sensory signals to the brain where their processing generates perceptions. I look out the window and there seem to be many objects outside. I look at my desk full of objects that seem to have forms and colours; I perceive and can grasp them: perception, thought, action. It would therefore be reasonable to suppose that my sensory organs provide an objective report of a mind-independent phenomenal reality, and that perception is a simple processing of sensory signals from the phenomenal world.

In fact, we perceive the world without being aware of the activity and energy consumption involved, nor of the fact that we do not have epistemic access to reality itself. We can perceive physical objects, touch and handle them; we are aware of their existence but not of how perception of them happens. Everything we believe to be real and therefore “true” in our environment depends not only on what we detect with our sense organs but also on our previous experiences, so that perception of an object is determined by incoming sensory signals and by knowledge, culture, our emotional state. Perceiving a watch that was a gift from a friend is quite different from perceiving any watch.

As we have already seen, physical objects that at mesoscopic level appear to us continuous, definite, consistent, like a table for example, are nothing but a simulation, a process of reduction to an average, by virtue of which people simultaneously perceive the resultant of a great number of elementary processes. Thus, the law of large numbers obscures the authentic nature of the individual processes.[64] In other words, a table appears to us as a stable physical object, with definite borders and a smooth continuous surface, but from a microphysical viewpoint it is not. Therefore, the perceptual image of the table we observe is a symbolic representation, an icon elaborated by our brain to denote the effectively existing world: this is obviously not a limit of our visual system or evidence of its presumed deceptiveness, because in any case it transmits information allowing us to comfortably navigate our ecological domain.[65]

Besides, as we know, the fundamental function of the eye is to project light reflected by objects in the surroundings onto our retina. Clearly what the retina processes is not the perceived object, but light reflected by it. Even if the reflected light carried all possible information on the object, light and object would still be distinct. It follows that we do not see objects of the phenomenal world directly, nor the pattern of light projected on the retina. Thus, it is impossible to state that visual perception gives us direct access to the objects of the phenomenal world, independently of the perceiver.

There is therefore an apparently irremediable gap in the relation between the perceiver and the percept: while it is true that perception ensures that the subject links up with the phenomenal world, nevertheless the perceiver is denied access to the deep structure of things, their microphysical constitution, reality itself. Many philosophers have dwelt obstinately on this gap, declaring the deceptiveness of our sensory organs, and nullifying all realist options.

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64. Cf. John von Neumann, *Mathematical Foundations of Quantum Mechanics*, ed. Nicholas A. Wheeler and trans. Robert T. Beyer, Princeton: Princeton University Press, 2018 [1932].

65. See J. Kevin O'Regan and Alva Noë, "A Sensorimotor Account of Vision and Visual Consciousness," *Behavioral and Brain Sciences* 24 (2001): 939-973, and Nanay, *Between Perception and Action*.

The levels of reality to which we are party are many, as are the possible descriptions of the phenomenal world. For example, there is no doubt that from a microphysical viewpoint, chairs are not rigid, stable objects with clear outlines, even though our sensory organs perceive them as such. Chairs, however, are part of our lives as objects we exploit for their properties. This belongs to the current mode of being of chairs, and cannot be confuted by any physical theory, specific knowledge of which is irrelevant to how chairs present themselves to our sensory organs.

Regarding the apparent contrast between ordinary and scientific knowledge, Arthur Eddington sustained that we are surrounded by objects "in duplicate": e.g. we simultaneously have a "familiar table", that of daily experience, which has a certain size, colour, stability, outline, and a "scientific table", that described by physics, without definite limits, made almost entirely of space in which microscopic particles move in all directions.[66] In other words, physics contradicts ordinary perception of the world: what we touch and that seems to us stable and consistent has a completely different constitution.

The thesis of Eddington refers to the classical distinction between the world of common sense and that of the physical sciences, i.e. those that Wilfrid Sellars called *manifest and scientific images*.[67] The former are based on things of which we have direct experience (e.g. a tree) and on categories; the latter are based on the postulation of unperceivable things (e.g. electrons), linked to observable reality via experiments and measurements.

It is therefore difficult to share the position of Sellars, according to whom the representation of ordinary material objects of medium dimensions (manifest image) is simply false, albeit not without cognitive value. Indeed, the scientific image of the table belies the manifest image only in the case in which the latter is considered an objective representation of the table, which it evidently is not, just as the corresponding scientific image is not, since it only reports the microphysical properties of the

66. Cf. Arthur S. Eddington, *The Nature of the Physical World,* (Cambridge: Cambridge University Press, 1928): chap. 8.

67. Cf. Wilfrid Sellars, "Philosophy and the scientific image of man", in *Frontiers of Science and Philosophy*, ed. Robert G. Colodny (Pittsburgh: University of Pittsburgh Press, 1962), 35-78; ; Willem A. DeVries and Timm Triplett, *Knowledge, Mind, and the Given: Reading Wilfrid Sellars's "Empiricism and the Philosophy of Mind"* (Indianapolis: Hackett, 2000), chap. 6; James O'Shea, *Wilfrid Sellars: Naturalism with a Normative Turn* (Cambridge: Polity Press, 2007).

table, to which the functional and aesthetic (macrophysically) properties cannot be reduced.

Even if the *Weltanschauung* derived from ordinary knowledge contradicts that of scientific knowledge, the two images inevitable coexist almost peacefully, and in a certain sense one can even sustain that science depends on common sense, since it is true that if it provides us with a description of the structure of the world, it is still always perception that tells us what there is in the world.

Descriptions of the world derived from perceptual experience are important above all from the referential viewpoint: indeed, they effectively fulfil the function of "fixing the reference", even if they turn out to be false in attributive terms and inadequate in descriptive terms. It follows that manifest and scientific images share the same gnoseological reference. And it would be a blatant error to consider the manifest image to be a "false" image of the world, since it is an adequate representation of the state of the things it refers to: it is adequate because it meets people's daily requirements, allowing them to "know" and operate in their environment.

But is it possible to refer to the world in different ways? Certainly, because the two images do not depend on two different worlds but are different versions of the world that use different ontological categories to identify the reference of our narratives and descriptions of the world.

The thesis that there exists a single world of reference to which ordinary knowledge relates constitutes the foundation of what is commonly known as common-sense realism. A standard way of characterizing this form of realism is to claim that reality exists independently of our minds and of what we think and say about it.[68] However, the notion of "independence" is only approximate and imprecise, since thoughts and words are themselves part of reality. When our thoughts change, reality also changes, insofar as thoughts belong to reality.

The claim that realism entails that reality exists independently of our minds is therefore untenable. Rather, it is more reasonable to endorse a representationalist, non-correspondentist form of realism, which can be expressed as follows:

> 1. in their daily cognitive activities, individuals are in constant epistemic relationship with the world; 2. their activities are based on a nucleus of

68. See Michael Devitt, *Realism and Truth* (Princeton: Princeton University Press, 19912); Ronald N. Giere, *Scientific Perspectivism* (Chicago: University of Chicago Press, 2006); Michela Massimi, *Perspectival Realism* (Oxford: Oxford University Press, 2022).

beliefs – so-called common sense – that is largely tuned to the world, also because such beliefs and the cognitive capacities of each individual, arose through interaction with the world; 3. in physical structure, the world is independent of how individuals represent it and is therefore ontologically objective, except for levels of reality made up of, or causally influenced by, thoughts, theories and symbols; 4. epistemic access to the world or external reality is possible through mental representations.

From this viewpoint, realism makes it possible to have different opinions and perspectives of the world, though a subject's perspective does not determine "his" world. There is only one reality, even if each of us can elaborate his/her own representation of the world.

The world with which our perceptual activity is concerned is the world of objects and events in which we move, orientate and act, a world made up of concrete, tangible things that we come into contact with daily because it is in the sphere of our experience: our body, our desk, our books, things like trees, stones, columns and mirrors, the realness of which seems completely evident. The reality that we have epistemic access to abounds in objects that endure, that resist time, that survive technological and scientific progress like the Colosseum or the cathedral of Chartres. It is also a world full of medium-sized objects, not too big and not too small.

In any case, the world of reference is only one, whereas there are many ways of referring to the world. At this point it is legitimate to ask how ordinary knowledge can refer to the phenomenal world. Ordinary knowledge of the phenomenal world is influenced and, in some cases, even determined by the constitution of the world. Ordinary knowledge of the world and its epistemological structure (methods, languages, concepts, theories, etc.) are therefore determined not only by the cognitive structure of the subject but also by the physical structure of the world.

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