UNIVERSITAT ROVIRA I VIRGILI

INTENTIONALITY, MODULARITY AND TIME

Michele Gentile

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Intentionality, Modularity and Time

Doctoral Thesis

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HAGO CONSTAR que el presente trabajo, titulado "INTENTIONALITY, MODULARITY AND TIME", que presenta Michele Gentile para la obtención del título de Doctor, ha sido realizado bajo mi dirección en el Departamento de Psicología de esta universidad.

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El director de la tesis doctoral

José Eugenio García-Albea Ristol

"Omnia, Lucili, aliena sunt, tempus tantum nostrum est; in huius rei unius fugacis ac lubricae possessionem natura nos misit, ex qua expellit quicumque vult."

Lucius Annaeus Seneca – *Epistulae Morales ad Lucilium* – Liber I

Dedicato a mia madre, con l'amore di un figlio…

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PREFACE

While drafting my bachelor's thesis I remember being “fascinated” by the correlation between the principle of *entropy* (postulated in the second law of thermodynamics) and the idea of *temporal flow*. This link fascinated me and led me to pursue my interest in psychological time, as I realized that *time directedness* dictates the life of organisms, from their physiological functions to the higher and more complex biological and cognitive ones. I wrote that thesis more than twelve years ago and, since then, my interest in psychological time has not vanished. During the last few years I have been working on the topic from different perspectives, trying to develop the hypothesis that if a ‘sense’ of temporal flow is present at any stage of our life, then an ‘internal time’ system has to exist in our minds from birth.

In this dissertation I attempt to advance an account of psychological time in relation to an examination of two topics which are central to philosophical and psychological literature: *intentionality* and *modularity*. The concept of intentionality is most often associated with the theory proposed at the end of the nineteenth century by Franz Brentano, in which it is argued that all intentionality, and in particular the intentionality of linguistic expressions, is derived from the intentionality of mental states. Brentano regarded that kind of intentionality as a primitive, irreducible mental phenomenon. Then, intentionality is what divides the mental from the physical: no description or explanation of it can be given using the terms in which physical phenomena are described or explained. Brentano's thesis was discussed in the influential writings of the physicalist Quine, in terms of the possibility of finding a place for intentional idiom in the natural order. However, perhaps the most influential discussion of the intentional thesis is that offered by Jerry Fodor, whose work could indeed be described as a sustained effort to provide the sort of examination of intentional idiom that Brentano and Quine argued was not possible. Fodor's theory of intentionality can be seen as composed of two parts. First, he proposed a theory of propositional attitudes, in which they are interpreted as attitudes towards sentences of a 'language of thought'. More recently, Fodor developed a theory of the content, or meaning, of the expressions that figure in mental language; the nature of Fodor's theory of content is determined by the implications of his theory of propositional attitudes. On the other hand, the concept of modularity is referred to in Fodor's theory of modularity of mind. The theory of modularity of mind has important theoretical and methodological implications for the study of mental architecture. There is a sense in which the theory of modularity of mind can be seen as linking Fodor's previous positions, insofar as it shares the functional level of psychological explanation,[1] endorses the perspective of intentional realism of propositional attitudes,[2] and maintains the characterization of the cognitive systems in symbolic and computational terms.[3] A principal aim of this theory was to explore the problem of intentionality (understood as the basic property of the mental) and computation from a perspective that establishes

[1] Fodor: 1968.

[2] Fodor: 1981.

[3] Fodor: 1975.

the limitations of the different components that compose the mental architecture. Whereas, a second aim was to lay the foundations for the development of alternative experimental methodologies in psychology on the basis of data and results obtained in other important research fields, such as neuroscience. Regarding the second aim, from its first appearance the theory of modularity of mind was destined to challenge views on the fundamental features of our mental architecture, since it posited a sharp distinction between modular systems and the central system. This distinction had important theoretical and epistemological implications not only for the methodology used in psychology, but also for scientific methodology in general. Therefore, the central tenet of Fodor's modularity theory is that human mental architecture is heterogeneous, since it is composed of two distinct kinds of components - modular and non-modular - which both process information via representations. Concerning the question of how such information is processed through representations, Fodor thinks that the classic framework of computational processing does not offer an adequate explanation for the functioning of non-modular systems. As García-Albea[4] has pointed out, despite the fact that the two aims of the modularity thesis are driven by different motivations and represent different questions (the former is laid out as a philosophical argumentation of the problem of intentionality, while the latter is presented as an empirical question subject to the judgment of psychological investigation), they often converge in the integrative theory of mind proposed by Fodor.

Therefore, my thesis is committed to examining the general concepts of intentionality and modularity in order to then advance an account of experienced time. Essentially, this thesis adopts the following argumentative structure. The first part is concerned with a general introduction to the theory of intentionality in light of the cognitive revolution and the consequent rise of functionalism and cognitive psychology. The positions advanced in these two fields of study are embedded within a common theory of mind, which will be examined in detail with regards to the project of naturalizing the intentionality of mental states. After this, I focus on two general issues tied to the problem of intentionality: *mental representation* and *mental causation*, and attempt to set out the theoretical and conceptual groundwork for the perspectives and theories that apply to these issues. In concluding the first part of this thesis, I allude to the link between the concepts of intentionality and modularity, which introduces the topic for the second part of the thesis. The second part attempts to build on Fodor's modularity thesis in order to take further steps towards a general account of mental architecture for time processing. After examining Fodor's modularity thesis, I describe different ways in which it applies to the study of perception in general. Then, I turn to the discussion of time perception, taking up the object of enquiry in relation to recent debates in experimental psychology and cognitive neuroscience. At this stage, I focus on two general issues concerning, respectively, the questions of *how* and *where* time is processed in the brain. I thus suggest adopting a general account of time perception based on the framework of modularity theory in order to capture what scientific theories in psychology, neuroscience, and philosophy have in common. I connect these psychological and scientific theories to the hypothesis that the mind includes a module for time processing. In particular, the theories of Paul Fraisse and other psychologists will be considered in order to discover the manner in which the time module is likely to work. After this, I describe the working of time processing within an integrative and larger

[4] Garcia-Albea: 2003.

cognitive architecture, arguing that the proposed mental architecture for time processing captures the typical properties of modular organizations. The plausibility of a module for temporal processing rests essentially on the analysis of timing-related deficits in neurologically impaired individuals, and to support my hypothesis I report empirical evidence from psychological and neuroscientific research. Finally, I conclude with some observations about the interrelationship between time perception and spatial perception, which may be examined in future studies. Although temporal perception might effectively facilitate the perceptual processing of the spatio-sensory world around us, on the other hand, the representation of time in the conceptual system is often accomplished by spatial correlates, as findings in linguistics demonstrate. Despite the fact that our experiences of time and space are distinct and distinguishable at perceptual and neurological level, it seems that at the representational level, time processing and spatial processing stand in an asymmetrical relation to each other. This suggests that there is an asymmetrical dependence between time and space at the perceptual and representational levels.

Therefore, the scope of this thesis is to provide an explanation of psychological time which adheres to the concept of modularity of cognitive functions as formulated by Fodor. This account seeks to demonstrate that our ‘sense’ of time (and the related ability to manage time information) is the cognitive result of a series of processes carried out by two independent and neutrally isolable processing components which are part of the portion of mental architecture dedicated to modular systems. These sub-systems can themselves be referred to as modules, as each has the potential to specialize in time processing. Using the reference of 'module' for the notion of *specious present* my argument proceeds to arrange time processing into a hierarchy, in order to represent time information from the early stages of perception to higher stages of cognition, and drafts a functional architecture in which delimitations between different processing methods are organised according to principles which have their basis in Fodor's modularity thesis. If such a hypothesis is correct, it could offer useful guidelines for exploring timing ability in humans, and provide a plausible framework for future investigation of the psychological and neuronal mechanisms responsible for time processing.

PART I

Intentionality

1

Introduction: Intentionality from Philosophy to Psychology

1. 1 The concept of Intentionality

Reflection on intentionality has a long history, not all of which is relevant to our concerns in this discussion. In the first part of my dissertation I want to introduce the issue by giving an overview of the conceptual scenario that laid the foundations for scientific psychology, explaining how the question of the intentionality of mental states and mental processes began determinant to the current development of philosophical theories of mind and psychological research.

Linguistically, the term *intentionality* is bounded up with the Latin noun ‘intentio’, which derives from the verb *intendere*, which literally means *to stretch*. The verb ‘intendere’ must be taken in the figurative sense of stretching one’s mind (or *aiming* one’s mind) at some object in thought (which is before the mind). From this point of view, *intentio* indicates the object of a state of mind, while intentionality reflects the basic idea that the mind is directed upon its ‘mental’ objects. In the last two centuries the issue of intentionality has been central to social cognition; it has been fundamental to the understanding of how people develop their ‘folk’ theory of mind. Psychologists and philosophers have often agreed that intentionality provides the conceptual groundwork for *folk psychology*. As we shall see, the term folk psychology indicates the cognitive apparatus engaged with connecting people’s behaviour to the mind in virtue of the functional role played by intentional states. Folk psychology is sometimes defined in terms of the body of ‘tacit knowledge’ (which is supposed to be structured into people’s perception of behaviour from infancy) to which people return to explain and predict behaviour. Before examining the fundamental aspects of intentionality tied to behaviour, I want to allude to the origins of the concept ‘intentionality’ in philosophical reflections.

Historically, reflection on the concept of intentionality originates from Aristotelian and medieval philosophy. Following Aristotle, the Scholastic philosophers of the Middle Ages were interested in the logical structure of concepts. They used the noun *intentio* in the technical sense of ‘concept’ or ‘notion’, remarking on the fundamental distinction between *prima intentio* and *secunda intentio*. The *prima intentio* is understood in terms of a concept that applies to particular objects, whereas the *secunda intentio* in terms of a concept that applies to the prima intention. Then, for the Scholastics, the term intention was applied to either logical items or psychological items. In its logical sense, *intentio* is the abstract entity that exists between logical relations; conversely, from a psychological point of view it is a component of states of mind. Whether *intentio* is intended in its logical or psychological sense, it is nevertheless something that might exist in our mind but not in the external world. This is a central idea of the Scholastic theory of intentionality: the Scholastics held that concepts are true of things, or properties, lying both outside and inside the mind. Most famously, St. Thomas Aquinas pointed out this fundamental feature of abstract objects. In particular, Aquinas (who was more interested in the psychological aspect of concepts than the abstract logical relations they hold with each other) developed his theory of intentionality on the basis of Aristotle's famous doctrine of sense-perception. According to the Aristotelian doctrine, the mind takes on the form of its perceived objects. This means that the environment has a continuous impact on people's perception, so that when people interact with their environment this interaction is instantiated into their mind. Central to Aristotelian philosophy is the assumption that the mind has no innate categories through which it organizes the information that comes from external reality. This idea was developed into an account of thinking in general by Aquinas, who argued that every set of sensorial stimuli arising from our perception of reality causes mental images in the "imagination". Aquinas defined mental images in terms of phantasma, which are unique and ephemeral as any sensorial impact. Note that this view does not take perception as the passive result of the impact of external objects (or events) on our senses. In Aquinas' view, perception plays an active role in our cognitive processes, because it is the active pre-condition for the occurrence of mental images in the mind. Since every mental image is oriented toward a mental object that is first in the mind, intentionality can be considered the fundamental feature of mental images. However, after the Middle Ages, most of the terms which derived from Aristotelian and Scholastic terminology, including the term 'intentio', were disowned. Then, with the rise of Cartesian philosophy in the Renaissance, philosophers shifted their focus from perception to reasoning.

1. 2 Cartesian Dualism and the Mind-Body Problem

Descartes is one of the most important intellectual figures of all time; he is considered the father of modern philosophy. Not only do his *Meditations* represents a milestone in the history of Western philosophy but his work also played a key role in the scientific revolution of the seventeenth century. It is well-known that Descartes endorsed the Platonic view that the world is structured in mathematical terms. Following Plato, Descartes developed a philosophical system based on the fundamental principles of algebra and geometry; consequently, he refused to accept Scholastic and Aristotelian physics and suggested replacing them with causal explanations based on mechanistic models. Descartes proposed one of the most influential philosophical perspectives of all time, so-called *Cartesian dualism*, but this perspective gives rise to an important problem concerning the causal relationship between mental and physical: the *mind-body problem*. I will introduce the problem below.

The philosophical system developed by Descartes has strong intuitive appeal since it endorses the basic idea that the universe is composed of two fundamental and opposite types of substances: physical substances (which are extended and non-thinking things) and mental substances (which are thinking and non-extended things). Descartes (and philosophers in general) used the term 'substance' to denote a thing that does not require any creature in order to exist (something that exists with only the help of God's concurrence), whereas, the term *mode* refers to a 'quality' or affection of that substance. Qualities like 'size' or 'shape' are modes of physical and extended objects as they are shared by every object belonging to this three-dimensional universe. In contrast, no mental substance has shape or size; and this is because a mind or a thought is supposed to be a non-extended thing which is purely spiritual in nature and radically non-spatial. According to Descartes, the mind is wholly distinct from the body that engages it or from physical objects of any sort: it is something with no proper place and space (so we might easily imagine it existing disembodied or in the absence of any physical world whatsoever). On this view, every person can be thought of in terms of a 'duality', that is, in terms of a pair of one mind, the *subject*, and one body, the *object*. These two kinds of substances are ontologically independent, in the sense that they do not require each other in order to exist (Descartes called the distinction between two or more substances "real distinction"). So *thinking* and *consciousness* represent the essence of mental substances, whereas *space* and *extension* represent the essence of physical substances. Descartes introduced his perspective of Cartesian dualism in his *Sixth Meditation*, where he argues that from the inside our minds do not feel physical at all. Although this idea might be seen as very compelling, it involves the problem of the interaction between mental and physical substances. Problems with Cartesian dualism arise as Descartes infers that ontologically distinct and independent substances can causally interact with each other. For example, we can think of our mind as causing the movement of our bodily limbs, and we also take external objects or bodily happenings to cause thoughts and sensations connected to experiences into our minds. But, if such interaction occurs, it does so in a three-dimensional universe. How then could mental states/events cause physical states/events in the brain or in the body? Descartes tried to solve the mind-body problem by suggesting that spiritual and material substances are ontologically distinct entities that can exist separately, despite being joined in a substantial union. Each mind is a separate entity of the same kind, whereas there is just one extended substance of the second kind, that is *matter*. Therefore, the solution suggested by Descartes is that the mind is metaphysically, but not physically, placed in the body's driving seat.

Thus far I have introduced the problem of the relationship between the mental and physical, but I have not said how it is related to the issue of intentionality. It must be recalled that Descartes did not make reference to the concept of intentionality, because his philosophical system was clearly opposed to both Aristotelian and Scholastic philosophy. First of all, the idea of Cartesian dualism did not integrate the fundamental Aristotelian dichotomy between the living and the non-living. According to Descartes, the mind can survive the destruction of the material body that engages it, thus, it can exist disembodied or in absence of physical reality (this entails that mental substances are indestructible, indivisible and eternal). In Descartes' view, the dichotomy between the living and the non-living was transcended by the even more fundamental dichotomy between those things that have a mind and those that do not. In fact, one of the chief goals of the *Meditations* was to define what it is to have a mind and what kind of relation the mind has with bodily or physical reality. In assuming that a 'substance' is a unified entity with properties (such as attributes, characteristics and qualities which belong to and inhere within it), which is wholly present at each moment of its existence and persists through changes in its properties (whereas particular 'things' that are not substances but 'events' consist of changes to other things), Descartes inferred that a mind is capable of independent existence only if it is independent of all other minds and bodies (this view was challenged by Spinoza who took dependence on God to its logical conclusion regarding the existence of only one sort of substance, both numerically and in kind, to exclude the possibility of a world where minds and bodies can exist separately). From this point of view, Cartesian dualism is nothing more than *substance dualism*. Conversely, the 'substance' dichotomy between the mind and the body was not considered by the Scholastic philosophers, who were only interested in the Aristotelian dichotomy between living and non-living.

A second aspect of Descartes' rejection of Aristotelian and Scholastic philosophy concerns his denial of the Aristotelian view that the mind takes on the form of its perceived objects. Following Aristotle, Aquinas had argued that this very thing -the occurrence of the form of an object- is what permits a thought to be a thought of an object and that object to be the object it is. For example, what makes a 'goat' a goat is the form of the goat, and that is what makes your thought of a goat a thought of a goat. From this, Aquinas concluded that there are different instantiations of the form *esse naturale*, namely, the 'thing', and *esse intentionale*, that is, the thought of such a 'thing'. But this view was attacked by Descartes in his *Third Meditation*, where he argued that the cause must have as much reality as its effect. For Descartes, we must distinguish the *formal reality* of the cause of an idea from the *objective reality* of that the idea. While the 'formal' reality is just reality, the 'objective' reality is confusingly the content of an idea but considered as if it were the idea itself, and this is the case of intentionality. With the affirmation of Cartesian dualism, philosophers abandoned the concept of intentionality along with Aristotelian and Scholastic philosophy. Leibniz replaced the term *intention* with the more general terms *intension* and *extension* (this logical distinction was later endorsed by proponents of Port Royal Logic, who distinguished between the *extension* of a term (the class to which that term applies), and the *comprehension* of a term (one's understanding of that term). Those logical philosophers maintained the logical term 'intension', assuming that this has fewer degrees of reality than the psychological the term 'intention'). Only at the end of the nineteenth century did the issue of intentionality come to the fore in light of the work of the psychologist Franz Brentano. However, Brentano's account of intentionality endorsed the view of substance dualism, and it therefore involved the mind-body problem.

1. 3 Brentano's account of Intentionality

At the end of the nineteenth century the psychologist and philosopher Franz Brentano tried to lay the foundations of the new science of psychology. On Brentano's view, if the 'body' is the subject-matter of physiology, and philosophy is engaged with metaphysical questions about the immortality of the soul, psychology is the study of mental phenomena. Brentano had the merit of rehabilitating the Scholastic term of intentionality in modern times, even if he maintained the classic Cartesian dichotomy between the mental and the physical. His account of intentionality endorses the kind of substantial dualism postulated by Descartes. Like Descartes, Brentano believed that mental and physical substances do indeed interact with one other, and thus that 'subject' and 'object' are distinct entities that bear causal relations between physical objects and mental phenomena. In his lecture *Psychology from an Empirical Standpoint*[5] he aimed to explore the characteristic features of mental phenomena that allow us to bear relations between mental acts and the external world. Brentano followed Aquinas' theory of intentionality, assuming that intentionality is the distinguishing mark of mental phenomena because no physical substance can exhibit it. How did he reach this conclusion?

Following the Scholastic philosophers, Brentano asserted that every intentional state is directed at the intentional object it is about (e.g. the 'believed' for a belief). The property of being directed

[5] Brentano: 1879.

upon something (either an individual or a state of affairs) would be an exclusive peculiarity of mental phenomena because physical phenomena do not generate *original intentionality*, that is, an intentional relationship defined in a first-hand manner:

> "(it) is characteristic exclusively of mental phenomena, since no physical phenomenon manifests anything like it."

The view that all mental phenomena are intentional phenomena is known as *intentionalism*. In defending this view Brentano said that all intentional phenomena share the following distinctive features: relation to a concept, direction upon an object and immanent objectivity. However, the most distinctive characteristic of intentionality is its so-called *intentional in-existence*. This term was used by the Scholastic philosophers to indicate the ontological status of indifference to the reality of the content of intentional states. Brentano argued that the object of an intentional state does need to apply to reality, since it might exist in that state of mind but not necessarily in the physical world:

> "every mental phenomenon is characterized by what the Scholastics of the Middle Ages called the intentional (or mental) in existence of an object, and what we might call, though not wholly unambiguously, reference to a content, direction towards an object (which is not to be understood here as meaning a thing), or immanent objectivity. Every mental phenomenon includes something as object within itself, although they do not all do so in the same way. In presentation something is presented, in judgement something is affirmed or denied, in love loved, in hate hated, in desire desired and so on. This intentional in-existence is characteristic exclusively of mental phenomena. No physical phenomenon exhibits anything like it. We could, therefore, define mental phenomena by saying that they are those phenomena which contain an object intentionally within themselves."[6]

Then, we can summarise Brentano's theory of intentionality as follows:

1. it is constitutive of the phenomenon of intentionality that mental states are directed upon things different from themselves;

2. it is characteristic of the objects upon which the mind is directed by virtue of intentionality to exist either in reality or in a state of mind;

3. as all and only mental states exhibit intentionality, the phenomenon of intentionality is then the mark of the mental.

Note that the first and the second statements can hardly be divorced, given that the intentional object in virtue of which one can exemplify the mental activity of thinking, desiring or believing is not required to actually exist or be obtained. The third statement establishes that everything that is 'mental' is equally intentional and, consequently, that intentionality unifies all mental phenomena. If taken together the statements above form the following argument:

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[6] Brentano: 1879, pp. 88-89.

- A) the reality-neutral feature of intentionality makes it the distinguishing mark of the mental, in that all and only mental phenomena are intentional in this sense;
- B) purely physical states and events cannot have intentional properties.

Now, theses A) and B) together imply Cartesian dualism, even if each thesis is controversial in its own right. Thesis A) is controversial in the respect that it takes only mental states and events to exhibit intentionality, despite there being things other than mental states that 'aim at' possibly non-existent objects. Linguistic items, such as the name *Santa Claus*, may be an example of this. On the other hand, thesis B) entails that purely physical phenomena do not exhibit intentionality, but this claim is controversial if we consider the case of human digestion or that of plants' disposition to move towards the source of light. How could we deny that these natural phenomena generate a form of goal-directed behaviour? Some might dismiss this objection by asserting that, although there are physical phenomena that exhibit some degree of intentionality, we should distinguish *original intentionality* from *derived intentionality*. The intentionality present in those natural processes is merely *derived* intentionality: it is derived from the thoughts of those who observe and explain those phenomena. Whereas, our minds have *original* intentionality, in that their intentionality does not depend on, or derive from, the intentionality of anything else. In other words, the plant's movement towards the light source does not intrinsically have intentionality, but only has it because this behaviour is interpreted by the observed. However, the interpretations provided by the states of mind of the observer do have intrinsic intentionality. Philosophers sometimes mark the distinction between minds and physical objects in this respect by talking about 'original' and 'derived' intentionality, but this seems to suggest that if something exhibits intentionality, then it is, or has, a mind. So, is mentality necessary for intentionality? This question is very tricky. One problem is that if we were to encounter something that exhibited original intentionality, it is hard to see how it could be a further question as to whether that thing had a mind. The difficulty with this line of thought is that, if it is false that something can have original intentionality without having a mind (that is, if only minds, as we know them, can exhibit original intentionality), then we encounter the same kind of problem as we found with Cartesian dualism. In particular, it is the second part of Brentano's thesis, that mentality is a necessary condition of intentionality, which brings us back to the mind-body problem, because this claim involves the Cartesian dichotomy between beings with a mind and beings without a mind.

1. 4 After Brentano: Intentionality, Representation and Understanding of Minds

Brentano's thesis that all and only mental phenomena exhibit intentionality has been very influential in recent philosophy and cognitive sciences. To summarise the question of intentionality, let us reformulate Brentano's argument by dividing it into two sub-questions:

1. Do all mental states exhibit intentionality?
2. Do only mental states exhibit intentionality?

The first sub-question may be recast as so: is mentality sufficient for intentionality? And the second: is mentality necessary for intentionality? In Brentano's view, to say that all mental states exhibit intentionality is to say that all mental states are representational; and to say that minds are the only things in the world that have intentionality is to say that only minds generate representations. Hence, the main implication of Brentano's thesis concerns the 'representational character' of intentionality. The idea of a state which represents the world and causes its possessor to behave in a certain way, entails that interpretation is necessary for representation or intentionality. The question of interpretation brings the nature of mental representation into focus: how do we know about the mind? The most plausible answer to this question is that people apply conjectures about people's minds in order to explain their behaviour. According to *folk psychology*, our understanding of why other thinkers do what they do is derived from knowledge of their observable behaviour. This is the reason why philosophers often say that the purpose of folk-psychology is the explanation of behaviour, in the sense that people explain other minds by attributing mental states to make sense of their behaviour.

However, still in the first half of the twentieth century, behaviourists in psychology and materialists in philosophy rejected the idea that people have intentional states. Behaviourism made the question of how we know our own minds very problematic, because it considered the knowledge of our own minds in terms of observation of our behaviour. The behaviourist denied that there is anything psychological lying behind behaviour and was not interested in the psychological facts that organize and underlie the behaviour. Even if he could accept, just as a basic fact, that certain interpretations of behaviour are more natural to us than others, the behaviourist would reject the description of how people's thoughts lead to their behaviour. This aspect of behaviourism ran parallel with its deliberate disregard of subjective, conscious experience and what it is like, from the inside, to have a mind. Conversely, the cognitive revolution inspired a new point of view of human agents, splitting off from the picture that they respond 'reflexively' to their environment. By the 1960s, the idea that we describe the assumptions and hypotheses we adopt when understanding other minds as a sort of theory of mind, known as folk psychology, became customary among philosophers of mind and cognitive psychologists. Those philosophers and psychologists subscribed to the view that intentionality is at bottom *mental representation* (and thus that mental states and propositional attitudes really possess Brentano's feature), although they had strong motives for rejecting Brentano's thesis B. Their chief aim was to offer a coherent theory of intentionality able to explain how humans take in information via the senses and, in the very process of understanding, make subsequent use of it to guide their behaviour. This project laid the groundwork for computational theories of mind, which are engaged with the very general notion of mental representation and the functional role a representation plays in containing information about the world, and combining to guide people's behaviour The focus on *functional organization* brought with it the possibility of multiple realizations: the general idea that irreducible mental kinds like properties, states or events, can be functionally realized or instantiated by distinct physical kinds (Putnam[7], Fodor[8], and Block[9]). According to the functionalist, all that is essential to mental states is the role they play within a system.

[7] Putnam: 1967.

[8] Fodor: 1968.

[9] Block and Fodor: 1972.

Hence, after the cognitive revolution, the question of intentionality became the question of finding a way to explain how a purely physical system - either a brain or a computer - can have functional intentional states which processes appropriate information about external entities, events and matters of fact; and how such a system can interpret that information. In the next chapter, I will give an overview of the cognitive revolution by examining recent debates in philosophy and psychology regarding the concepts of mental representation, computation, and nativism. After introducing functionalism, I will report the principal affinities of this philosophical theory with cognitive psychology, and then focus on two underlying commitments of functionalism: folk psychology and physicalism. After this, computational theories of mind will be discussed. In particular, here I focus on the project to vindicate the truth of folk psychology and maintain the physicalist ontology. Successively, I will stress the two most thoroughly canvassed problems tied to intentionality: the problem of *mental representation* (the general problem of how the mind obtains a mental representation) and the problem of *mental causation* (the problem of determining the nature of content of mental representations). Here I will outline some of the most influential attempts to overcome the effects of these philosophical problems. Finally, I will conclude this first section by highlighting the relationship between the issues of intentionality and *modularity,* which introduces the topic of the next section.

2

Toward the cognitive approach

2. 1 From Academic Psychology to Cognitive Psychology

The foundation of psychology as a separate field of study is traditionally associated with the development of its own methods and questions. Although psychology is a separate science from philosophy it was built upon philosophical foundations. Like many other sciences, psychology had its origins in philosophy, and much work in the psychological field still explicitly positions itself in relation to claims made by philosophers. To a great extent modern psychology originated in the reflections offered by Descartes and his work on mental-physical interaction and the first-person perspective, which laid the ground for real scientific progress in the experimental research carried out by those that followed him. Concerning mental-physical interaction, it is important to remember that Descartes was not the first to talk about this subject (the philosophical distinction between mind and body can be traced back to the ancient Greeks); nevertheless, he revisited this problem in a completely new way that profoundly affected psychological history and caught the attention of other thinkers. In principle, Cartesian dualism[10] can be summed up in the following claims:

- one's own mind can be better known than one's body,
- the mind is metaphysically in the body's driving seat,
- there is a theoretical problem: how do minded individuals know that "external" and everyday objects exist at all?

In addition to the claim that the body can influence the mind and the mind can affect the body, Descartes made the claim that consciousness is innate. His *Second Meditations* were conduced to show how anyone can intuitively grasp the truth of the claim "I exist". Here Descartes attempts to reach that truth by recurring to the *first-person perspective*, that is, the view that human subjects are immured within the movie theatre of their mind, although they can infer what goes on outside it. From the view of ourselves from the inside, Descartes tried to meditate and establish absolutely certainty through the famous reasoning "cogito, ergo sum". But, how did he reach the conclusion *I think, therefore I am*? Though in the *First Meditations* Descartes had doubts about all sensory beliefs, in the *Second Meditation* such beliefs are now considered false. Descartes started his argument by considering the falsehood of the belief "'I' do not exist". Suppose I have to convince myself that all my beliefs are false, including the belief "'I' have a body endowed with sense organs". Although I convince myself that my beliefs are false, there is still an 'I' to convince. But even if an evil demon had deceived me to believe this there is an 'I' to deceive. According to Descartes, the mere fact that I am thinking, regardless of whether or not what I am thinking is true

[10] Descartes: *Meditations*.

or false, entails that there must be a thinking individual, namely the 'I', who is engaged in such mental activity. Consequently, whatever the case we hold the proposition 'I' results ontologically necessary:

> "I must finally conclude that the proposition, 'I am,' 'I exist,' is necessarily true whenever it is put forward by me or conceived in my mind (AT VII 25: CSM II 16-17)."

From these considerations Descartes concluded that, the claim 'I exist' is an indubitable and absolutely certain belief that serves as an axiom from which stem other and absolutely certain truths, and that it can be deduced exclusively from the first-person perspective (that is, the view that from the inside of our minds we are immured despite having some defensible ways of inferring what goes on outside them).

Starting from the perspective of Cartesian dualism and the thesis of the innateness of consciousness, Descartes laid the foundations for early scientific psychology. But, going beyond ideas of how consciousness and the interaction of mind and body really function, it was due to the scientific works of psychologists such as Ernst Heinrich Weber, Gustav Theodor Fechner, Wilhelm Wundt and William James that psychology developed its own methods and experimental research. From the second half of the nineteenth century psychologists began to conduct experiments designed to test conscious experiences. If Weber can be considered the pioneering sensory physiologist, and Fechner the father of psychophysics, Wundt is instead the father of experimental psychology. It is important to remember that Fechner paved the way for Wundt and experimental psychology by demonstrating how to measure and carry out experiments on psychological processes (even if Heidelberg[11] has argued that Wundt himself came to realize that experimental psychology does not have its origins in the narrow method of psychophysics, but rather in the broader interests of sensory physiology). Wundt and the other experimental psychologists used the method of introspection, which mainly relied on subjective observation of one's own experience. This method aimed to analyse individual sensory experiences through the self-observation of conscious experiences, looking inward at pieces of information passing through consciousness.

Nonetheless, by the second decade of the twentieth century scientific psychology had dismissed the introspection method, as well as its interest in conscious experiences. In the same period in which behaviourism dominated the scenario in scientific psychology, the debate in philosophy of mind witnessed the dispute between two general and opposite approaches: dualism and materialism. If the dualistic approach considers the mind a non-physical substance, conversely, the materialistic approach takes the mental as not distinct from the physical, and assumes that all mental events, states and processes are in principle identical with physical events, states and processes. The materialistic view is fully consistent with the principles of Newtonian mechanics but stands in sharp contrast to the principles of Cartesian metaphysics. As a result of the affirmation of materialism in the philosophy of the early twentieth century, Cartesian dualism and the first-person perspective gradually fell into disrepute. The appearance of the *verification theory of meaning* convinced philosophers to abandon the first-person perspective in favour of an inter-subjective verification criterion, according to which science must adopt an inter-subjective third-person perspective on

[11] Heidelberg: 2004, p. 233.

everything observed. According to the inter-subjective third-person perspective, one can imagine being oneself the subject of certain mental states, in a case in which certain other things are true, and ask what this shows about the relation of body to mind. This criterion entails that the meaning of a sentence is just the method of its verification, therefore mental ascriptions should be scientifically and meaningfully describable in terms of physically testable verification conditions. On the other hand, behaviourists followed materialists as they argued that all talk of mental causes should be eliminated from the language of psychology in favour of environmental stimuli and behavioural responses. Conversely, other materialists called type-identity theorists contended that there are mental causes which are identical with neurophysiological events in the brain. These type-identity theorists also subscribed to the doctrine of physicalism, which mainly transfers the success of naturalism in science to social sciences such as philosophy and psychology.

With the rise of physicalism in the mid-twentieth century, philosophers of mind took a deeper 'naturalistic' turn. Before the advent of this philosophical doctrine, philosophy and science were seen as two opposite descriptions of reality (and not as a 'continuum' of the same description). Philosophy dealt exclusively with mere ontological and conceptual issues, but over the previous five decades most of the prominent attempts to solve the traditional philosophical issues had been integrated with the scientifically evaluable evidence of the natural sciences. Throughout the second half of the twentieth century, philosophers of mind continued to make connections with developmental psychology, carrying out a considerable number of pressing theoretical and scientific researches. Not only has twentieth century philosophy of mind explored the empirical side of developmental psychology in extended ways, but the works of philosophers of mind have had a great impact on developmental psychology. The scientific framework within which psychology and philosophy of mind have operated in the past fifty years was characterized by the results achieved through the theory of mind known as *functionalism*. Functionalism, which is neither a dualist nor a materialist approach, emerged from philosophical reflection on the developments that emerged from cognitive sciences: the interdisciplinary area in which different fields of study, such as artificial intelligence, cybernetics, linguistics, psychology and computational theory, converge. Each of these fields is committed to the cognitive approach for the investigation of the mind and cognition, having in common a certain level of abstraction and a concern with systems that process information. Functionalism provided a philosophical account of this level of abstraction, admitting the logical possibility that systems as diverse as human beings (including intelligent/programmed machines and disembodied spirits) can all have mental states. According to this viewpoint, the psychology of a system depends not on what it is made of but on how it is put together. The functionalist insists on arguing that scientific psychology must seek to build a theory of mind capable of resolving the traditional philosophical issues, such as the mind-body problem, the nature of intentional states and whether or not we have innate knowledge. Much of the work in this theory of mind draws upon the observations made by thinkers like Searle, Dretske and Fodor, according to whom scientific psychology needs a naturalized theory able to account for the intentionality of mental states and mental processes.

I earlier concluded chapter 1 by alluding to the implications of Brentano's thesis, according to which intentionality alone marks out the subject matter of psychology (and thus, that intentionality is the exclusive characteristic of mental phenomena). I said that, despite Brentano's revival of intentional terminology and placement of the concept of intentionality once again at the centre of philosophy and psychology, he did not solve the problem of mental-physical interaction (for example, his approach did not explain how mental phenomena can causally interact with physical ones). However, Brentano's theory of intentionality has been taken as a starting-point in contemporary psychological and philosophical reflection. Many theorists (especially those influenced by cognitive sciences) concur with Fodor that intentionality is at bottom mental representation, and that propositional attitudes really do have Brentano's feature. Fodor believes that internal physical states and events realize mental states; in turn, mental states represent actual or possible states of affairs whose existent or non-existent intentional objects are representational contents akin to the meanings of sentences. For Fodor, the brain contains a whole representational system through which people understand the external world; in this way he tried to give a coherent explanation of how mental properties, along with more familiar special science properties, are constituted by physical properties. Before examining the solution to the mind-body problem that he suggested, I first want to talk about the scientific and conceptual developments that led to the cognitive revolution of the mid-twentieth century.

2. 2 The dominance of Behaviourism in Scientific Psychology

In the early years of the twentieth century experimental psychology witnessed the affirmation of an emerging doctrine called *behaviourism*. Behaviourism had a great impact on the development of psychology as a rigorous science grounded in empirical evidence, and it was thus destined to dominate academic debate throughout the English-speaking world during the early to mid-twentieth century. To a large extent, behaviourism endorsed the principles of materialism, as both rejected either Cartesian dualism or Brentano's account of intentionality. The behaviourist dispensed with immaterial Cartesian egos, ghostly non-physical events and every metaphysical excrescence (such, as thoughts and beliefs) which makes no reference to physical reality. He eschews the mentalist notions of intentionality and mental states, and refuses to accept every psychological theory which make reference of unobservable phenomena that cannot be settled by observable data over behaviour. According to the behaviourist, there is nothing more to behaviour, nothing internal to the mind but simply 'observable' data over behaviour expressing physical events. All mental states are thereby reduced to behavioural states, which bear causal relations between stimuli and response, whereas the psychological practices of explaining and predicting behaviour are seen in terms of controlling stimuli and rewarding appropriate responses to them. On this view, whatever psychology that postulates immaterial and non-spatial causes of physical behaviour has to be dismissed since it has no explanatory import, nor legitimate role in explanation, prediction or control of directly observable behaviour. What is more, the methodology proposed by the behaviourist completely differs from that used by Wundt.

To describe the dominance of behaviourism in the scientific psychology of the first half of the twentieth century it is useful to distinguish between two distinct phases. Behaviourism was founded by the psychologist John Watson, but it came to fruition in the research carried out by the psychologist Skinner in the middle of the twentieth century. Here I want to look at the version of behaviourism proposed by the psychologist John Watson, which is generally known as *radical behaviourism* The following paragraph will be dedicated to the version most famously associated with Skinner, which is known as neo-behaviourism. Concerning radical behaviourism, Watson advanced this perspective in his paper *Psychology as the Behaviorist views it*,[12] where he stressed the role of scientific psychology which must be scrupulously objective and search for rigor and reduction. Watson thought of consciousness as something deeply problematic. Hence, instead of disputing how the conscious mind should be studied, he defined the domain of psychology as a relatively narrow field of interest: behaviour. On Watson's view, Wundt's approach lacks any trace of objectivity demonstrable on the basis of empirical facts, since it instances a class of mysterious and inaccessible phenomena which might not exist. Watson rejected the method of introspection in favour of the method of measurement of observable actions limited to observation and objective testing/experimentation. Radical behaviourism rejects any individual interior mental activities, as well as the mentalist notions of 'mind', 'mental states' or 'consciousness', which are not directly observable.

For the behaviourist, the objective observation of behaviour is the only fit subject for psychological study, and psychology is therefore a system that studies directly observable events, namely, the study of objectively observable behaviour described in terms of physiological responses to stimuli. All thoughts and psychological processes can be controlled and explained through association of irreducible elements defined in terms of stimuli and responses, which are also adequate to explain creative thought and verbal behaviour. For any given stimulus there is an associated response; in turn, any response can be associated with another response and one's stimulus-response combination can also be associated with someone else's stimulus-response combination. The entire process of 'learning' would then consist of learned responses made to stimuli which signaled reward. Adopting a pure scientific approach restricted to observation of behaviour, Watson argued for *extreme environmentalism*: the idea that the situations and the context in which a person grows up completely shape the way that person behaves. Accordingly, the environment is what greatly controls our behaviour, so that psychology is no more than the understanding of how a certain environmental stimulus elicits a particular behavioral response. Watson tried to investigate the causal effect of behavioral mechanisms through a series of experiments on animal psychology. While dictating that all mentalist concepts are useless, he argued for the continuity between humans and animals. Watson placed special emphasis on experiments on nonhuman animals rather than human research participants because animals represented, for him, an appropriate avenue of study to understand humans. Watson preferred the study of animal subjects because he believed that the simpler the organism's emotional and physiological makeup, the less the researcher needed to worry about the interference that can plague psychological research with humans as participants. According to him, the empirical results of experiments conducted on animal psychology are all applicable to human psychology.

2. 3 From Behaviourism to Neo-behaviourism

In the third decade of the twentieth century the behaviorist agenda faced some fundamental challenges which led to the affirmation of so-called *neobehaviorism*. Neobehaviorism continued much of the rigor of behaviourism while widening the scope of acceptable behaviours for study.

[12] Watson: 1913.

The second phase of behaviourism in psychology is famously associated with the works carried out by the psychologists E. C. Tolman, C. Hull, and B. F. Skinner. Like thinkers including Thorndike, Watson, and Pavlov, the neobehaviorists believed that the study of learning and a focus on rigorously objective observational methods were central to scientific psychology. Unlike their predecessors, the neo-behaviourists were more self-consciously attempting to formalise the laws of behaviour. It must be said that neo-behaviourism was influenced by the perspective endorsed by the group of philosophers such as Rudolph Carnap, Otto Neurath and Herbert Feigl called logical positivists. In principle, logical positivism held the position that meaningful statements about the world had to be cast as statements about physical observations; anything else was metaphysics or nonsense, not science, and had to be rejected. According to this philosophical perspective, knowledge has to be built on an observational basis, and can be verified to the extent that it is in keeping with observation. As knowledge must be based on the presence of something which physically exists, then it must be objective and undebateable. In logical positivism, hypothetical constructs and ideas must be defined so that they can be logically inferred, so any topic studied from this perspective has to be operationally defined in observable, measurable terms. Similarly, neo-behaviourists were interested in studying only phenomena that are directly observable and undebateable. Like the logical positivists (who hastened the need for operational definitions with their assertion that theoretical concepts that are not directly observable may be nevertheless studied if defined in terms of directly observable behaviours), the neo-behaviourists argued that every theoretical construct, including those whose results are not directly observable, can be studied as long as the actual behavior measured was observable. Hence, the neobehaviorists widened the focus of behaviours acceptable for study in psychology.

Now I want to examine neobehaviorism in relation to the major contributions designed to define this new phase of academic psychology. In 1932, Tolman published *Purposive Behavior in Animals and Men*,[13] in which he focused his experimental work largely on rats learning their way through mazes, by illustrating examples of learning which could not be explained by simple behavioural principles theorized by Watson (that is to say by simple rewarded stimulus-response habits). While technically a behaviorist, Tolman differed from his behaviourist predecessors since he took a more holistic approach to behaviour than they had. Rather than talking in terms of atomistic, isolated stimuli and responses, Tolman emphasized their integration with the environment, referring to them in terms of *stimulating agencies* and *behavior acts*. With the notion of the *intervening variable,* he intended the link between stimulus and response that helps us to determine behaviour, arguing that intervening variables could exist between a stimulating agency and a rat's decision to move in a certain direction at a choice-point in a maze. Tolman's experimental research led him to conclude that even rats form expectations and mental representations (or 'cognitive maps') of their spatial surroundings. For Tolman, purpose and cognition play an important role in behaviour, but instead of interpreting them in terms of 'mental entities', he assumed that they are rather outwardly observable features of behaviour which are describable in objective language.

The second figure of neobehaviorism is Hull, who is probably the most ambitious neobehaviorist in terms of the construction of a formal theory of behaviour. Inspired by the certainty of scientific knowledge achieved by the natural philosopher Isaac Newton, Hull proposed a method which

[13] Tolman: 1932.

applied mathematical rigor to the observation of behaviour, insisting that psychology must be based on its own hypothetic-deductive method. According to this method, the psychologist must begin with the observation of behaviour, then derive axioms from that observation and deduce consequences from the axioms. He then tests the consequences through experiment and finally refines the axioms, establishing the laws of behaviour on a firm observational and experimental footing. Hull's rigorous scientific method became central to his formulation of laws of behaviour. These are expressed in mathematical terms, filling his *Principles of Behavior: An Introduction to Behavior Theory*[14] with complex equations. Hull believed that he had found the fundamental law of learning or habit-formation: the *law of stimulus generalization*. According to Hull, not only is this the underlying law of all behaviour in animals and humans, but this principle was also basic enough to unify all the social sciences. Hull attempted to connect the involuntary learning studied by Pavlov with the voluntary learning studied by Watson and Thorndike. He was particularly influential for his claim that the laws of behaviour can be quantified and expressed in terms of numerical quantities, like the laws of other scientific disciplines. According to the *law of effect*, a response could be called forth by an unconventional stimulus as long as that stimulus was associated, either temporally or in character, with the stimulus that usually called forth the response. As long as the unconventional stimulus was similar enough to the usual one it could elicit the response. Pavlov had noted this effect when his dogs salivated at the ringing of a bell. Following Pavlov, Hull theorized that, when an animal is trained to respond to a particular positive stimulus (or to avoid a negative stimulus), the aspects of that stimulus that impinge on the animal's senses are gradually associated with a specific response. This means that the animal learns in an incremental way (not in an all-or-nothing burst); thus, the appearance of stimuli could precisely control the animal's ability to form habits. According to Hull, these laws of behaviour can explain how all learning takes place without resorting to immaterial notions like soul or free will, in order to exclude any reference to nonmaterial entities.

The third and perhaps most important neobehaviorist is Skinner, who reinvigorated behaviorism by rejecting Hull's formal theory and returning to Watson's project to develop psychology on the exclusive basis of observation of behaviour. In 1938 Skinner carried out an intense experimental research study that led to the publication of *Behavior of Organisms*.[15] Skinner contributed to scientific psychology with a series of experiments on the conditioning of simple animal behaviour like that of rats and pigeons. Skinner's development of automated chambers for animal testing allowed for great experimentation, as well as control and consistency over stimuli and procedures. In an early experiment Skinner devised an experimental set-up, known as the 'Skinner box', in which a pigeon or a rat was rewarded for accomplishing a specific act, such as raising its head above a certain line, or pressing a lever, by the release of food pellets. The experiment principally consisted of placing the creature into a box which was set up in a special way. A bar-level was attached to one of the box's internal walls, and if it was pressed, a food pellet was then released. Skinner observed that the rat's behaviour to press the bar-level was conditioned and reinforced by the presence of food into the box. Thus, the presence of food makes the rat reinforce its external responses conditionally, in virtue of which, the rat will respond to analogous situations by engaging

[14] Hull: 1943.

[15] Skinner: 1938.

in the same behaviour. This experiment was extended to demonstrate that the way a creature behaves in response to certain stimuli is conditioned by means of reinforcement: the behaviour to press the bar-level increases the rat's likelihood of obtaining food, and this has a real effect on its subsequent behaviour. According to Skinner, given that behaviour is made conditional by factors tied to the external environment, all simple-intelligent animal behaviour is governed by the *law of effect* (which was originally formulated by Thorndike). So, explanations and predictions of behaviour would be ensured by knowledge of the animal's current stimulus plus the history of its reinforcement. But Skinner went a step further, as he assumed that the law of effect also applies to human psychology; and that even though human behaviour is more complex than simple animal behaviour, it can be equally controlled and predicted by analogous means of reinforcements.

Skinner had argued for his radically inductivist and empiricist approach in his *Science and Human Behavior*,[16] where he introduced the principles underlying his psychology. Skinner's understanding of psychology brings us to a model of science entirely based on and restricted by the level of behavioral observation, in which theories and hypotheses that apply to physiology play a limited role. According to Skinner, psychology does not need to be reduced to physiology, and physiology is no more fundamental than psychology. On the other hand, Skinner argued that knowledge, imagery and other such mentalistic entities are to be dismissed as metaphors or fictions. In his view, since only past consequences of behaviour can motivate future actions, mental states and mental events should be interpreted as behaviour-memory. In a successive work titled *Verbal Behavior*[17] Skinner clearly attempted to define thoughts and language in terms of reinforced movements. Here he argued that verbal behaviour, and behaviour in general, can be shaped by controlling the rewards or reinforcements meted out in response to them. According to his theory of language-learning, the human capacity to learn a language is a process whereby the language learner is conditioned by means of reinforcement to executive behavioural responses to environmental stimuli. Skinner's linguistic account considers only immediate and non-intentional effects on language users to be *explanatorily relevant* to the analysis of linguistic phenomena. Skinner stated that linguistic phenomena are identical to behavioural phenomena, and thus they are directly observable and classifiable on the basis of their immediate (and non-intentional) effects on language users. So, questions like *what is a desire?* or *what is it to be in pain?* should be formulated in terms of the linguistic usages, or the criteria, that allow competent speakers to decide how to use the linguistic rules that govern language. For example, learning the word *cat* just is a matter of being conditioned to utter *cat* when confronted by the particular physical thing defined 'cat'. Skinner used the term "controlling relation" to indicate the relationship between the speaker's current motivational state, his current stimulus circumstances, his past reinforcements and his genetic constitution. Note that the reference to the term *control* here relates to the concept of 'causation' understood in its purely functional sense. Since Skinner takes verbal behaviour to be an orderly and controlled datum that is sensitive to the circumstances of the speaker, his analytical apparatus only includes terms that are empirically acceptable to explanations of objective dimensions of verbal behaviour.

[16] Skinner: 1953.

[17] Skinner: 1957.

2. 4 The Cognitive Revolution and the birth of Cognitive Psychology

Although it remained dominant for the first half of the twentieth century, in the end of the 1950s behaviorism fell into disrepute. Psychology witnessed the decline of this doctrine and the consequent challenge to the focus of mental investigation; returning to the earlier interest in consciousness and inner mental states and processes, psychologists endorsed a perspective called *cognitivism*. Cognitivism is the view that emphasizes the importance of thinking for understanding much of human behaviour, it holds the basic claim that how we think is the key for understanding how we behave. The cognitive movement began with the event of *cognitive revolution*, which gave rise to an ongoing research programme known as *cognitive sciences*, in which different disciplines converged, including: cognitive psychology, philosophy of mind, anthropology, linguistics, neuroscience and AI. The topics of study of cognitive sciences are wide-ranging; subjects such as attention, memory, problem-solving, reasoning, logic, decision-making, creativity, language, cognitive development and intelligence represent some of the many areas of interest within this discipline. Although each discipline operates in an independent field of research and employs its own theoretical or empirical methodologies, they all are committed to the explanatory role of intentional states and intentional processes. In turn, the advancements in those research fields have permitted the emerging field of cognitive psychology to operate with different research agendas while assuming an intentional view regarding the characteristic cognitive capacities relating to mental states and processes.

Cognitive psychology is not quite yet a system of psychology, but rather an approach in experimental psychology. In the field of experimental psychology it has been applied in a variety of areas of study, including those concerning thinking, emotion, daydreaming and imagination. Its principal focus remains the study of how people perceive, learn, remember, and think about information, and therefore how people use language, think, solve problems and make decisions. Cognitive psychologists are particularly interested in the study of how mental processes work, and how knowledge is formed and used, rather than in the study of external behaviour defined in terms of pairs of stimuli/responses. Although in the field of experimental psychology cognitive psychology is currently the dominant area, success in construing a model of experimental psychology able to account for intentional phenomena depends on its capacity to overcome Brentano's problem and the mind-body problem. Furthermore, since cognitive psychology is a form of experimental psychology that grew out of and as a reaction to neobehaviorism, it also has to respond to the classic materialistic objections to mentalist psychology.

The first formidable attack on neobehaviorism was launched by the famous linguist Noam Chomsky. Chomsky inspired the cognitive revolution of the 1960s and the major shift in the orientation of psychology from behavioural to cognitive inner states. In 1957 Chomsky published a revolutionary work on linguistics titled *Syntactic Structures*,[18] in which he asserted that language and grammar are innate capacities of the human brain and not mechanisms learned by simple behavioural habit. In his *Review of Skinner's Verbal Behavior*[19] Chomsky launched a powerful

[18] Chomsky: 1957.

[19] Chomsky: 1959, p. 31.

criticism of behaviourism concerning the inapplicability of its scientific methods to the study of human psychology. A central insight contained in Chomsky's criticism regarded the behaviourist claim that human behaviour is stimulus-dependent. According to Chomsky, when an intelligent agent produces a behaviour in response to a specific stimulus, this behaviour depends upon the kind of mental state the agent is in at the time of the stimulation, and not upon the nature of the stimulus plus the history of reinforcement. Chomsky's argument stems from considerations about language learning: when a child learns a language, he does so too quickly for this process to be wholly dependent on such straight-forward learning. Language seems to be too complex to be learned one sentence at a time; furthermore, children can utter sentences never heard before, hence, language learning cannot arise just from repeated stimuli and imitation. Chomsky's analysis of linguistic phenomena provided significant evidence for the assumption that human behaviour is stimulus-independent. Chomsky argued that individuals are able to generate an endless number of novel sentences that make sense, or to identify sentences that are ungrammatical, since they possess an *innate* cognitive apparatus consisting of a collection of rules for sentence construction. According to Chomsky, all natural languages share common grammatical building blocks, such as *nouns* and *verbs*. Then, he stated that there must be an *"*universal grammar*"* consisting of a large collection of "linguistic universals" that governs linguistic usage in natural languages. For Chomsky, universal grammar is innate as it is automatically acquired by minded individuals at birth due to the anatomic structure of the human brain.

If Chomsky's non-behavioristic point of view began the shift away from behaviourism and towards more cognitively based models of psychology, a further attack on behaviourism emerged from the developments in the field of digital computers. In the mid-twentieth century the early success of artificial intelligence had inspired the view that the mind is like a computer. This picture entails that a computer engages in an activity that very much resembles cognition, and that mental states and mental processes can therefore be compared to computational states and computational processes. Technically, a computer is an artificial device that mechanically manipulates symbols by means of the application of certain symbol-manipulating rules. The symbols manipulated are interpreted by appropriate programming through which the machine processes information and solves complex information-processing problems. Thus, on the basis of such results, cognitive psychologists entertained the idea that cognition is a sort of computation, and that computational states and processes can be mechanically executed by an appropriately programmed and interpreted computer. Cognitive psychologists used the mind-computer analogy to uncover the computational processing underlying the human mind, assuming that the exercise of cognitive capacities (including those of perceiving and categorizing objects and features of external world, remembering and recalling past events, understanding utterances of our fellow human beings, expressing our own thoughts by means of language, coordinating our behaviour in such a way that we fulfill our goals, solving problems and developing reason in general) involves the recourse of intentional states and intentional processes. The view subscribed to by cognitive psychologists echoes that of a group of philosophers called functionalists. Before discussing the theory of functionalism, I want to say a little more on the materialistic theories of mind that dominated philosophy of mind until the 1960s.

2. 5 The affirmation of Logical Behaviourism in Philosophy of Mind

In the same period that academic psychology was dominated by behaviourism a parallel theory about the nature of mental states came out of the debate in philosophy of mind. Behaviourism had evident hostility to the practice of explaining behaviour by means of inner mental states. The behaviourist tends to deny inner mental states, or to reduce them to behavioural states that mediate the causal link between external stimuli and behaviour. Analogously, proponents of the materialistic theory known as *logical behaviourism* disregard the idea that intentional phenomena are accessible to scientific observation. Logical behaviourism, which was formulated by the philosopher Gilbert Ryle,[20] represented one of the first worked-out materialist views about the mind inspired by logical positivism and the empirical methods used in natural sciences. This materialist theory of mind does not appeal to the souls or the independent realm of mental properties, but tries to explain everything in terms of ordinary physical properties, such as behaviour and dispositions to behave. Logical behaviourism had the merit of preserving some positive aspects of empirical investigation in the field of philosophy of mind, so it might appear attractive to thinkers who want to reject dualism.

The principal aim of the logical behaviourist is to reduce every state, whether physical or mental, to a *dispositional state*. A dispositional state is a relational notion. Generally, dispositions include properties like being crushable, being fragile, being soluble and so on. Consider the property of being highly-flammable. An object is highly-flammable only if it bears an implicit relation between the 'disposition' to be highly-flammable and the behaviour to burn under certain conditions. However, something can have a disposition even if it has never happened to manifest it. For example, something can be crushable even though it is never crushed. It merely has to be such that it *would* be crushed if certain sorts of gentle forces were applied to it. The events of being flammable, being crushed, and so on, would then be the *manifestations* of the relevant dispositions. According to the logical behaviourist, to be causally responsible for a particular disposition is not to be per se causally responsible for the manifestation of that disposition. In general, having a disposition does not require that a thing actually undergo any changes, it only requires that the thing *would* undergo those changes if it were placed in the appropriate circumstances. Usually, there are some underlying facts about the object in virtue of which it has the dispositions it does: these underlying facts are the *categorical basis* of the disposition. For instance, the sugar cube is disposed to dissolve in water, and the categorical basis of this disposition is a certain kind of molecular and crystalline structure, due to which the sugar will dissolve when placed in water.

Hence, logical behaviourists hold the claim that mental states are just dispositional attitudes. Even properties like having toothache are defined in terms of how a subject is disposed to behave in response to specific kinds of stimulation. Accordingly, all there is to having toothache is to be disposed to behave so that the toothache is relieved. But this strategy does not seem to be a very plausible view of toothache; after all, there is a real difference between having toothache and *acting as if* I have toothache. Certainly, when I have toothache, there is a lot more going on than just my external behaviour. In fact, there is also something pretty awful going on *inside me* that causes me to behave in those ways. Problems with the dispositional approach arise because mental states can hardly be identified with the internal physical state that causes behaviour. This difficulty marks out the explanatory gap between dispositional explanations of physical states and dispositional explanations of mental states. Even if we consider another kind of mental state, like a belief or

[20] Ryle: 1949.

desire, the problem remains insoluble. Consider the belief that *Santa Claus is in Rome*. Concerning this belief, the logical behaviorist would say that it corresponds to a disposition that *causes* us to give a certain answer to the question: "Where is Santa Claus located?". So, all there is to believe that Santa Claus is in Rome is to be disposed to give that answer if asked "Where is Santa Claus located?". Similarly, regarding intelligence the behaviourist would say that being intelligent is simply to be disposed to give sophisticated, sensible answers to arbitrary questions (that is, to be disposed to behave so that the thing in question appears as genuinely intelligent). Following this line of thought, to pass the *Turing test* means that a thing has the property of *being intelligent*. However, the behaviour in question is not merely evidence that a thing is intelligent, thus, causal explanations of mental states in terms of dispositional attitudes do not seem to be genuine causal explanations.

2. 6 After Logical Behaviourism: Type-Identity Theory

The popularity of logical behaviourism in philosophy of mind waned in the early 1960s when an alternative materialist theory of mind called *type-identity theory* (or *central state identity theory*) was proposed by the philosophers Smart[21] and Place.[22] These philosophers took very seriously the project of explaining behaviour by appealing to inner mental causes, and they assumed that the concept of mental causation is as rich as the concept of physical causation. Basically, type-identity theory shares with logical behaviourism the spirit of scientific speculation, together with a materialistic view of mind that contrasts sharply with Cartesian dualism. But, at the same time, it reintegrates the idea of the inner mind repudiated by behaviourists. If the behaviourist maintains that mental terms refer to nothing or to the parameters of stimulus-responses relations, conversely, the type-identity theorist identifies mental states and processes with neurophysiologic events in the brain, and properties of mental states with 'causal' properties of neurophysiological states. According to this view, if we had to pick something in the behaviourist's picture to be my toothache, it seems that some C-fibres firing in my brain would be better candidates than the disposition itself. After all, that would be what *causes* me to behave as I do when I have toothache, and this would be proof that behavioral effects might sometimes have a chain of mental causes.

The type-identity theorists were inspired by the ontological doctrine of physicalism, that is, the view that all natural sciences are hierarchically structured on the basis of physics (which is per se the most basic and 'complete' science). The physicalist says that physics needs no reduction nor recourse to any other science, whilst all natural sciences have branches in which physical laws and measurements receive special emphasis. Generally, the term *special science* indicates a science that studies phenomena which come under the laws and generalisations of physics. From this point of view, every special science is said to govern a mere sub-component of the very general physical realm. According to the physicalist, the most important achievements in sciences depend on the capacity to discover *identity relations* between special sciences states/events and physical states/events. The physicalist holds that all special sciences properties must figure into physical

[21] Smart: 1959.

[22] Place: 1956.

properties, and all special sciences laws must be deductible from laws of physics. Following the principles of physicalism, type-identity theory tries to discover the *identity relations* between *mental types* and *physical types*, and to uncover the essence of psychological laws by reducing these to laws of neurophysiology. For the type-identity theorist, neurophysiology is the most likely candidate for defining the causal identity-relations between mental types and physical types. Hence, psychology is a science that reduces to neurophysiology, and neurophysiology is a science that reduces to chemistry, which in turn is a science that reduces to physics. Types of mental states are supposed to be physical since they are identical to types of brain states. Then, for any intelligent agent *I*, to be in the mental state type *m* is just to be in a specific neuronal state *n*, which is defined in terms of C-fibres firing, which is directly connected to the bodily agent's responses. In turn, mental properties are supposed to be identical to neuronal properties. According to the type-identity theorist, the identity relations between mental properties and neuronal properties belong to the same kind of identity relations as those between the property of being 'water' and the property of being composed of 'H_2O' molecules.

2. 7 The rise of Functionalism

The influence of type-identity theory was short-lived, as in the late 1960s it was pushed aside by the work carried out in the ongoing research programme called *functionalism*. Functionalism is a theory about the nature of mental states and mental processes that makes use of specific causal relations amongst a rich network of sensory inputs, mental states and types of behaviour; it was the result of the work of a group of physicalist philosophers such as Hilary Putnam,[23] Donald Davidson[24] and Jerry Fodor.[25] While operating under the influence of *physicalism* (the view that science is hierarchically organized on the ground of more fine-grained categories corresponding to specific disciplines, all underpinned under the domain of physics), functionalists took a naturalistic turn, shaping the dichotomy which was often invoked to talk about philosophical issues and issues specific to particular kinds of natural sciences. Thus, after the appearance of functionalism the traditional issues of philosophy of mind were discussed in a completely new way.

Functionalism was destined to dominate the debate of philosophy of mind in the second half of the twentieth century; it was designed to solve the dilemma for the materialistic programme in the philosophy of mind. Both logical behaviourism and type-identity theory involved several problems. On the one hand, logical behaviourism had correctly identified the relation between the environmental circumstances and the agent's behavioral responses, but it was unable to account for the relational character of the mind and the body. On the other hand, type-identity theory had correctly described the relational character of mental properties and the causal powers of mental states, but it endorsed the deeply anthropocentric view that radically different physical systems cannot share the same mental states. As opposed to materialistic views that appeal either to

[23] Putnam: 1960, 1967.

[24] Davidson: 1970.

[25] Fodor: 1968.

eliminativism or reductionism, functionalism does not foresee the elimination of intentional states and concepts from the explanatory apparatus of psychological theories. On the contrary, it makes sense of the causal nature of the mental. Although this approach superseded the fundamentals of behaviourism and type-identity theory, it integrated a delightful synthesis of both these views. To a certain extent, functionalism presents a similarity with behaviourism in respect to the claim that behaviour bears causal relations between environmental inputs and predictable outputs (corresponding, for the behaviourist, to stimuli and responses respectively). Conversely, functionalism and the type-identity theory share the project of construing causal explanations for inner-mental phenomena (which are supposed to be special entities with causal powers). However, unlike type-identity theory, functionalism rejects the perspective of *type-physicalism*. In principle, type-identity theory can be held either as a doctrine about mental particulars (such as *my fear of ‘that’ spider*), or as a doctrine about mental universals or properties (such as *being afraid of spiders* or *having beliefs that spiders are dangerous*). These two doctrines, called respectively *token physicalism* and *type physicalism*, differ in strength and plausibility.[26] Token physicalism maintains that the mental particulars which occur in our brain are neurophysiological, however, it does not exclude the logical possibility that there might be computers and disembodied spirits with mental properties. Conversely, type physicalism makes the more drastic claim that all the mental particulars that there could possibly be are neurophysiological in nature. Following this view, neither machines nor disembodied spirits can be said to have neurons or mental activity. Now, functionalism is compatible with token physicalism but not with type physicalism. The functionalist, like the cognitive psychologist, recurs to the mind-computer analogy (the distinction that computer sciences draws between hardware and software) to display the deficiencies of both the materialist and the dualist. For him, type physicalism is not a plausible view of mental properties, because it takes the psychological constitution of intelligent systems to depend on their physical composition, the *hardware*, and not on their program, the *software*. Token physicalism, on the other hand, does not rule out the logical possibility that correctly programmed computers can have mental states with mental properties, despite their physical structure or organisation.

How did functionalism demolish type-identity theory? To answer this question we may report some of the most powerful objections to type-identity theory. A particularly remarkable objection is that made by H. Putnam to the idea that mental states and brain states bear identity relations. The type-identity theorist defines a mental state in terms of a mental ‘type’, which is identifiable with the neurophysiological/brain state assigned to it. On this view, only physical systems with an identical brain can generate what is accurately recognized as a mental state and defined in terms of c-fibres firing. However, Putnam argued that this claim contrasts with accumulating evidence in neurosciences that demonstrates that animals (like dogs and apes) share relevant aspects of our mental activity, despite their central nervous system being quite different from ours. Putnam said that different physical systems can find themselves in the same identical mental state, but only certain intelligent systems, whose brains behave very similarly to the typical *functions* of the human brain, can be said to share partial aspects of our mentality. According to Putnam, even if we take mental states to belong to mental types, it is only the *functional*, or *causal* role that a mental type plays in one’s internal economy that is explanatorily relevant. The work performed by a mental type

[26] Fodor: 1981.

in a system is what permits bearing causal relations to bodily stimulations, mental states and types of behaviour. Consider *pain*: Putnam takes it to be engaged with no one particular type associated with specific neurophysiological or biochemical C-fibres, but just with the *function* that such C-fibres would have contributed to the operations of the organism taken as a whole. According to Putnam, pain and such other mental states are tokens of mental types. To token a state of a particular mental type is to token an internal state with an appropriate causal role that is central to someone's identity. To be in pain is therefore just to token an internal mental type that specifically occupies the pain role. Putnam defines the characterization of the pain role in terms of "functional types". Since distinct mental types can play the same identical causal role, the functional type is what tokens of distinct mental types have in common. Putnam's definition of mental tokens, in terms of the abstract causal-functional role that mental types (such as C-fibres) share with their potential replacements, or surrogates, entails the idea that mental tokens are *multiple realizable*. According to the thesis of multiple realizability, for any given type of mental state *T*, *T*'s role will be occupied by the same internal mental state *M* for a large variety of intelligent species. As mental tokens can be physically embodied in a large variety of different ways, then, complex physical systems, which vary considerably, can be said to realize the same mental state.

Another objection to type-identity theory emerges from Fodor's reflections. Yet in his classic book *Psychological Explanation*,[27] Fodor critiqued psychological behaviourism, logical behaviourism and the type-identity theory, suggesting replacing them with functionalism and cognitive psychology. In a more recent paper titled *Special Sciences*[28] Fodor launched a devastating attack on type-identity theory. Fodor's criticism regards the assumption that psychological laws reduce to laws of physics in virtue of the mediation of laws of neurophysiology. Despite his endorsement of physicalism, Fodor thinks of psychology as an 'autonomous' special science concerned with accounting for a distinctive aspect of reality, whose generalisations have considerable explanatory and predictive powers. For him, psychology captures generalisations over types of phenomena that physics, and the other sciences, can hardly explain or predict. Moreover, even if Fodor admits that psychological states have a physical substrate that implements them, he rejects the identity relationship between psychological states and neurophysiological states; rather, these two different kinds of states would be coextensive. Fodor argues that the level of abstractions at which the generalisations of psychology are most naturally pitched, is something that cuts across differences in the physical composition of the systems to which psychological generalisations apply.

2. 8 Functionalism, Cognitive Psychology and Mental Causation

Functionalism was particularly well-suited to be the philosophy of mind of the cognitive revolution because it contributed important theoretical foundations and conceptual analysis to the emerging cognitive sciences. In particular, functionalism was the theoretical framework most attuned to cognitive psychology. Over the last 50 years, the most important issues of cognitive psychology (such as the causal role of semantic, or representational, level properties in computational theories

[27] Fodor: 1968.

[28] Fodor: 1974.

of cognition; the nature of concepts, and what kind of relations they bear to each other; the nature of the cognitive architecture) have been investigated as questions of interest to philosophy of mind. In turn, the philosophical reflections on such issues have been ultimately informed and influenced by the results achieved in cognitive psychology. Despite operating in different disciplines, the functionalist and cognitive psychologist subscribe to the same perspective about the intentionality of mental states and mental processes. The cognitive psychologists endorsed the view that the mind is a neurophysiologically embodied computational system (the brain), and that mental states and processes are causally efficacious events that occur in it. Such states and processes would be *computational states* and *computational processes* (in principle) perfectly reproducible by a computer that shares some of our fundamental cognitive capacities. Similarly, the functionalists believed that a considerable part of our mental activity can be mechanically reproduced by specific and relevant programs of artificial systems. Influenced by the *theory of computability* and the work on the digital computer of Alan Turing, the functionalists argued that mental states and processes can be compared to the computational states and processes of a Turing machine.

A chief focus of the agenda subscribed to by both the functionalist and the cognitive psychologist was the centrality of mental causation in psychological explanations. The principal drawback of Cartesian dualism concerned its inadequateness to provide a scientific explanation for the causality of mental states. If we assume that the mind is not placed in space, it is difficult to see how mental causes could produce physical effects. For the dualist, the question of how immaterial substances cause physical events is not much more obscure than that of how physical events cause other physical events. However, it may be objected that there are many clear cases of physical causation but not one clear case of non-physical causation, so the non-physical interaction might be just an artifact of the immaterialist construal of the mental. Unlike dualism, functionalism recognizes mental causation as a species of physical causation. Functionalism became increasingly popular in cognitive sciences because it provided a way to preserve the explanatorily efficacy of mental causation without violating the generality of physics. In functionalism, mental states and processes causally mediate the link between sensory stimulation and behaviours, moreover, they are multiply realizable at different physical levels. The functionalist strategy for solving the problem of mental-physical interaction is to recognize mental particulars as physical entities. The functionalist holds both these assertions: first, mental properties must be defined in terms of their relations; second, interactions of mind and body are typically *causal* in however robust a notion of causality is required by psychological explanations. Conversely, the logical behaviourist holds only the first assertion, and the type-identity theorist only the second. Therefore, to a certain extent, the functionalist tolerates the materialist solution to the mind-body problem advanced in identity theory. The functionalist does not exclude that brain events turn out to be the only things with the functional properties typical of mental states, nonetheless, he thinks that what determines the psychological type to which a mental particular belongs is the causal role performed by it in the organism's mental life. On his view, the concept of causal role is construed in such a way that a mental state can be defined by its causal relations to other mental states. For example, toothache, or any other state is identified with the types of mental state that among other things causes a disposition to move in a certain way (like taking medication in the belief that it relieves a headache, or desiring to rid oneself of the pain one is feeling). *Functional individuation* is therefore a kind of differentiation with respect to the causal role. I shall return to the issue of mental causation in chapter 6; however, in the next chapter I will consider functionalism in relation to two general commitments: folk-psychology and physicalism.

3

Behind Functionalism: two fundamental commitments

3. 1 Functionalism and Folk-Psychology

I have already spoken about folk psychology, or *commonsense psychology*, as the theoretical account that explains how and why people routinely act or perform their behaviour. In folk psychology it is generally assumed that people engage in behaviour under the influence of their intentional states, and return to the intentional vocabulary to explain and predict behaviour. This explanatory, descriptive and predictive strategy is bounded up with the view that intentional states are explanatorily relevant, because their job is to figure as they do in intentional explanations and predictions. Fodor takes the explanatory role of intentional states to be related to certain fundamental features, which can be reported as follows:[29]

- Intentional states have *semantic properties*. Since intentional states have 'meaning', or 'content', which refers either to particular objects or possible states of affairs, they have truth or satisfaction conditions.

In principle, intentional states can be distinguished on the basis of either their mental content or the kind of relation they bear to the external world. In the case of the former, we distinguish between mental states on the basis of their different semantic content, for example, when we distinguish between the belief that *Santa Claus is coming to town* and the belief that *the Pope is coming to town*. In the case of the latter, we distinguish between two or more intentional states with the same intentional content on the basis of the different kind of relations they involve. Consider the difference between the belief that *Santa Claus is coming to town* and the desire that *Santa Claus is coming to town*. As these mental states have the same identical semantic content, what differentiates them is the different kind of relations they bear to the state of affairs. Different mental states involve different kinds of relations: the belief 'that *x*' involves one's standing in the belief-relation to the semantic content *x*; whereas, the desire 'that *x*' involve one's standing in the desire-relation to the semantic content *x*.

- Intentional states have *causal properties* that are causally efficacious to affect people's behaviour. Intentional states are mainly involved in the following causal processes:

- Intentional states can be caused by environmental factors. For example, my sighting of someone who looks like Santa Claus will probably cause to me to believe that Santa Claus has come to town.

[29] Fodor: 1987, chap. 1.

- Intentional states often cause subsequent intentional states. For example, my belief that 'Santa Claus has come to town' will probably suggest to me that this event routinely occurs every year.
- Intentional states often cause behavioural responses. For example, my belief that the object called Santa Claus is a real entity that comes to town in a particular period of the year will probably affect my future behaviour in terms of expectations of the occurrence of such event.

On Fodor's view, the attribution of *causal powers* to intentional states allows us to understand folk psychology as an intentionally regulated and law-governed causal explanation of behaviour, that is, an explanation that bears causal relations amongst individuals, mental content referring to states of affairs and environmental impingements.

- Intentional states are *systematic*, in the respect that there is a systematic relation between their causal power and their semantic properties.

Intentional states tend to cause other intentional states and behaviour to which they are semantically related. Take the process of reasoning, which constitutes a general case of employment of systematic relations among intentional states and thoughts. When an intelligent system enacts reasoning, it gives the rise to a chain of thoughts that in turn causes other chains of thoughts. Suppose that a system *I* has the belief that the object *x* stands in *R*-relation with the object *y*, then, for any given *R*-relation and any given couple of objects *x* and *y*, *I* will believe that *y* stands in the same *R*-relation with *x*.

- Intentional states are *productive*, because there is an infinite number of possible ways for an individual to form new intentional states, concepts and thoughts, or to adapt them in a completely new fashion. Equally, there is an infinite number of possible ways for a competent speaker to form or understand sentences of natural languages.

In virtue of such features, Fodor and the other functionalists understand folk psychology as a psychological theory of mind principally committed to the intentionality of mental states and concepts. The functionalists take intentional states to play an explanatory role by being part of a 'folk' theory of how physical systems, such as humans, behave such that each of us acquires by age three most of what we will deploy for the rest of our lives. This picture describes mental concepts as ensconced in folk psychology by means of a system of generalisations, which is acquired by people very early and used in their dealings with the social world.

3. 2 Folk Psychology and the Standard View of Mind

Now I want to introduce a very general issue of folk psychology: the question of how mental states work in predictions and explanations of behaviour. In the debates of cognitive sciences this question has often been posed as the question as to whether the intentional practice of 'explanation' is symmetrical to that of 'prediction'. Generally, the tendency amongst philosophers and cognitive scientists is to consider prediction as the paradigmatic practice that arises from the attribution of mental states; and explanation as the practice that is always behind prediction. According to the *standard view of mind*, predictive adequacy and explanation are just one and the same practice. This view is generally held by thinkers as Lewis, Churchland,[30] Fodor,[31] and Dennett.[32] Most famously, Lewis provided his definition of folk psychology in terms of the 'functional' theory of mental states that reflects the everyday human practices of predicting, explaining, interpreting and judging. All these practices would occur by means of relating intentional platitudes able to connect either sensory stimuli and mental states to behaviours, or mental states to one another: "when someone has a combination of mental states and the environmental sensory stimuli he receives, he tends with probability to be caused thereby to go into mental states and produce motor responses."[33]

Lewis's theoretical model of folk-psychology can be reported as follows:

- prediction and explanation are symmetrical, in the same way that explanation can also be used to make prediction, just as prediction can also serve as explanation;
- common-sense platitudes that connect behaviour and mental states make up the body of the theory \ the covering laws;
- mental states are the core causes of behaviour.

As Lewis has argued, prediction and explanation are symmetrical, because the attribution of intentional states that involves prediction cannot prescind from explanation, and vice-versa. He considered the psychological mechanisms behind the attribution of intentional states to be the primary means of explanations, and explanations to be carried out by means of inductive generalizations over behaviour.

Lewis's explanatory model of intentional explanation was importantly inspired by the deductive-nomological model of scientific explanation advanced by Hempel and Oppenheim. Both these explanatory models present a similar syntactical structure. In Hempel's and Oppenheim's deductive-nomological model,[34] every scientific explanation requires the explanandum E to be jointly explained by the covering laws $L1$, $L2$,..., L^n plus the initial conditions $C1$, $C2$,…, C^n. Analogously, as Lewis' theoretical model compares 'intentional states' to the *explanans* of Hempel and Oppenheim's deductive-nomological model, the argument of the symmetry of scientific explanation applies, *mutatis mutandis*, to the symmetry of psychological explanation.

3. 3 Two interpretations of Folk Psychology: Theory-Theory vs. Simulation Theory

[30] Churchland: 1989.

[31] Fodor: 1987.

[32] Dennett: 1986.

[33] Lewis: 1972, p. 256.

[34] Hempel and Oppenheim: 1948, p. 138.

Another general issue of folk psychology regards the question of whether the ability to ascribe intentional states to themselves and others is something that is acquired by children in the late preschool years, or is instead something innate. Cognitive scientists had widely debated the way children develop the ability to relate language, intentional states and ascriptions of mental states. There is a large agreement that children's self development of such ability is involved in the intentional practices of prediction and explanation. However, it is not so clear how people effectively construct explanations and predictions of intentional states or behaviour. With regard to this question, two contrasting hypotheses have been pursued. Both hypotheses assume that the attribution of mental states is fundamental to all commonsensical practices and cannot be explained by appeal to mere direct perception. In contrast, the hypotheses in question involve different understandings of folk psychology.

According to *simulation theory*, the practices of prediction and explanation provide a characterization of behaviour by imagining and replicating the fundamental aspects of one's mental life. This view takes the individual's own experience to be the measure of everyone else's observed behaviour, since prediction and explanation are supposed to work when one puts oneself in someone else's place. The simulation theorists think of folk psychology as a set of abilities directed to identify someone with another person in imagination and re-enact the fundamental aspects of one's mental activity. Conversely, according to *theory-theory*, the intentional practices of prediction and explanation work via construction of an inductive psychological theory about people's actions and mental experiences, a theory that shares many attributes with the typical scientific theories. The theory-theorists identify folk psychology with a psychological theory constituted by a system of rules-knowledge generalisations which are implicitly employed in the construction of explanations and predictions of mental states and behaviour. According to this view, infants and small children make sense of their social world by means of such a constructive system of rules-knowledge of mental representations and inferential laws. Children's ability to ascribe intentions would thus be related to the ability to hold an utterance in mind in the form of a quoted expression, in combination with causal relations between syntactic rules and actions. A central insight of the theory-theory is that children's ability to ascribe intentions is an innate cognitive capacity.[35]

The argument of the innateness of mental ascriptions brings us back to Chomsky's argument of the innateness of universal grammar. I have already mentioned Chomsky's linguistic argument,[36] which claims that the best explanation of how native speakers obtain an utterance in mind in the form of a quoted expression is that they have a form of unconscious knowledge of the grammar of their language. According to Chomsky, competent speakers know the constituent grammatical and syntactic rules of their natural language perfectly because they possess a "universal grammar". It is in virtue of the universal grammar that one can naturally specify, for a finite string of words, whether it constitutes a grammatically correct sentence. The unconscious knowledge of the linguistic universal principles would thus be 'innate' and encoded in the human brain at birth. The view that certain skills or abilities are 'native' or 'hard-wired' into the brain at birth is known as *nativism*. Fodor suggested generalising Chomsky's linguistic perspective of generative grammar to

[35] Baron-Cohen, Leslie and Frith: 1985; Baron-Cohen: 1995.

[36] Chomsky: 1986.

all the essential aspects of the human mind. On Fodor's view, the best way to account for our ability to explain and predict behaviour is that we have a *tacit knowledge* of a rich battery of causal generalisations, which connect intentional states to other mental phenomena, environmental impingements, sensory input and observable behaviour. Fodor is a theory-theorist who thinks that folk psychology is a psychological theory consisting of a large collection of sentences which assert the existence of an internally-represented 'knowledge-network' of causal generalisations. Intentional explanation and prediction would then be particular types of 'causal' explanations and predictions employed in special sciences. Like the inductive reasoning and covering law models employed in basic science, folk-psychological practices would form a deductive argument in which covering laws are implicitly deployed.[37] But the covering laws of folk psychology are not laws of the universal type. Conversely, psychological generalisations are 'probabilistic' laws of the deductive type that admit exceptions. These laws typically include universally quantified conditional statements known as *ceteris paribus*, that is, 'all else is equal', clauses. They have a syntactic structure in which there is an antecedent that is the conjunction of the relevant explanatory factors; and a consequent consisting of the external events involved in the inductive reasoning by which intentional explanations and predictions are carried out:

- if *x* wants that *p*, and *x* believes that not-*p* unless *q*, and *x* believes that x can bring it about that *q*, then, *ceteris paribus, x* will try to bring it about that *q*.
- 'If *x* intends to do *p*, *ceteris paribus, x* will tend to do *p*'.

For Fodor, psychological generalisations play the same role in explanation and prediction of behaviour as that usually reserved for strict physical laws: strict laws and hedged laws with satisfied *ceteris paribus* conditions operate alike in terms of their roles in covering law relations and in terms of their roles in covering law explanations.[38] He also maintains the nativist view that most of our folk-psychological knowledge is as innate as the knowledge of the universal principles that govern natural languages.

3. 4 Physicalism and mental reality

I want to conclude this brief section with the second commitment of functionalism: the metaphysical doctrine of *physicalism*. Roughly speaking, physicalism is the ontological view that reality is at bottom physical in nature. Central to this perspective is the principle of *completeness* of the physical realm, or the *causal closure thesis*, which claims that the physical realm is complete in the sense that the sum totality of physical facts determinates the sum totality of facts in the world. The most intuitive consequence of this assumption is that all the phenomena (including objects, properties, states, events or processes) that inhabit the world are necessarily physical in nature, so that the deterministic laws of physics underpin all the laws governing special sciences forces, including magnetic and chemical ones among others. The acceptance of physicalism entails that there is a systematic relation between physical laws/properties, and the laws/properties of special

[37] Fodor: 1987, p. 7.

[38] Fodor: 1990, p.154.

sciences. There are basically two ways to determine this systematic relation. Assuming the *identity relation* is to say that special sciences laws are identical to laws of physics, whereas assuming the *supervenience relation* is to say that special sciences laws supervene upon physical laws.

What is wrong with the physicalist view? One problem is that, despite the fact that our brain is certainly a complex physical system whose states and properties are necessarily physical, physical laws apparently do not underpin psychological laws, and nor do mental properties seem to reduce to physical properties. What is more, mental states have a number of salient features that apparently stand in contrast to the fundamentals of physics. In fact, the kind of content of mental states refers to objects that might not exist, or to states of affairs that might not hold. Another problematic aspect concerns the fact that minded individuals are finite physical systems, even if they can generate an infinite number of content-distinct mental states. How could a finite physical system carry out an infinite battery of rational and intentional states with contents, which are causally efficacious to external behaviour?

The philosopher Quine posed the question of the irreducibility of mental phenomena to the physical realm in terms of the irreducibility of the intentional vocabulary to the vocabulary of physics. For Quine, the question of naturalising intentional states is largely an issue of how an individual can interpret or translate, for one purpose or another, a belief into someone else's idiom; therefore, an issue of how symbols get meaning. Quine asserted that, even if the language of intentionality were necessary for our best predictions or explanations of behaviour, it could not be naturalised in any case. The problem he raised is whether 'irreducible' intentional idioms can be integrated with the language of natural sciences; this dilemma is known as *double standards* and consists of two basic and equally contradictory arguments. The 'argument of indispensability' claims that propositional attitudes should be included in the domain of mathematical objects as they are 'indispensable' to our best explanations of the world. Grasping the first horn of the dilemma entails that folk psychology provides the best psychological theory, despite the fact that meaningful intentional states do not reduce to any term that indicates parts of the physical realm. Conversely, the argument of the 'indeterminacy of reference' claims that the reference of any language, including the language of intentionality, is highly 'undetermined'. Since a behaviour has no unique reference, it might be interpreted by two different and equally warranted predictive/interpretative strategies: "manuals for translating one language into another can be set up in divergent ways, all compatible with the totality of speech dispositions, yet incompatible with one another."[39]

Grasping the second horn of the dilemma is to admit that intentional phenomena are scientifically empty and baseless. As regards Quine's dilemma, some agree that intentional idioms cannot be an integrative part of the natural sciences vocabulary, while others declare their congruence with it. Then, the physicalist dilemma gives the rise to this taxonomy:[40]

- Eliminative Materialism, defended by Quine and Churchland;[41]

[39] Quine: 1960, p. 27.

[40] Dennet: 1981.

[41] Churchland: 1981; 1989.

- Intentional Realism, defended by Davidson, Putnam, Kripke, Fodor and Dretske;
- Instrumentalism, defended by Dennet.

The viewpoint of *eliminative materialism* is held by those who resolutely opt for the second argument of Quine's dilemma. This perspective disclaims the truth of intentional idioms and propositional attitudes: if behaviorists tend to *eliminate* intentional states, conversely, type-identity theorists identify intentional states with neuronal/physical states and translate the vocabulary of intentionality into the language of neuroscience. According to the view of *reductive materialism*, mental states are states of the brain, or central nervous system, which are defined on the grounds of a number of different bio-physical structures and processes. Nevertheless, amongst theories of mind that are engaged with eliminative or reductive materialism, the tendency is to reject any kind of inferential computation over syntactically structured sentences or logical formulas. Within Artificial Intelligence the materialistic theories of mind reflect the cognitive models, according to which the brain works by entirely distributed holistic *connectionist* networking, together with a physically hard-wired vector coding of coordinate transformations.

On the other hand, *intentional realism* is the view that defends the reality of intentional states. The realist claims that intentional idioms are ontologically 'true' and equally 'irreducible' to the physical language, so he resolutely opts for the first argument of Quine's dilemma and rejects the argument of indeterminacy of reference. Intentional realists are generally functionalists like Jerry Fodor,[42] who demands the reality of intentional states by appealing to the existence of a mental language formed by mental symbols with syntactic and semantic properties. Fodor considers the mental language to be at the base of every natural language, and the intentional states and thoughts of such mental language as taking the form of mental tokens, or mental representations. Like sentences of natural languages, mental tokens are supposed to have syntactic and semantic properties, so that they are grammatically and semantically structured in the brain. Fodor's view echoes that of Davidson,[43] who argued that all that is needed to explain mental causality is an account of representations of psychological states defined in terms of mental tokens, plus inductive reasoning.

An alternative position to materialism and realism is represented by *instrumentalism*, a viewpoint proposed by Daniel Dennett.[44] Unlike realism, instrumentalism invokes purely factual descriptions of states of affairs that do not require any normative assumption to be licensed. According to this view, sentences which include intentional idioms do not really describe any entity of special kind, but only serve to systematize more familiar phenomena. Dennett's idea can be summarised in this way: given the absence of detailed knowledge of the physical laws that govern behaviour, intentional idioms can be taken as an useful stance for predicting behaviour. On Dennett's view, intentional items are mere calculation-predictive devices, and not inner mental mechanisms.

[42] Fodor: 1975, 1987, 1994, 1998, 2008.

[43] Davidson: 1970.

[44] Dennett: 1971, 1979.

According to his epistemological strategy of *intentional stance*,[45] to predict behaviour of mechanical devices, creatures, and humans we have to distinguish between three basic levels of descriptions. The *physical stance* applies to the basic physical level whereas the *design stance* applies to the functional description of reality and the *intentional stance* defines prediction in terms of the matter of extrapolating rationally the behaviour one individual expects from another in a particular situation. Dennett argued that the performance of an individual to predict behaviour of another individual is exactly the same as predicting the behaviour performed by a thermostat: we do not know exactly how the calculator works, however, we expect it to produce particular behaviour in response to a particular circumstance.

[45] Dennet: 1987.

4

Computational Theories of Mind

4. 1 The linkage between Functionalism and Cognitive Sciences

Thus far I have discussed the theory of functionalism in relation to the dramatic developments that led to the cognitive revolution of the mid-twentieth century. I said that the failure of philosophical behaviourism and identity-theory in philosophy of mind, together with the success of naturalism laid the ground for the advent of functionalism, a theory which specifies the role of intentional items for psychological explanations. On the other hand, Chomsky's novel mentalistic theory of language,[46] plus the results of experimental instruments achieved in psychological research and AI, have been fundamental to the replacement of the behaviorist approach in psychology with the cognitivist one.

Functionalism and cognitive sciences are complementary projects. If the impact of functionalism depended on its linkage with cognitive sciences, conversely, it inspired the overarching picture that explicates the goals and practices of the cognitive scientists, furnishing the conceptual foundations for cognitive sciences. The working hypothesis of cognitive sciences is to define the mechanisms underlying our cognitive capacities as computations that operate on mental representations, that is, as species of information processing. Cognitive scientists try to specify the computational structure of cognitive systems, thoughts, beliefs and so forth, and what type of computational state is each cognitive capacity, thought, and any other mental type. On the other hand, functionalism is the project of philosophers whose concern is to formulate a comprehensive theory of mind that understands cognitive capacities, thoughts, beliefs and so on in terms of computational states specified in formal-syntactical terms. Inspired by the computational models of cognition, the functionalist claims that the thought that 'water is wet' is a computational type; nonetheless, he does not specify what computational type it is. The task of the functionalist is not to give a detailed specification of the functional organization of the thinking organism, nor that of providing a computational description of the organism's thoughts and beliefs. This specification is the task of the cognitive scientist, who attempts to discover the functional organisation of cognizing organisms by specifying which computational type each mental type is. In this chapter I will examine the most remarkable versions that grew out of the functionalist approach. After giving a brief overview of Putnam's formulation of *computational functionalism*,[47] I will talk more about Fodor's *computational theory of mind*.[48]

[46] Chomsky: 1957.

[47] Putnam: 1968.

[48] Fodor: 1975.

4. 2 Putnam and Computational Functionalism

Hilary Putnam can be considered the father of computational functionalism, a theory about the nature of mental states which takes mental states and events to be computational states of the brain. It essentially includes two claims: *computationalism* and *functionalism*. Computationalism is the claim that organisms with minds have *functional organization*, which describes the organism in terms of states and their relations to each other and to inputs and outputs. Computationalism is often associated with the maxim that the brain is a sort of computer, and as such, runs a program: the software. Conversely, functionalism is the claim that to have a mind is to have the right sort of functional organisation, and that every mental property is a certain *kind* of this functional organisation. Functionalism is commonly associated with the maxim that the mind is the software of the brain. The doctrine of computational functionalism has been outlined by Putnam in a series of papers beginning with *Minds and Machines*[49] and culminating in *The Nature of Mental States*,[50] so we can divide its development into two phases.

In his earliest papers Putnam[51] did not put forward a theory about the nature of mental states but used the analogy between minds and machines to set out the concepts and ideas underlying computational functionalism. Accordingly, it is possible to clarify issues pertaining to the mind in terms of a machine analogue, since, there is a striking analogy between humans and machines. Their internal makeup and behaviour can be described either in terms of physical states governed by physical laws or, more abstractly, in terms of logical states (machines) and mental states (humans) governed by laws of reasoning. In assuming that the mind-computer analogy can help us clarify the notion of mental state, Putnam posed the question of the nature of mental states (or the mind-body problem) and the problem of other minds in the context of their machine analogue:

> "The various issues and puzzles that make up the traditional mind-body problem are wholly linguistic and logical in character…all the issues arise in connection with any computing system capable of answering questions about its own structure."[52]

The paradigm example of a computing machine he used is a Turing machine. He argued that minds and Turing machines are similar in that they carry out similar behaviour, and present a similar internal composition. Minds and Turing machines have both two possible descriptions. There is a description that refers to their physical and chemical structure. If we take a Turing machine, it is a physically realised object, which is characterized in terms that refer to its physical states, chemical or electronic components. This kind of description corresponds to the hardware of the computing machine. Moreover, there is a kind of characterization in terms of the program by which the Turing machine runs. Consider, for example, a flow chart: this computing machine can be described in terms of sequences of logical states, as it determines the order in which the states succeed each other, and which symbols are printed. The flow chart specifies laws governing the succession of the

[49] Putnam: 1960.

[50] Putnam: 1967b.

[51] Putnam: 1960, 1964.

[52] Putnam: 1960, p. 362.

machine's logical states. These logical states are states that can be described exclusively in logical or formal terms. Putnam identified the sequence of logical states with the *functional organization* of the Turing machine: the machine's software.[53] In short, the machine's makeup as well as its behaviour can be analyzed in terms of either the software it runs (a characterization of mental/computational states expressed in logical-mathematical language) or the hardware that physically realises the software. Unlike the hardware, either thoughts or programs are open to rational criticism. Putnam claimed that a special Turing machine that behaves according to rational preference functions is a "rational agent*"*. On Putnam's view, the rules of inductive logic and economics theory are arguably the very rules that govern the psychology of human beings.[54]

In a successive paper titled *The Nature of Mental States* Putnam went a step further, and suggested identifying the mind with the functional organization of the thinking organism, and mental states with functional states:

> "to know for certain that a human being has a particular belief, or preference, and so on, involves knowing something about the functional organization of the human being."[55]

Putnam made the claim that mental states are *functional states* of the organism. A functional state is a state of the whole organism's functional organization, which is defined by its causal relations to other states (like the belief that *I am in pain*), inputs (such as being hurt), and outputs (like my vocalization *ouch*). Considering pain, Putnam said that to be in pain is to have a property that is characteristic of the organism's functional organisation:"being capable of feeling pain is possessing an appropriate kind of Functional Organization".[56] Putnam's specification of pain is reductive in the sense that it is formulated not in mental terms, but in terms of computational parameters plus relations to biologically characterized inputs and outputs. Functional states do the job of bearing causal relations between internal brain states, sensory inputs and outputs to the motor system. Then, the specification of a mental state in terms of other mental states is eliminated in favour of a formula that contains logical terms (such as: 'there is', 'and'), variables (such as: ., x, S_1,…, S_n), and biological/physical terms (for the inputs and outputs). Putnam wanted to demonstrate that the nature of the mind is independent from the physical make-up of the brain but depends on the kind of functional organization, or software, possessed by the organism: that is, the way in which mental states are causally related to each other, to sensory inputs, and to motor outputs.[57] Unanimated physical objects cannot possess what can be specifically defined 'minds' because they do not have a sufficiently complex kind of functional organisation to render them minds. All there is to being intelligent, really having thoughts and other mental states is implementing some very complicated software. For example, the software implemented into our brain might be implemented in many different sorts of hardware, like Martian brains or computers. Putnam concluded that, if a Martian

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[53] Putnam: 1960, p. 373.

[54] Putnam: 1967a, pp. 409-410.

[55] Putnam: 1967a, p. 424.

[56] Putnam: 1967b, p. 434.

[57] Putnam: 1975b, p. 291.

brain, or a computer, implemented that sort of software, it would have real thoughts and mental states. As long as there is hardware with internal mental states that stand in the right causal functional relations to each other and to inputs and outputs, we can say that it has a mind.

4. 3 Fodor's Computational Theory of Mind

From the early stages of his career Fodor saw in functionalism a theory amenable to the view of mind underlying that of the cognitive revolution of the 1950s. He was also enthusiastic about cognitive psychology, arguing for the continuity between the theories of cognitive processing and the developments carried out by functionalism. Then, between the 1960s and the early 1970s, Fodor manifested an active interest in the empirical study of language and linguistic processing which led him to write a collection of papers about some of the philosophical issues arising out of Chomsky's framework in theoretical linguistics.[58] These empirical works in psycholinguistics plus the earlier commitment to both functionalism and cognitive psychology laid the groundwork for the formulation of his *computational theory of mind*. The computational theory of mind (CTM), was proposed in Fodor's books *The Language of Thought* and *Propositional Attitudes*;[59] it is principally a theory of intentional states and processes which aims to subscribe to a task based on the co-existence of intentionality and the physicalist ontology. CTM resembles the conception of mind of the cognitive revolution and it bears considerable affinities to functionalism as regards the idea that intentional states are causally efficacious functional relations which are multiply realisable. Although CTM claims that intentional relations are functional relations, it rejects the functionalist theory of content. In introducing Fodor's CTM, I will follow the exposition given by M. J. Cain in his book *Fodor: Language and Philosophy*;[60] as we shall see, CTM consists of two argumentative components: a theory of intentional states and a theory of intentional processes.

4. 4 CTM and Intentional States

Fodor's CTM is inspired by a doctrine of mind of the seventeenth and eighteenth centuries known as *representational theory of mind*, which claims that mental representations are meaningful symbols that reside in the mind in the form of mental analogues of spoken and written sentences, maps, pictures and the like. What CTM adds to this doctrine of mind is the functionalist view that intentional states are subjected to computational interactions, and that mental representations involved in token intentional states are closer to sentences of natural languages than to mental images. CTM can be summarised in these statements:

I. intentional states are subjected to computational relations operating on mental representations;

[58] Fodor and Katz: 1964.

[59] Fodor: 1975, 1978.

[60] Cain: 2002.

II. intentional processes are processes involving the manipulation of mental representations by means of formal operations (computation);

III. mental representations belong to an innate language: the *language of thought*.

According to CTM, distinct types of intentional state relations are nothing more than distinct types of functional relations to LOT sentences. The type of intentional state relation one bears to a sentence of LOT is something that depends on the functional role of the LOT sentence. Fodor advanced this line of thought in *The Language of Thought*, where he argues that mental representations belong to the language of thought, or "Mentalese", and that such mental language has a number of salient features common to all natural languages.

First, like sentences of natural languages, mental representations are definable in terms of tokens with a complex symbolic structure, which is made up of simple symbols combined in a particular way. Each singular syntactic constituent that contributes to forming a mental token is engaged with the application of specific grammatical or syntactic rules. In turn, the syntactic rules involved in the course of combining the distinct component parts determine how the singular grammatical constituents must be put together, what combination of grammatical constituents counts as legitimate and what does not. Second, like the syntactic rules that govern natural language, the syntactic rules that govern LOT are recursive: they can be employed over and over again in such a way that minded individuals can generate tokens that they had never previously had. There are some finite syntactic rules, yet infinite distinct mental tokens. This seems to suggest that LOT and natural languages are both productive and creative. Third, like words and sentences of natural languages, thoughts and mental representations are meaningful. Generally, in natural languages the syntactic properties of sentences play a systematic and disciplined role for meaning determination. Fodor believes that the same kind of meaning determination occurs in LOT. LOT is a codified system of mental representations with combinatorial syntax and semantics, in which the meaning of a given sentence is exhaustively determined by the meaning of each of its well-formed symbolic components.[61] There are infinitely many distinct sentences of LOT that can be constructed, as well as infinitely many distinct meanings that can be expressed by mental tokens.

Although LOT has much in common with natural languages, it should not be identified with any natural language. Rather, LOT would be the necessary prerequisite for learning natural languages, since it is involved in the acquisition of the knowledge of the meaning of words. For Fodor, to learn the meaning of a word is just a matter of constructing and confirming certain hypotheses about what that meaning represents, but there is no way to construe and confirm hypotheses unless there is a representational system to do so. Fodor argues that natural languages are linguistic systems used to communicate and represent intentional states; nevertheless, pre-verbal infants demonstrate the ability to engage in thought without having mastery of any natural language. From this he draws the conclusion that, the knowledge of the universals of LOT is an *innate* and necessary precondition for managing any natural language, and that LOT is physically embodied in the human brain at birth.

[61] Fodor: 1981.

4. 5 CTM and Intentional Processes

Fodor posed the question of specifying the functional role of a sentence of LOT as a matter of how a psychological mechanism manipulates mental tokens and LOT symbols. According to CTM, the mental mechanisms that manipulate LOT sentences are causal computational processes which relate mental states to computational or logical states by virtue of rules governing symbolic manipulation. This understanding of mental mechanisms can be traced back to the work of Alan Turing in mathematical logic and the theory of computability.

In the 1950s Turing carried out a series of researches that inspired substantial changes in our understanding of the mental, as he explicitly compared specific capabilities of modern computers to exclusive capabilities of the human mind. For Turing, there is a certain similitude between the sort of reasoning and problem-solving skills exhibited by computers and individuals: both have memories and a certain form of inductive reasoning, plus their own language necessary to communicate and interact with the world. The computer takes symbols as inputs and, by virtue of the application of certain syntactic manipulating rules, processes them and produces other symbols as outputs. The symbols manipulated have semantic properties, so that when the computer manipulates symbols the process executed results semantically, or logically, coherent. A mechanical device that exhibits the capacity to process the information received from the environment, and produce a reasonable response to it (to generate an output that makes sense), can be qualified as intelligent. The computer possesses an appropriate *interpretation* of the symbols manipulated, however, it has no really understanding of the meaning of the symbols manipulated but is sensitive only to the syntactic properties of the symbols manipulated, and to the symbol-manipulating rules applied. Since all the relations amongst inputs, internal processing information, and outputs are ‘causal’ and ‘systematic’, the process of reasoning is governed by mere syntactic generalisations.

Turing’s theory of reasoning provided important inspiration for Fodor's development of CTM as a theory of mental processes involved in our intentional practices. For Fodor, thinking is the act of employing certain syntactic operations to the content of mental representations. If the syntactic properties of mental representations are responsible for the process of reasoning, we may consider a Turing machine able to manipulate mental tokens through a series of operations which correspond to a semantically coherent logical calculus. The Turing machine elaborates information reasonably, given the operations performed by certain syntactic rule-governed transformations over symbolic strings. When an intentional process occurs, a computational mechanism (the software) embodied into the hardware (the brain) takes a sentence of LOT as input and generates a sentence of LOT as output, in a way that results logically coherent. As the symbolic constituents of that LOT sentence have semantic properties which are tracked by corresponding syntactic properties, then the syntactic manipulation of mental content is sufficient to cause behaviour:

> “If you say '19' when I say '7 plus 12, please', your reply could undoubtedly be explained in part in reference to your knowledge of numbers. But this is not enough, given that, after all, knowledge does not translate into behavior in virtue of only the content of propositions. It seems evident that mechanisms are needed which put into action that which is known, mechanisms which have the

function of making the organization of behavior conform to the propositional structures which are known."[62]

On Fodor's view, the logical coherence of psychological processes is strictly related to the capacity to obey the principles of mental composition that specify the symbols of LOT, the meaning of their constituents, and the syntactic rules that operate over such symbols. Fodor says that this level of symbolic abstraction is reached by codified systems that meditate in the right set of causal and systematic relations to specific physical inputs, inner mental states and physical outputs. Then, for any mental state type *M*, CTM specifies a function *F* that *M* plays in the global economy of a computational system *S*. The functional state *R* can be faithfully reproduced in a number of different physical hardware configurations, given that its realization prescinds from the physical substrate that implements it. If two physically instantiated intelligent systems manipulate syntactically the structured symbols of the same language, apply the same body of symbol-manipulating rules, and instantiate the same functional states, then they can be understood as computationally equivalent.

4. 6 An argument for CTM: concept acquisition

I said above that the chief idea underlying CTM is that individuals predict and explain their behaviour due to a sort of 'tacit knowledge' that counts on a rich battery of concepts, causal generalisations over environmental conditions, intentional states and external behaviours. This tacit knowledge is internally structured in the brain in terms of LOT, so to generate a concept is a matter of having a symbol of LOT with an appropriate content. However, how do individuals acquire concepts in terms of LOT symbols?

The question of concept-acquisition was addressed by Fodor in *The Language of Thought*. Here Fodor proposed his *nativist* view about the innateness of human internal-mental language and cognitive capacities. Nativism is the perspective that a thing is innate if it is present at birth or is acquired automatically under certain experiences. Fodor suggested generalizing the linguistic perspective of generative grammar articulated by Noam Chomsky, because he thinks of LOT as an innate language constituted of innate concepts. Most of our concepts would be as innate as the psychological capacities through which we recognize, identify, form, construe, correct and create any possible well-formed sentences of LOT. In contrast, to learn a non-innate concept is a matter of having an intentional description of the acquisition process, which reveals the concept-learning as rationally related to the experiences that gave rise to it. Fodor's explanation of concept-learning coheres Chomsky's explanation of language-learning, according to which, individuals have an innate knowledge of the principles of "universal grammar". Chomsky argued that, unlike the knowledge of universal grammar and the related cognitive capacities, natural languages are not entirely innate (since competent speakers are able to learn a whole range of new concepts). Similarly, Fodor takes the mental processes involved in concept-acquisition as processes of hypothesis-testing and confirmation, so when an individual formulates a hypothesis that is confirmed a number of times, he will endorse it as the correct one. However, in order to test and

[62] Fodor: 1975.

confirm the hypothesis as the correct one, the individual has to grasp a previous target concept related to that hypothesis:

> "Suppose, e.g., that you are a stage one child trying to learn the concept C. Well, the least you have to do is to learn the conditions under which something is an instance of (falls under) C. So, presumably, you have to learn something of the form (x) (x is C iff x is F) where F is some concept that applies whenever C does. Clearly, however, a necessary condition on being able to learn that is that one's conceptual system should contain F. So now consider the case where C is, as it were, a stage two concept. If something is a stage two concept, then it must follow that it is not co-extensive with any stage one concept; otherwise, the difference between stages wouldn't be a difference in the expressive power of the conceptual systems that characterize the stages. But if the stage one child can't represent the extension of C in terms of some concept in the system available to him he can't represent it at all since, by definition, his conceptual system just is the totality of representational devices that can be used for cognitive processing. And if he can't represent the extension of C, then he can't learn C since, by hypothesis, concept learning involves projecting and confirming bi-conditionals which determine the extension of the concept being learned."[63]

Thus, learning a concept is a process that involves hypothesis-testing and confirmation, but in order to frame the relevant hypotheses one needs to have a previous and innate target concept to grasp. Fodor argues that the construction of complex concepts requires the employment of specific combinatorial functional operations to the simpler concepts that compose them. What children or adults learn when they acquire a 'higher-stage' concept is something that can be mentally represented in terms of its lower-stage concepts (given the representational powers of LOT symbols). If higher-level conceptual systems are acquired from lower-level conceptual systems, in turn, lower-level conceptual systems cannot be learned. According to Fodor, target concepts are necessarily innate because their content cannot be gradually acquired:

> "To say this is to say that learning the concept 'red' is learning something like '(x) x is red iff x is sufficiently similar to Ei' where Ei names some such exemplar of the color as a poppy, a sunset, or a nose in winter. Patently, environmental inputs could make an essential contribution to this sort of concept learning: viz., by supplying the exemplar. The present point is that the process by which one becomes acquainted with the exemplar is not itself a process of hypothesis formation and testing; it is, rather, the process of opening one's eyes and looking."[64]

In *The Present Status of the Innateness Controversy*[65] Fodor returned to the question of how mental processes are involved in concept-acquisition, suggesting that individuals acquire concepts by means of innate brute-causal mechanisms, instead of rational-causal mechanisms. The term *brute-causal process* denotes a psychological mechanism with no intentional characterization. In maintaining that the body of knowledge constituted by the range of target concepts is innate, Fodor

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[63] Fodor: 1975, p. 90.

[64] Fodor: 1975, pp. 96-97.

[65] Fodor: 1981.

advanced two arguments as confirmation of his nativist viewpoint. The first recurs to the evidence that concepts and thoughts are universal. Accordingly, the universality of concepts and thoughts is innate because individuals acquire them regardless of any learning experiences or social/cultural background. The second (the *poverty of stimulus argument*) stems from the consideration of that learning experience which is too poor to enable acquisition of concepts. Furthermore, Fodor's endorsement of radical nativism appears in a more recent work titled *Concepts*,[66] in which he claims that most, if not all, of our concepts are innate (including concepts as 'red', 'table', 'carburetor', 'knob' or 'telephone').

[66] Fodor: 1998.

5

Mental Representation

5. 1 The problem of Mental Representation

So far we have seen how functionalism increased interest in scientific psychology, while cognitive psychology provided the traditional philosophical issues with empirical groundwork. In alluding to this linkage I have detailed the version which developed from functionalism called computational theory of mind, explaining that it is a physicalist theory of intentional states and intentional processes which resembles the theory of mind suggested by cognitive psychologists. CTM tries to explain the nature of ideas, concepts and mental content by postulating the actual existence of a system of mental representations (LOT). However, CTM has some limitations: first, it fails to explain why intentional states have the content they do, for example, it does not tell us why the belief that *Santa Claus is coming to town* has that particular content instead of many possible others. Another problem is that it does not reveal how physical properties can generate semantic or intentional properties. The deficiencies of CTM could threaten the project to vindicate the scientific status of folk psychology; to overcome the inherent limitations of CTM, Fodor therefore proposed adoption of an *atomistic* theory of content that specifies the physicalist determinants of the content of LOT symbols by means of mind-world causal laws and relations of asymmetric dependence amongst those laws. In this chapter I will introduce Fodor's theory of content in relation to a general issue of intentionality: the problem of *mental representation*. The problem of mental representation can be seen as the general problem of how the mind gets a mental representation, that is, the problem of providing an acceptable explanation of how an inner mental state comes to represent a particular external object, event or fact it is about.

5. 2 Naturalistic Theories of Contents

Generally, philosophers of mind and cognitive scientists use the term mental representation for a hypothetical internal cognitive symbol that represents external reality, or else a mental process, that makes use of such a symbol. *Representationalism* is the view that minded individuals access external reality by virtue of mental representations, and that the process of thinking occurs within an internal system of mental representations; the representationalist asserts that mental representations represent to the mind the physical entities of the world. How do representations come to represent the particular objects, events or facts that they do?

The problem of mental representation demands the construction of a 'naturalistic' theory of content, but is a theory like this really needed? First, a naturalized theory of content would be important to all parts of philosophy that use or assume a theory of thought, besides being a centerpiece of cognitive sciences. We have seen that Fodor's theoretical account relies on a representational system consisting of an internal language of thought, within which the content of thoughts is represented in symbolic structures that resemble a syntax and semantics like those of natural languages (but on a much more abstract level). However, the mere assumption that the content of mental representations is an abstract object (such as a property, relation, or proposition) does not suffice to explain why representations come to have the content they do. The problem of mental representation is not just that of giving a naturalized account of the abstract content of mental representations, rather it is that of specifying, in naturalistic terms, the content-determining relations between mental representations and the abstract object they express. Amongst philosophers of mind, there are those who have approached this problem reasonably by speculating about the manner in which empirical stories turn out. This approach, which links the empirical facts about human knowledge-ascriptions with the facts about how intentional states are regulated, or enable, organisms to get around the world, is essentially the guiding line for Fodor's *Psychosemantics*[67] and Dretske's *Explaining Behavior*.[68] Both Fodor and Dretske consider the goal of philosophical theories of causation and the goal of theories of knowledge in the same kind of way.

In fact, the debate in cognitive sciences handles two opposite naturalistic theories of content-determination: *causal-informational theories* and *functional theories*. The causal-informational theories[69] hold that the content of mental representations is grounded in the information it carries about what '*does' or* '*would'* cause it to occur. However, the main limit of the causal-informational approach is that physical objects (including artificial devices like thermostats and ringing telephones) that carry information about what they are causally related to do not represent the information they carry out. In other words, causal-informational relations are not sufficient to determine the content of a mental representation, since a representation may be caused by something that it does not represent at all. Causal-informational theorists have suggested two different ways for specifying what makes a causal-informational state a mental representation. The solution suggested by Fodor is to distinguish mere "informational relations" from "representational relations", on the basis of the higher-order relations that the former bear to the latter.[70] Fodor's *asymmetric dependency theory* gives an explanation of why tokens of mental state types carry information about the external objects they represent. On the other hand, the *teleological theories* take the representational relations in terms of relations whose representation-producing mechanism selects by means of a 'function' of establishing, a function that can be achieved by either evolution or learning. According to this view, the mechanism by which a mental token is produced has the selected function of indicating the object of that specific representation: for example, horses cause horse-representations by means of a representation-producing mechanism that responds to horses. As opposed to causal-informational theories, *functional theories*[71] consider the content of a mental representation to be (at least) partially determined by its causal, computational and inferential relations to other mental representations. Proponents of this account

[67] Fodor: 1987.

[68] Dretske: 1988.

[69] Dretske: 1981, 1988, 1995.

[70] Fodor: 1987, 1990a, 1994.

[71] Block: 1986; Harman: 1973.

generally opt for *holism*, the view that the content of a mental representation is determined by its inferential/computational relations with 'all' other representations; this view is in contrast to the view of *atomism*, according to which the content of a mental state depends on *none* of its relations to other mental states.

5. 3 Fodor's Theory of Content and Informational Semantics

The chief aim of Fodor's theory of content is to reinstate the *naturalization project* and improve CTM. Fodor approached the naturalization problem on the basis of CTM; in *Psychosemantics* he argued that the meaning of a concept, or symbol of LOT, is essentially a matter of the property that it expresses and consequently, that concepts and symbols expressing the same property, or alternatively having the same reference, are semantically equivalent. According to Fodor, the contents of members of relevant chains of thoughts are semantically related to one another in such a way that the sequence of thoughts reflecting the relationship among propositions forms a logically valid argument:"...one of the most striking facts about the cognitive mind as commonsense belief/desire psychology conceives it... (is) the frequent similarity between trains of thoughts and arguments."[72]

Hence, CTM takes the content of mental states to be inherent in sentences of LOT. The content of a LOT sentence is determined by the meaning of the symbolic components plus its syntactic structures. However, CTM alone does not explain everything about the intentional properties. In particular, it fails to explain how concepts, or symbols of LOT, express the same semantic property, or how physical properties generate semantic or intentional properties. Fodor supplied an atomistic theory of content to CTM, a theory that makes reference to the meaning of simple symbols (or words) of LOT, by specifying the content of mental states in *non-intentional* terms, that is, not in terms of relations between primitive non-logical symbols or other LOT symbols. This atomistic account specifies the necessary and sufficient conditions that lay bare the nature of intentional properties. Fodor thinks that the properties attributed to intentional states are those generated by the typical properties recognized by natural sciences.

Fodor's theory of content is inspired by another atomistic theory called *informational semantics*. Informational semantics is an effort to understand the kind of meaning characteristic of thought and language as arising out of and having its source in natural meaning. The basic idea underlying it is that the very existence of thought, and thus the possibility of language, depends on the capacity of systems to transform information (normally supplied by perception) into meaning. Accordingly, the primary sources of meaning are located in the mind in the form of symbol-world relations defined in information-theoretical terms, such as source, receiver, signal, and so on (as opposed to Fodor, who believes that the primary source of meaning takes the form of more general causal terms, so that the LOT symbol 'HORSE' means *horse* because tokenings of that symbol are exclusively caused by horses). Informational semantics grounds the meaning in an objective notion of information that is used for an objective and mind-independent relation between a sign or signal (information a signal carries about a source is taken to be what such a signal indicates or *means).* It

[72] Fodor: 1987, p. 13.

is atomistic in the sense that it takes the meaning of simple and primitive symbols to be determined by the property that symbols causally covary with, and not by the relations that symbols bear to other symbols.

5. 4 The Disjunctive Problem

The major problem of informational semantics is that it rules out the possibility of error or misrepresentation of the world. We might see a cow on a dark night and mistakenly think it is a horse: this misrepresentation would cause to us to token 'HORSE' instead of 'COW'. But if we assume that either cows-on-a-dark-night or horses cause tokening of HORSE, then we have to conclude that tokening of HORSE has disjunctive content. The mistaken attribution of disjunctive content might be avoided if we uncover the non-intentional properties that render causal connections between horses and the tokening of 'HORSE' relevant and causal connections between cows-on-a-dark-night and tokenings of HORSE not. As Dretske suggested, the *disjunctive problem* can be solved if we take the content of a LOT symbol to depend upon the property with which its tokening covaries in the *learning period*.[73] Accordingly, the causal connections that determine the content of a LOT symbol are those that hold in the period in which the symbol is learned. Then, our misrepresentations would occur when a tokening of a symbol is caused by something that does not have the property the LOT symbol covaries with in the learning period. However, Fodor has objected that there is no objective way to establish when exactly the learning period ends and the misrepresentation becomes true.

Another way to explain our misrepresentations of the world makes appeal to the *ideal circumstances*, according to which, the causal connections that determine the meaning of a symbol are those that hold in ideal conditions. Ecologically normal situations can be specified as those conditions under which the perceptual mechanisms that mediate the relation between the property of *cowness* and the token 'COW' function optimally. On this view, misrepresentations occur when there are not optimal conditions to determine the real nature of external objects. For example, if an individual were confronted by a cow on a sunny day, he would probably not have misrepresented the symbol 'COW'. This strategy affords teleology to the mental states underlying psychobiological functions: functioning optimally could be analyzed as a function that contributes positively to the survival value of the organism. The fact that the mechanism functions optimally in normal conditions could be taken as the evolutionary, and non-intentional, cause of its being retained and reproduced in the process of natural selection. Accordingly, a belief can count as a *biological state* only if it has a content that results evolutionarily relevant to a *proper function*. The term proper function here indicates the function a mechanism *M* selected for producing tokens of symbols *S* in response to instances of *P*. However, Fodor has objected that the *teleological approach* (Van

[73] Dretske: 1981.

Gulick,[74] Millikan,[75] Dretske[76]) does not overcome the effects of the disjunctive problem; on the contrary, it entails that symbols have no determinate content, as there is no objective way to justify the preference of one of proper functions to the other for determining the content of symbols. According to Fodor, the strategies that recur to learning period, optimal circumstances and proper function do not specify (in non-intentional terms) the circumstances in which the tokening of a LOT symbol is caused by the kind of property which that symbol expresses. Then, to solve the disjunction problem, Fodor credits his theory of content, which can be formulated in this way:[77]

A representation *R* expresses a property *P* if:

- it is a law that *P* causes *R*;
- if *R* is also caused by *P**, then this causation is asymmetrically dependent upon the causal relation between *P* and *R*;
- that one causal relation is asymmetrically dependent upon another means that you can break the former without breaking the latter, but not the other way round.

Here the causal relation between cows-on-dark-nights and 'HORSE' tokens depends, asymmetrically, upon the relation between horse and 'HORSE' tokens. In other words, cows-on-the-dark-night can cause tokenings of 'HORSE' if and only if there are horses that cause tokenings of 'HORSE'. Hence, the existence of the former kind of relation depends on the existence of the latter kind of relation, but not vice versa.

5. 5 A non-atomistic approach: Conceptual Role Semantics

Above I dealt with some influential atomistic approaches. As I said, both Fodor's theory of content and informational semantics endorse the view that the meaning of primitive non-logical symbols cannot be determined by causal relations between linguistic or mental symbols. The resulting semantics of these approaches is in contrast to that suggested by the non-atomistic theory called *conceptual role semantics*,[78] according to which every symbol or concept that belongs to a system of meaningful items inherits its content from the distinctive relations it bears to other symbols. Following this view, we cannot have any particular concept unless we possess a whole battery of concepts related to it. For example, to grasp the concept of HORSE we need to have in our mind the concept of ANIMAL, so that we can infer from the thought '*x* is a HORSE' the thought '*x* is an ANIMAL'. Conceptual role semantics locates the meaning in the relations that symbols have to one another or, more broadly, in the way they are related to one another, to sensory

[74] Van Gulick: 1980.

[75] Millikan: 1984.

[76] Dretske: 1988.

[77] Fodor: 1990.

[78] Sellars 1963; Block 1986; Field 1977; Lycan 1984.

input, and to motor output. This non-atomistic approach tries to explain the content of mental states on the grounds of epistemic-causal relations that members (concepts and thoughts) of the same conceptual scheme bear to one another, to sensory inputs and to motor outputs.

However, conceptual role semantics was attacked by Fodor because it involves *holism*, the extreme logical non-atomist position that the content of concepts, or symbols, is entirely determined by the relations that meaningful items bear to each other in one's linguistic/conceptual scheme. For Fodor, holism has complications that may undermine the viability of intentional psychology because it does not exclude the possibility that two individuals, or time slices of the same individual, have different concepts or intentional states. Consider the following example, there are two individuals, '*x*' and '*y*', who are alike as regards their beliefs about dogs but in the following: *x* believes that dogs are dangerous, while *y* believes that they are not. As the symbol 'DOG' is causally linked to the symbol 'DANGEROUS' only in *x*'s brain, then 'DOG' plays a different causal role for *x* and for *y*. The differentiation between *x*'s belief (that dogs are dangerous) and *y*'s belief (that dogs are not dangerous) would lead to the holistic conclusion that symbols or concepts of the same distinctive language might not be equivalent in meaning. Fodor thinks that conceptual role semantics makes the laws of intentional psychology explanatorily inefficacious.

Another objection regarding computational role semantics concerns the inadequacy of this account to explain the *compositionality* of mental content.[79] On Fodor's view, the productivity and systematicity of thought provide evidence for the assumption that concepts are compositional. According to CTM, complex concepts are compositional since the content of a mental token is determined by the token's symbolic constituents and syntactic structure, that is, by the way the constituents are combined. Conversely, computational role semantics individuates the content of a LOT symbol on the basis of the causal role it plays in one's conceptual scheme. But Fodor argues that the determination of the content of a LOT symbol is not a matter of individuating its causal role. Accordingly, unlike mental and linguistic symbols, causal roles are not compositional. This objection to computational role semantics echoes Fodor's attack on the *prototype theory*, according to which, the prototype of a complex concept is not determined by the prototypes of its constituents. As neither causal roles nor prototypes are compositional, they cannot then be compared to concepts or thoughts.

[79] Fodor and LePore: 1992, chap. 6.

6

Mental Causation

6. 1 The problem of Mental Causation

In the previous chapter I introduced the issue of mental representation as the question of how the mind obtains a mental representation, or how inner mental states come to represent the particular external object, event or facts they do. Now I want to talk about another general issue of intentionality: the problem of *mental causation*. In the debate of cognitive scientists and philosophers of mind, the term 'mental causation' applies to causal transactions involving mental events or mental states. Although this term is generally used to refer to cases in which a mental state causes a physical reaction, it relates to two distinct viewpoints. On the one hand, there is the 'phenomenon' of mental causation that covers cases in which the causal transaction occurs just among mental states themselves, such as when we entertain a series of thoughts in planning, remembering, solving a problem, and so on. The phenomenon of mental causation is thoroughly commonplace and regularly involved in our daily life; it is fundamental to our performance of intentional actions and central to the concepts of agency, free will, and moral responsibility. Our performances of intentional actions are something that we do intentionally, like when we wink to catch someone's attention; while our involuntary actions, such as bodily motions, are performed without the occurrence of intentional processes. It seems that mental states are the direct causes of intentional actions, but if the phenomenon of mental causation seems obvious enough, the 'explanation' of how it occurs is far from being obvious. From an explanatory viewpoint, mental causation is the problem of making intelligible the very idea of representation in naturalistic terms, and thus the problem of explaining how mental events can cause physical actions, or have causal effects on physical events. Originally, this problem was formulated in terms of explaining how immaterial minds, or souls, can interact with the body. Although nowadays philosophers of mind and cognitive scientists repudiate the Cartesian conception of soul, the problem of mental causation has not gone away, since there has been a shift in focus from the individuation of mental substances to the individuation of mental *properties*. In fact, the question of how mental properties can be causally relevant to bodily behaviour encounters certain putative marks distinctive of mental states, which pose problems for the mental states' capacity to wield causal powers. In this final chapter I will examine this issue in relation to some sub-categories of problems, including: the property-based problem; the problem of anomalism (the question of how to conform to law-like regularities), the problem of externalism (the question of how mental states are extrinsic to the agent's body), and the problem of causal exclusion (the question of how mental states are supplanted by brain states).

6. 2 The Property-Based Problem

The main assumption that had generated problems for mental causation comes from the perspective of dualism. We have already encountered this doctrine in chapter 1, where I introduced the fundamental distinction between mental phenomena and physical phenomena. As I said, dualism was affirmed in the modern age thanks to the reflection of Descartes, who still represents the classic source for defences of this perspective. While the dualist claims that the mental is not reducible to the physical, the reductive materialist thinks that mental phenomena are nothing more than species of physical phenomena consisting of physical substances, properties and laws governing behaviour. As opposed to the dualist, the reductive materialist does not face the problem of mental causation because he treats mental causation as a form of physical causation. This problem is central to the framework of the dualist, whose perspective comes in two principal versions: *substance dualism* and *property dualism*. Standard discussions also divide the issue in terms of traditional and contemporary problems of mental causation.

Substance dualism is (the classic perspective that derives from the Christian tradition) the claims that every individual consists of both a body and a soul that can survive the destruction of the body. With Descartes, substance dualism found its full and developed formulation, taking the name of Cartesian dualism, the doctrine that the mind and the body each constitute their own substance. In Cartesian dualism, a substance is everything that can logically exist on its own, that is, everything that can be coherently conceived without having to conceive of it with anything else, whereas things that are not substances necessarily need to be a part of something else in order to exist. Regarding the mind, Cartesian dualism postulates that it has no physical features (such as shape, location, mass, and so on) and so no physically detectable qualities. In turn, the body has no mental features: it cannot think, feel or perceive. Until the nineteenth century the problem of the efficacy of mental phenomena was still engaged with the presumed interaction between spiritual and material substances. But the denial of the Cartesian 'first-person' perspective (the view of ourselves from the inside of our minds that pictures human individuals as immured within their minds, even though they may infer what goes on outside their minds and imagine their minds disembodied) and the pressing acceptance of physicalism facilitated the other form of dualism called *property dualism*. This perspective allows for the brain to think, feel and perceive, as it claims that thoughts, feelings, and perceptions are instances of mental properties not reducible to physical properties. Accordingly, a single physical property can occur in many different substances, for example, snow and bones share the physical property of whiteness (unlike substances, properties are repeatable). On the other hand, a mental property can occur in many different mental states, like beliefs and desires amongst other *propositional attitudes*, as well as sensations, pains, or itches, which are all irreducible to the physical. We may clarify the difference between substance dualism and property dualism in these terms. Philosophically speaking, a *substance* is something that belongs to its specific ontological category and must be distinguished from its attributes or *properties* (but also from its *states*, which are things having a property at a specific time; which in turn must be distinguished from *events*, which are 'particulars' with temporal parts). If substance dualism takes the mental and the physical as two different categories of substances, conversely, property dualism takes the mental and the physical as two different *properties* which belong to one and the same substance.

6. 3 The Anomalism Problem

If in the last century the problem of mental causation was characterized in terms of the contraposition between substance dualism and property dualism, contemporary discussions divide the issue into three principal problems: *anomalism*, *externalism*, and *causal exclusion*. I begin here with the major problem for the causal relevance of mental properties, the anomalism problem, which arises from the contraposition between three different assertions.[80] Although this problem has its origin in Davidson's argument of *anomalous monism*, it has been acknowledged by other philosophers, and most explicitly by Kim.[81]

Davidson's argument of anomalous monism tries to render consistent the following apparently inconsistent set of statements: the *principle of causal interaction*, the *principle of nomic subsumption*, and the *principle of anomalism of the mental*. Each statement is independently plausible, but taken together they generate an inconsistency. Generally, on a view of causal relevance a property is causally relevant only if it is nomically subsumed, that is, only if it appears in a strict law. According to the principle of nomic subsumption, all states that events relate as causes and effects fall under strict deterministic laws. This means that a cause has the capacity to produce an effect only in virtue of a law-like generalization that applies to that effect. Suppose we have two different types of events. Take the event *c* to be of the type *F* (*c* has the property *F*), and the event *e* to be of the type *G* (*e* has the property *G*); then, property *F* is causally relevant to property *G* only if there is a law to the effect that events of type *F* cause events of type *G*. On the other hand, the *principle of causal interaction* is the statement that mental causation occurs when (at least) some mental events causally interact with physical events. But the basic root of the anomalism problem is the *principle of anomalism of the mental*, a statement that includes all the generalisations of folk psychology. Accordingly, there are no strict deterministic laws on the basis of which mental events we can predict or explain, because, there are no laws which connect mental properties with physical properties. If strict laws are necessary for causal interaction (nomic subsumption) but no law couches in mental terms (psychophysical anomalism), then mental events cannot have causal powers (as opposed to causal interaction). Davidson endeavors to solve this inconsistency with *token physicalism*, the view that mental events are causally efficacious by virtue of some token-identity with causally efficacious physical events. However, Davidson's construal of causation was roundly criticized with a number of pressing objections, and his endorsement of token physicalism has been interpreted as leading to *epiphenomenalism*, the view that mental properties are causally irrelevant.[82]

6. 4 Epiphenomenalism and some hypotheses of solution

The threat of epiphenomenalism posed by the argument of anomalism can be summarised as: if only properties that appear in strict laws are causally relevant (nomic subsumption), but mental properties do not appear in strict laws (anomalism), mental properties are not causally relevant at all (epiphenomenalism). To avoid epiphenomenalism various strategies have been pursued.

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[80] Davidson: 1970.

[81] Kim: 1989.

[82] Antony: 1989; Kim: 1989b, 1993c; LePore and Loewer: 1987; McLaughlin: 1989, 1993.

Some suggest returning to *ceteris paribus* clauses; this strategy maintains that mental property *M* of event *f* is causally relevant to physical property *P* of event *e*, if and only if, there is a strict causal law connecting *M* with *P*, or a non-strict law connecting *M* with *P*. However, it might be objected that *ceteris paribus* clauses may render laws vacuous, and that we thus need to replace such clauses with explicit statements that make reference to strict laws.[83] Another more radical objection is that mental properties are not the kind of properties that appear in laws, strict or otherwise. Some considerations have been availed in support of this skeptical view, in particular, those made by proponents of *simulation theory* (the view that mental states are attributed to an agent by placing one's self in the agent's situation, that is, a psychological process that does not require the existence of mental laws).[84] But others assume that despite the fact that mental properties may be the kind of properties that appear in laws, they cannot avoid the problem of *causal exclusion*.

Another way to solve the anomalism problem was suggested by LePore and Loewer,[85] and Horgan,[86] who try to capture the causal relevance of mental properties by recurring to *counterfactuals*. According to the strategy of *counterfactual causal relevance*, the effect is counterfactually dependent upon its cause, in the sense that a mental property is causally relevant only if its non-occurrence means that the effect also would not have occurred:

property *M* of event *c* is causally relevant to property *P* of event *e* if:

- a) *c* causes *e*;
- b) *c* has *M* and *e* has *P*;
- c) if *c* did not have *M*, then *e* would not have had *P*;
- d) *M* and *P* are metaphysically independent.

The appeal to causation in a) does not render this partial analysis circular because the analysis is for causal relevance, not causation per se. If condition b) highlights the role of properties in causal transactions, condition c) states the counterfactual relation between the properties that allegedly suffices for one's being causally relevant to the other. Conversely, condition d) comes from the Humean view that logically or metaphysically connected properties cannot stand in a causal relation, and so it is given to ensure that *M* and *P* are candidates for causal relevance. However, some criticized this strategy because the mere holding of counterfactuals does not secure the causal relevance of mental properties. Accordingly, the counterfactual dependency of bodily motion *G* upon mental properties *F* is not exhaustive since it does not suffice for *F*'s causal relevance to *G*.[87]

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[83] Schiffer: 1991; Fodor: 1991b.

[84] Heal: 1995.

[85] LePore and Loewer: 1987, 1989.

[86] Horgan: 1989.

[87] Braun: 1995; McLaughlin: 1989, p. 124; Kim: 2006, pp. 189 – 194.

6. 5 The Exclusion Problem

Another problem with the causal efficacy of mental states is the *exclusion problem*, which can be introduced in the following terms. Mental states bring about behaviour in virtue of the causal role they play in psychological processes; nonetheless, the states of our neurophysiological system seem to be fully sufficient to bring about all bodily motions. If the neuronal correlates of mental states were fully equipped to perform all the causal work, it is unclear what role mental states should have given. If physiological facts are definitely sufficient to account for action, mental states are then superfluous. The *exclusion problem* points out the presumed causal and explanatory irrelevance of mental states, because brain states make them superfluous. It can be laid out as follows:[88]

1. *Exclusion*: If a property *F* is causally sufficient for a property *G*, then no property distinct from *F* is causally relevant to *G*, barring overdetermination.
2. *Closure*: For every physical property *P*, there is a physical property *P** that is causally sufficient for *P*.
3. *Dualism*: For every mental property *M*, *M* is distinct from *P**.

4. *Epiphenomenalism*: For every physical property *P*, there is no mental property *M* that is causally sufficient for *P*.

The scheme above does not subscribe to any particular view about the nature of causation or its relationship to laws, but just invokes metaphysical considerations on the largely held physicalist principle of *causal closure*. The simple reference of this principle is that the physical realm is causally closed, complete and comprehensive, in the sense that, all phenomena that inhabit it necessarily have a prior physical story. This highly intuitive claim entails that every special sciences force, law or generalisation can be classified on the basis of physics. So every special science would be delimitated to a specific domain of objects, events, properties and states of affairs, having its own theoretical vocabulary delimitated to a respective range of phenomena. However, psychology does not seem to satisfy this condition, because mental properties can hardly be reduced to physical properties, neither can mental causes be equated with physical causes. To avoid epiphenomenalism, the view that mental states and events play no role in causal chains, several strategies have been pursued:[89]

- *Reduction Strategy*: For every mental property *M*, there is a physical property *P* with which *M* can be reductively identified.

- *Supervenience Strategy*: mental properties supervene upon physical properties, and supervening properties can be causally relevant if their base properties are causally relevant.

- *Realization Strategy*: mental properties are realized by physical properties, and mental properties are causally relevant if their realizing base properties are causally relevant.

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[88] Yablo: 1992, pp. 247 – 248.

[89] Kim: 1989a, 1990.

- *Dual Explanandum Strategy*: there are different ways to explain how *M* and *P* are causally relevant.

I will report these principal lines of response to the exclusion problem.

6. 6 Reductive Strategies vs. Non-reductive strategies

Unless we opt for mind-body dualism (the view that in no case mental properties can be reduced to physical properties) we need to individuate which physical and intrinsic facts are determinant to individuals' mental experiences. How does psychology, whether scientific or folk psychology, classify mental states on the basis of properties that crucially depend on physical properties? In principle, there are two ways to relate 'systematically' mental properties to physical properties. The first kind of systematic relation is a strict identity relation between relevant prima facie mental properties and physical properties, and it is usually held by both the identity-theorist and the reductive materialist who state that mental properties are identical to our intrinsic physical properties. However, problems with this kind of relation arise because there is an identity and explanatory gap between mental properties and physical properties. If the type-identity theorist reductively identifies mental property *M* with physical property *P*, conversely, the functionalist argues for the thesis of multiple realizability of mental states and mental properties.[90] According to the functionalist, there are many different physical properties - *P1, P2, ..., Pn* - each of whose instantiation can suffice for the instantiation of its corresponding mental property *M*. Here the upshot is that multiply realizable mental properties should not be identified with, nor reduced to, physical properties (if *P1* and *P2* are distinct realizers of *M*, *M* cannot be identified with either *P1* or *P2*).

An attempt to accommodate the multiple realizability argument is provided by the viewpoint of *disjunctive reduction*, according to which *M* can be reduced to the disjunction of all the physical property realizations (*P1* or *P2* or … *Pn*), so that generalisations of the form "*M if and only if* (*P1* or *P2* or … *Pn*)" hold as a matter of law. Some have objected that the disjunctive reduction is committed to disjunctive properties unsuitable for appearing in physical laws.[91] A variation of this approach called *local reductionism* takes *M* to be reduced to a single physical kind *P* relative to some species *S*, giving us laws of the form: '*S only if* (*M if and only if P*)'. Nevertheless, this account seems to compromise the idea that mental properties are species-invariant, as it holds the claim that mental states might be caused by the same kind of mental properties in humans, Martian, or computers. Another way to preserve the *identity-relation*, while pursuing a strategy that is similar to the ones just sketched, is the *trope strategy*.[92] According to this approach, the term *property* can refer either to what characterizes an object, or to what unifies several objects. Properties that appear in a multitude of different objects are *types*, namely, the unifying properties that all creatures share, whilst *tropes* are the characterizing and particularized instances of properties unique to each object.

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[90] Fodor: 1975, 1980a, 1980b; Putnam: 1960.

[91] Armstrong: 1978, 1983.

[92] Macdonald and Macdonald: 1986; Robb: 1997.

Unlike tropes, types are repeatable, but they are not taken to be the sort of properties efficacious in the production of behaviour; this role is occupied by tropes. The essential idea underlying the trope strategy is that it is not mental properties that are reduced per se but rather their instances or tropes, so *m-trope* and *p-trope* are taken to be one and the same trope falling under two types: the mental and the physical. However, one might reasonably ask if tropes are causally relevant in virtue of their being mental tropes as opposed to their being physical tropes. Apparently, the same underlying epiphenomenalist implications that plague Davidson's token-physicalism can be raised for the trope approach.

On the other hand, the second kind of systematic relation is a relation of non-causal determinations among distinct families of properties, including mental properties, that metaphysically supervene upon physical properties. The *supervenience relation* entails that every change, or difference, which occurs in a mental property necessarily supervenes upon some change that occurs in a physical property:

> "Necessarily if something has any mental property M, there is a physical property P such that the thing has P, and necessarily anything with P has M; where the notion of necessity in play is taken to be metaphysical necessity."[93]

This second kind of systematic relation is held by non-reductive physicalists. Despite ensuring a sort of causal dependence between the mental and the physical, it risks being threatened by the principle of causal closure. If the physical realm is causally 'closed', everything occurring in it must have a physical causal ancestry that is sufficient for its occurrence. This essential condition is required for the very wide range of properties accounted for by the typical methods of special sciences; nevertheless, mental properties do not intuitively satisfy such a condition. If it is true that mental facts supervene upon physical facts, then for any given mental event, there might be two possible causes which are both responsible for the occurrence of that event. But this claim violates the principle of *no over-determination*, according to which no event can be determined by two or more causes. The contradiction might be avoided if we assume that mental properties are realized in, or constituted by, physical properties that lay the ground for their occurrence. However, Kim has argued that the thesis of multiple realizability requires that physical effects are over-determined.[94] His argument for explanatory/causal exclusion threatens the assumption that mental properties are irreducible entities.[95] Accordingly, the assumption that mental-functional property *x* is realized, or instantiated, into a system *S* in virtue of its having the physical property *y* entails that the effect produced by *S* has two possible and independent causes: the mental property that causes *S*'s action, and the physical property that realizes that mental property. Unless we assume that *x*'s functional role is excluded by the work carried out by *y*, *S*'s behavior will be systematically over-determined. Kim draws the conclusion that non-reductive physicalism relies on mental properties whose explanatory-causal relevance is systematically excluded at the fundamental physical level, whilst reductive materialism can avoid epiphenomenalism.

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[93] Kim 1998, pp. 38 – 46.

[94] Kim 1998, pp. 77-87.

[95] Kim 1993, p. 281.

6. 7 The Dual Explanandum Strategy

The problem of exclusion presents us with the picture that physical properties alone are sufficient to produce some behaviour, and thus mental properties must either find a way to do the work that their physical realizers already do or face exclusion. An attempt to preserve causal relevancy of mental properties from a non-reductive viewpoint can be found in Dretske, who believes that mental properties enjoy causal relevance in their own right without being threatened by exclusion. On Dretske's view, the mental and physical are causally relevant to different properties of the effect. Although psychological and physical explanations accomplish different theoretical objects, such objects are not in competition with each other because the causal relations they track are themselves different relations.

The line of thought underlying Dretske's *dual explanandum strategy* is that causation cannot be separated from the explanatory schemes that are expressed in it.[96] Every event is supposed to have two causes that satisfy different types of explanatory interests. The *triggering cause* is the kind of cause explained by physical explanations. It tells us *how* a behaviour came about but does not explain *why* an individual performs that particular behaviour instead of others. Conversely, the *structuring cause* gives us this explanation. Let me clarify the difference between these two kinds of causes with a simple example. Consider a simple mechanic artifact, like a thermostat programmed to turn on the furnace when a certain temperature is registered. The thermostat's performance that switches the furnace on due to the cool temperature of the room is something that occurs due to the triggering cause, while the wires connecting the thermostat to the furnace are the set of pre-existing background conditions that allow for the triggering cause to exert that particular effect, that is, the structuring cause. Dretske assumes that, just as the thermostat relies on internal sensors calibrated to turn on the furnace when a particular temperature is registered, individuals rely on an internal representational system coordinated with the motor system to trigger the appropriate bodily movement when an internal state occurs in it. A strength of the dual explanandum strategy is that it takes mental properties and their physical realizers to be part of separate and autonomous causal lines, although this account maintains an unique *explanandum* for both explanations. But the claim that an act of behaviour has a mental origin that is compatible with, but is equally irreducible to, a physical origin is ambiguous. The assumption that an effect can be produced twice, once directly by M and another indirectly by P, entails that it is systematically over-determined. According to Kim, epiphenomenalism would in any case ensue from the problem of explanatory exclusion. Even if putative mental causes can determine the subject's actions, psychological explanation of a non-reductive type cannot give a different causal story than that operating at the neurophysiologic level. All the causal work is done at the neurophysiologic level, so there is just one real causal explanation that provides the real causal story.

6. 8 The Externalism Problem

Another version of the problem relating to the causal relevance of mental properties is the *externalism problem*. So far as we have assumed that mental properties are properties in virtue of

[96] Dretske: 1988, 1989.

which mental states have a *content* which represents some aspects of physical reality and which figures in the production of behaviour. Mental states have causal powers that cohere with their content, and the causal processes which involve them are typically rational. Basically, we can distinguish between two different kinds of mental content. On the one hand, *narrow content* is content entirely determined on the ground of the agent's intrinsic properties; on the other hand, *broad content* is content determined on the grounds of the agent's extrinsic properties. The dichotomy between narrow content and broad content gave rise to two different semantic theories.

Internalism is the theory of content that assigns mental causation to an individual's intrinsic properties. The internalist argues for the thesis of *local causation*, assuming that a thing can have causal power (some capacity, or *disposition*, to produce effects) exclusively on the basis of its intrinsic features. Though facts about the environment might affect one's actions they have causal relevancy because they supervene upon intrinsic facts. Conversely, *externalism* individuates the content responsible for behaviour on the ground of causal, social, and historical relations that people bear to their surrounding community. The externalist rejects the thesis of local causation in favor of the thesis of *broad causation*; he refuses to accept the claim that meaningful states owe their meaning to their intrinsic make-up because, on his view, the content of our thoughts is extrinsically rendered. According to this view, besides the kind of neurological causation involving bodily motions, there is a kind of mental causation individuated on the basis of broad content. But if causation involves intrinsic features of physical objects and events, it is difficult to see 'extrinsic' mental properties as genuine causes of physical actions. How could content individuated by extrinsic mental properties make causal difference? The problem with externalism is that, whenever we try to explain behaviour by appeal to extrinsic content there is a local and intrinsic property that is available as a 'causal surrogate' to produce that behaviour. The principle of completeness entails that physical causes and physical effects are either spatially connected to each other, or mediated by things that spatially link them together. Actions which are physically disconnected from their causes cannot be possible, and this point alone highlights the externalist problem: since intrinsic surrogates are always needed for mental causation, why should we assume the causal relevance of broad external content?

6. 9 The 'Twin Earth Argument'

Hilary Putnam has proposed one of the most prominent arguments in defense of causal efficacy of broad content. His *twin earths argument*[97] was designed to establish natural externalism of linguistic and mental content individuated on the ground of external mental properties. The argument begins by determining the content of reference of the very familiar word *water*. Imagine the existence of a 'twin earth' perfectly identical to Earth except that instead of a physical substance called *water*, and defined using the chemical compound of 'H_2O', on this 'twin earth' there is a similar substance with many common features and functions. Like water, this substance is drinkable; falls from the sky; fills lakes, rivers and oceans, and so on. However, it has a different chemical compound, for example *XYZ*. This 'twin earth' is also populated by individuals perfectly

[97] Putnam: 1975.

identical to us who share most of our intrinsic and indistinguishable properties. For example, they are competent users of sentences of English and use the term *water* for the substance '*XYZ*', ignoring its intrinsic physical structure. But if in 1750 an earthling mysteriously found himself on twin-earth and were confronted with the substance *XYZ*, he would have probably used the term *water* for *XYZ*. Since *XYZ* and H_2O are quasi identical but distinct physical entities (having many common observable characteristics), even in the counterfactual case of the twin-earthling he would have probably used the term *water* for H_2O. The earthling and the twin-earthling share exactly the same intrinsic properties, and their beliefs should therefore be identical too. Nevertheless, these intrinsically identical individuals use the same term for completely different things: when the earthling utters *water* his utterance refers to H_2O; whereas, when the twin-earthling utters *water* his utterance refers to *XYZ*. Therefore, the utterance of *water* has different content for intrinsically identical individuals. From this Putnam concludes that linguistic or mental references are extrinsic to the agent's body, because mental or linguistic meaning fails to supervene upon the agent's internal properties.

Putnam's argument seeks to prove the thesis of *natural-kind externalism*, the view that natural environment is fundamental for realizing the mental properties responsible for actions.[98] According to Putnam, different things can have an identical *natural kind*. A natural kind is the kind of thing which items such as H_2O and *XYZ* share, it is a common nature which is not directly observable but which provides us with an account of observable properties exhibited by different items. On Putnam's view, when we have thoughts about natural kinds we often do not know anything about an object's essential features. Rather, it is the meaning of words we routinely use in our environment that transfers over to the content of our thoughts. So the meaning of our thoughts cannot be restricted to the object's internal factors. A variation of this view known as *social externalism* was proposed by Burge.[99] Social externalism claims that social institutions play a role in determining the content of our thoughts about many kinds of things, including those that do not involve natural kind concepts. This view stresses the contribution made by social environment in which some individuals are more expert than others about what is (and what is not) included in the concepts mentioned above, and it takes the meaning of thoughts to depend on intrinsic properties plus our social expert opinions.

6. 10 Broad Causation vs. Narrow Causation

Above I reported one of the greatest arguments for *wide causation*, now I want to turn to Fodor's argument for *narrow causation*.[100] Fodor's *conceptual role* (or *procedural-semantics*) *approach* is committed to individuating the content of mental representations underlying mental causation on the basis of intrinsic properties. Although Fodor does not exclude mental states having broad

[98] Putnam : 1975, p. 227.

[99] Burge: 1979, 1986.

[100] Fodor: 1987, chap. 3.

contents (contents which stand in some complex environmental relations to our surroundings), he argues that a notion of 'narrow content' is necessary for psychology.

Fodor's argument can be reported in these terms. Suppose you insert a quarter of dollar into a vending machine. The coin inserted has a wide range of intrinsic properties, such as size, colour, design, texture, and so on, which are all common to whatever coin is accepted by the vending machine. Furthermore, it has a wide range of external properties such as value, provenance, individual history, and so forth. According to Fodor, properties that stand in some kind of relation to external facts do not affect the vending machine, so the coin's extrinsic properties (like its provenance or history) are causally irrelevant to the actions it performs. Conversely, the coin's intrinsic properties, like its size, design, or texture, are properties that can affect the behaviour of the vending machine. Fodor argues that the mind works like a vending-machine: it has either extrinsic or intrinsic properties, but produces responses only to the incoming stimuli coming from the latter. According to him, narrow content is the kind of content that supervenes upon the intrinsic make-up of physically identical individuals. If taken in the same environment, the earthling and his duplicate will achieve parallel results despite having different wide contents, and this is because their thoughts have always the same narrow content with the same casual powers. Fodor explains this common psychological aspect by assuming that the kind of mental content that supervenes upon the agent's *intrinsic* properties has the right kind of internal functional role to produce identical effects. Then he proposed a *criterion of causal relevance* defined on the basis of pattern of counterfactual dependence which cannot be satisfied by contents externally individuated:[101]

-property *M* is causally relevant to behavior *B* if only if:

- when *M* has failed to occur, then *B* has not occurred;
- when *M* has succeeded in occurring, then *B* has occurred.

In a later essay Fodor partially modified his internalist view, assuming that broad content cansatisfy the criterion of causal relevance, but that we have to distinguish extrinsic properties that affect twin-individuals' causal powers from extrinsic properties that do not.[102] However, in still more recent works, Fodor argued that the notion of narrow content is probably not needed in psychology.[103]

6. 11 Dretske's causal-informational theoretic approach

A very different way to preserve the casual role of broad content can be found in Dretske's *causal informational theoretic approach,*[104] which reinforces the externalist view that most of the contents of mental states and representations postulated by folk psychology turn out to be wide contents.

[101] Fodor: 1987, chap. 2.

[102] Fodor: 1991.

[103] Fodor: 1994, 1998.

[104] Dretske: 1988, 1989, 1993.

This approach makes reference to the *dual explanandum strategy*, maintaining an implicit dependence between 'causal' and 'explanatory' relevance. The dual explanandum strategy is quite powerful since it promises to solve two outstanding problems of mental causation, the exclusion problem and the externalism problem, assuming that causation cannot be separated from the explanatory schemes of *triggering causes* and *structuring causes*. Accordingly, intrinsic physical properties are the triggering causes responsible for bodily motions (as they *trigger*, or *initiate*, a process ending in some bodily movement), whereas mental properties are the structuring causes responsible for the causal processes that constitute instances of behaviour in the brain. On this view, behaviour is a physical process that includes, as a component, its mental cause: if wide mental properties have a causal role for the fact that a mental event *x* can cause a process ending in some bodily event (movement) *y*, then behaviour can be understood as the whole process of *x* causing *y*.

Dretske argues that wide content becomes causally relevant to behaviour because there is a "counterfactual" or "informational" dependence between mental states and facts about the environment. Therefore, the theoretical connections between mental and behavioural descriptions point to a kind of *explanatory* relevance.[105] Nonetheless, this assumption gives rise to a couple of questions.[106] We might ask if these causal connections really have causal relevance, given that the apparent relevance of the broad properties is already obtained by the narrow physical properties. If narrow properties do all the work in the description and explanation of behaviour, mental states underlying causation are sensitive to the local, intrinsic agent's features. Then, our conceptualization of both causes risks being an illusion created by the way we try to assign causal, or explanatory, relevance to broad mental properties. This scenario motivates the original epiphenomenalist arguments that mental content under externalism fails to supervene upon the agent's intrinsic internal properties. Another question to raise here is whether intentional states deliver the kind of causal relevance we need. The physical and the mental are supposed to produce different properties of the effect. When an individual raises her hand, the structuring of the relevant processes in her brain presupposes a *rationalization* of the hand-raising behaviour by means of the agent's beliefs, desires and intentions. We expect the mental structuring processes that cause the hand-raising behaviour to be relevant by virtue of our intentions, but this behaviour may be the result of the physical triggering processes alone, that is, the result of the unconscious and automatic processes which occur in the brain.

To summarise, in this final chapter I dealt with the multiplicity of problems surrounding the issue of mental causation: the problem of anomalism, the problem of externalism, and the problem of exclusion. After alluding to the established relations between physics and special sciences, I examined psychology as revealing the very features (including multiple realizability, higher-level and *broad* properties) that look at actual scientific practices and determine what science requires for acceptable causal explanation. Beyond the conceptions of causation routinely invoked in scientific causal explanations, the issue can be treated as a problem in applied metaphysics. Metaphysicians are inclined to tinker with an a priori conception of mental causation, posing apparently insuperable difficulties by recurring to *truthmakers* for psychology. Realism about the mental requires that

[105] Dretske: 1981; Stalnaker: 1993.

[106] see Fodor: 1991; Burge: 1995.

mental predicates figuring in causal accounts of behavior designate distinctively mental properties. The metaphysician has the goal of preserving *mental truths* instead of mental properties. On his view, truthmakers for psychological truths include the irreducibility of mental properties, and he seeks to give plausible truthmakers for psychological and psycho-physical claims, including claims about mental causation. However, the purview of the metaphysician might stand in contrast to our actual scientific beliefs and practices. If the aim of psychology is to show how mental properties can be causally relevant to physical occurrences, then our conception of causation needs to fit the explanations typically invoked in sciences that fall under physics.

7

A brief conclusion to discourse of Intentionality

In the first part of my dissertation I engaged in an examination of the most thoroughly canvassed approaches to the theories and problems of intentionality in philosophy and psychology. Starting from the origins of the concept of intentionality, I introduced Brentano's account and the principal philosophical commitments to intentionality over the last hundred years. After this, I turned to the birth of scientific psychology and explored the scientific background that led to the cognitive revolution, and stressed the emerging field of study of cognitive sciences and the philosophical approach pioneered by functionalists. So far we have learnt that in the nineteenth century Brentano argued that intentionality is the mark of the mental. However, Brentano's thesis that intentionality resists naturalization was echoed in the twentieth century. In the middle of the twentieth century functionalists and psychologists searched for a way for mental phenomena to be naturalized, and the problem of intentionality thus became the problem of explaining the mental in naturalized terms.

In introducing functionalism, I said that it is a philosophical theory about the nature of mental states and mental processes which involves two major commitments: the explanatory and descriptive practice of folk psychology, and the metaphysical doctrine of physicalism. Yet the physicalist philosophers Feigl,[107] Oppenheim and Putnam[108] provided formulations of valid arguments in favour of the dominance of physics for special sciences, including psychology which must reflect the methods of modern sciences. In almost the same historical period as functionalists were carrying out their research programme, the cognitive revolution marked the birth of the interdisciplinary study of the mind known as 'cognitive sciences', in which the results of research conducted by cognitive psychologists, proponents of artificial intelligence, theoretical linguists, neuroscientists and philosophers converged. With the advent of the cognitive revolution, psychologists came to change their conception about the research focus of their disciplines. Shifting their central concern to that of explaining intentionally characterized cognitive capacities, cognitive psychologists postulated that the explanation of such capacities requires an appeal to central representational states and processes. Therefore, as I explained, the proposal of cognitive psychologists coheres with that of functionalism, since they both reached similar results. While endorsing the commitments of intentional psychology and physicalism, functionalists were expected to account for the intentional properties of psychological states by resorting to causal explanations similar to those used to explain the kinds of properties typically recognized by non-intentional special sciences. The central aim of functionalists was to point out the problem of establishing how and to what extent the contents of our intentional states can be ultimately determined by their physical properties. Functionalism, which can be traced back to the work of those philosophers of mind, received its canonical treatment in the work of Jerry Fodor, who developed the nativist view of Noam Chomsky. Fodor gave an account, defined in rounded terms and modern dress, of the most

[107] Feigl: 1958.

[108] Putnam: 1958.

fundamental issues of psychology and philosophy of mind, including those of mental representation, computation, innatism, realism, and mental efficacy. He also was engaged with providing a naturalistic theory of the content of intentional states, a theory that appeals to the non-intentional properties recognized by natural sciences.

Thus, the naturalization project is the project of construing a scientific psychological framework able to successfully account for the intentionality of mental states and mental processes. A theory of intentionality defined in these terms would demand the possibility of defining intentional properties as properties that can be reduced to or supervene upon physical properties, and would entail acceptance of the thesis that intentionality, or the 'mental', does in some way inhabit the physical domain. This claim clearly challenges Brentano's thesis that the physical cannot generate intentionality, but not his thesis that intentionality is the mark of the mental. In the last two chapters, I identified two general questions concerning the intentionality of our mental activity, and I therefore discussed the much-debated problems of mental representation and mental causation, and reported some ontological and epistemological consequences for research in developmental and comparative psychology. The former problem concerns determining the *form* of our mental representations. Generally, from the perspective of folk psychology, to understand representation is to understand representational states of mind. We have seen that folk psychology is a theory of mind that claims that what people know about the mind is related to the way they apply conjectures about other people's minds to explain their behaviours. When we apply a theory of the mind we recur to a theory that helps us to answer the following question: what do we know about the mind? Folk psychology claims that beliefs, desires and thoughts are states of mind representing the world and having effects in it, because a state that represents the world causes its possessor to behave in a certain way. Based on this assumption, the functionalist thinks that the theory of mind postulated by folk-psychology is one that can be applied to human beings, animals or computers: as our knowledge of thoughts is derived from behaviour, then it is (in principle) possible to apply the basic elements of common-sense psychology to other beings too.

Concerning the question of determining the *form* of mental representations, this question unleashes a dispute about whether all mental states are representational; that is, whether all mental states exhibit intentionality. Thinkers who reject Brentano's view argue that not all mental states are representational, since there are mental states, like pain and bodily sensations, which have non-representational properties. Generally, non-representational mental states are defined in terms of *qualia*. According to some identity theorists, at least some types of mental states, including those states like pain or the taste of an apple, ought to be identified with particular types of brain states. On this view, similar to the way that lightning is identified with electrical discharge, or water with H_2O, these identifications would be necessarily a posteriori. On the other hand, the view of *representationalism*, or *intentionalism*, takes all mental states (in all their aspects) to be representational in nature. I discussed representationalism in relation to the mind-computer analogy, explaining that this view tries to provide a very influential contemporary answer to the question of the *form* of mental representation by assuming that the brain functions like a Turing machine which processes representations in a systematic way. A central assumption of the mechanical view is that the mind is a natural part with a regular, law-governed causal structure, which is a *computational* structure because some mental states and processes are computational. Even if computation can be understood in terms of representations, only those mental states which are purely representational can be candidates for being computational states. In principle, the more plausible examples of computational states and processes are those which are essentially purely representational in nature. Beliefs and desires, amongst other propositional attitudes, look like the best candidates for being computational states of mind: their essence is to represent the world, and despite often appearing in consciousness, it is not essential for them to be conscious. However, the computational theory of mind is controversial as regards the question of whether pain is purely representational, and equally controversially, whether there can be a purely computational theory of pain.

Thus far we have seen that, the computational theory of mind paints a picture according to which representational states are related to one another in a computational way, similar to the way that a computer's representational states are processed by means of algorithmic rules. The nature of representational states such as belief is exhausted by how it represents the world as being, and the properties it has as a consequence of that. There is no reason to think, from the perspective of commonsense psychology, that intentional states have any properties other than their representational ones. But this claim leads us to the question: can the representational properties of mental states guarantee genuine causation of physical actions? The question introduces the issue of mental causation which, as I said, poses metaphysical arguments for the much-discussed property-based problems, including Davidson's argument of *anomalous monism*;[109] Block's argument against *externalist theories of mental contents*;[110] and Kim's argument of *causal exclusion* of intentional states. These outstanding variations of problems related to mental causation reveal the difficulties arising from the very features routinely invoked in causal explanations of *multiple realizability*, *higher-level* and *broad properties*. The arguments alluded to here regard mental causation with suspicion, suggesting a revision of our conceptions of mental causation, mental properties and causal powers. Worries about mental causation are tied to the question of *how* mental properties can be considered causally relevant to physical effects if they are not identical to physical properties. One of the main reasons for thinking that the whole idea of mental causation is not applicable at the level of fundamental physics concerns the claim that psychology should not be reduced to neurophysiology. Yet even among philosophers who are skeptical about mental causation at the fundamental physical level, there are those who think that causation has a firm place in the special sciences at least. The proposal of those philosophers of mind and cognitive psychologists was to demonstrate a way to link the mental with the physical so that the mental is not causally inept.

The issue of mental causation brings the debate of philosophers and cognitive scientists to the question of the nature of mental representations, that is, the question of *what* it is that cognition covers. But another question arises from the discussions on mental causation, regarding the nature of cognitive architecture and processing, or rather, *how* cognition proceeds. There is simple evidence for the purpose of uncovering the cognitive architecture while subsuming our folk psychological practices under propositional attitudes defined in terms of mental representations. The evidence alluded to in the models developed by the functionalists and the cognitive psychologists can be introduced in these terms. Although the central mental machinery (with which

[109] Davidson: 1969.

[110] Block: 1990.

individuals are equipped) is sensitive to what is relevant in the environment, it has enough complexity to be simply characterized in terms of the mere environment. This simple evidence has inspired those reflecting on the nature of cognitive architecture to separate *classic* from *connectionist* approaches to mental architecture. Proponents of connectionist architectures and, more recently, of *dynamic approaches* to cognition have often introduced their views as avoiding the postulation of the sort of mental representations posited by folk psychology. The connectionist denies there is any structure in terms of representations and identifies the mind with the brain, which consists of a vast network of nodes whose different and variable excitation levels explain intelligent learning. Connectionism has aroused interest especially among those wary of positing significant 'hidden' mental structure not evident in ordinary behavior. In contrast to this form of eliminativism, classicist accounts of cognitive processing explain the nature of the basic design or cognitive architecture of human systems in a totally different way. The classicist endorses the view that 'cognition' is a form of computation that can be explicitly defined in terms of *symbolic manipulation*, that is to say, in terms of mental representations and the employment of functional rules for them. However, we need to be a bit more precise about whether the way *we* think is (partly or wholly) through computing. How do intelligent creatures, in their interaction with the world, process or manage information? How is the information which is managed structured? How should the mind of creatures that manage that information be structured? Such questions are all engaged with the problem of explaining how ideas, or knowledge, reach our minds. In the history of philosophy, this problem has been approached from two opposite poles. On the one hand, the *experiential view* tries to offer a response to the problem by assuming that ideas, and knowledge in general, reach our mind through experience with the world, according to the claim that mind is like a tabula rasa, in which the act of experiencing determines the acquisition of knowledge or ideas. This position is held by *empiricists* and *environmentalists*. Conversely, the *innate view* claims that either ideas or knowledge are already built into the mind at birth (in the 'black box' according to the classicist); this position is held by *nativists* and *rationalists*. From the perspective of cognitive sciences, the question of how the mind processes the information which comes from the external world is related to the issue of the mind's cognitive architecture and organisation.

In the last forty years the study of mental organisation has received special attention from many areas of cognitive sciences. Several studies have focused on exploring the phenomena of production or comprehension of language under the influence of, or by embracing, the experiential or innate views; it is thus no surprise that the philosophical distinction between experiential and innate views reflects, within the perspective of cognitive sciences, the distinction between classical and connectionist theories of the architecture of mind. These principal versions of the computational theory of mind --the classicist approach and the connectionist approach-- correspond to the main proposals that exist about the mind's cognitive architecture. The areas that lend themselves most naturally to the computational theory of mind are those most famously associated with logic, commonsense and practical reasoning, as well as natural language syntax. In particular, research on these topics in cognitive psychology and AI has become deeply intertwined with the classical approach, which is consistent with the hypothesis that the computations take place over representations that possess the kind of logical, syntactic structure which is captured in standard logical form, typically based on Turing machine models. In the first 30 years of cognitive sciences, the computational view obtained its specific formulation following the appearance of the work carried out by the pioneers of AI Allen Newell and Herb Simon. According to their proposed *physical symbol system hypothesis*, a physical symbol system has the necessary and sufficient means for generating intelligent actions.[111] Newell' and Simon's hypothesis takes the heart of human cognitive architecture to be formed by chains of condition-action rules defined over data structures expressed in symbolic terms; their model of cognitive architecture has usually been formulated in terms of explicit computational models that generate *intelligent* behaviors that approximate some aspect of human cognitive behavior. Variations on this general view were predominant in much of AI and psychology until the 1980s, when the types of behavior to which their computational models were applied most extensively were problem solving and reasoning. However, the literature of cognitive architecture has received important contributions especially in the recent years, following the affirmation of the approach based on syntactic rules and mental representations associated with Fodor[112] and Pylyshyn. This classicist approach to cognitive architecture maintains the framework of LOT as computational hypothesis (according to which mental states are computational relations to LOT sentences, and mental processes are computational processes involved in the *manipulation* of such sentences), because it invokes representations that are manipulated or processed according to formal rules. The ambition to preserve the explanatory power of folk psychology, from a viewpoint that takes mental representations to be 'local' as opposed to 'distributed' in their nature, was determinant to the development of the *theory of modularity of mind*. In 1983 Fodor published his book *The Modularity of Mind*, in which he carried out an important psychological study of mental architecture in defence of LOT architecture. As we shall see in the next part, significantly, Fodor's modularity thesis distinguishes the central processing system from the modular processing systems, providing a model of the computational architecture of the mind/brain which is compatible with the naturalized commonsensical account of mentality.

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[111] Newell and Simon: 1972.

[112] Fodor: 1981, 1987.

PART II

Modularity and Time

8

From Intentionality to Modularity

8. 1 The Computational Theory of Mind: a model of Symbol Manipulation

I want to begin the discussion on modularity with the question I posed at the end of the first section: how is the mind cognitively structured and organized to process information? Our best explanation for this question is to assume that the *mind* is a computer. The mind-computer analogy relies on some basic ideas. We know that a computer is a causal mechanism which contains representations or, still better, processes representations in a systematic way. To process information systematically, the mechanical device is supposed to have a language, and to possess knowledge of the rules governing that language. One fundamental idea of the machine metaphor concerns the abstract mathematical notion of computation, and another how computation can be automated. To understand the two ideas underlying the computational nature of representational mental states it is useful to appeal to the notion of Turing machine, which enables a relatively abstract specification of mental state types that does not pin them down to particular neural structures. Accordingly, representational states are related to one another in a computational way, similar to the way in which the representational states of a computer are processed by means of algorithmic, or logical, rules. If a theory of a natural phenomenon can be represented algorithmically, then it can be thought of as *computable*. The machine analogy shows that many kinds of different physical entities could be in the same mental state. In the context of the computational theory of mind, the term ‘cognition’ indicates that the concern of the theory is with cognitive processes, such as reasoning and inference, that link cognitive states like beliefs or desires. This provides a small explanation for why the computational theory of mind has been taken to form the philosophical basis for cognitive sciences.

In 1965 Herbert Simon predicted that machines would soon be capable of doing any work that people could do, yet fifty years later this prediction does not appear completely plausible. Many thinkers remain skeptical about Simon’s claim, in particular Dreyfus[113] and Searle saw the failure of the computing analogy (or at least its representational version) as a problem-in-principle for AI, and not just as a matter of time. For Dreyfus, if a computer is going to have general intelligence, that is, it is to be capable of reasoning about any kind of subject matter, then it has commonsense knowledge. However, he said that a significant part of what we call thought and behaviour cannot be formalized, because they cannot be reduced to explicit rules, and translated into a computer program. In a similar fashion, Searle launched his attack on the central thesis of AI that thinking is formal symbol manipulation. The upshot of the famous argument of the *Chinese Room* is, at the very least, that although we let the outside world have an impact on the room, a person in it, or the room alone, cannot understand any meaning or ‘semantics’ that compose Chinese. Nothing can think simply by being a computer because thinking itself cannot be simply symbol manipulation. If

[113] Dreyfus: 1972, 1992.

it is true that nothing can think *simply* by being a computer, should we discard the whole idea of thinking computers? The question of whether commonsense knowledge can be represented in terms of rules and representations remains a general issue of AI, despite the fact that it is evident that a (more or less) consistent portion of mental phenomena is beyond the reach of those techniques dearest to the computationalist. Besides being dominant in a lot of the research in cognitive science, Fodor's representational theory of mind is the version of the computer metaphor which forms an implicit methodology for much research in AI. I do not intend here to repeat the examination of the main ideas underlying this theory of mind, rather, for my purpose, I want to focus on the idea that mental representations and information processing are essentially *symbol manipulation*.

The central tenet of Fodor's mental theory is that the mind is a logic machine that operates on sentences from a mental language by symbol manipulation. The states of mind represent the world, whereas the atoms which compose mental representations are symbols that combine to form meaningful expressions. The symbols can be concatenated to form expressions in the language of thought (LOT), that is, the system of mental symbols constituting the neural basis of thoughts. This mental system is structured like a natural language, although it cannot be identified with any natural language. The content of a LOT sentence is a person's belief or thought, and a mental state is identified with a set of attitudes towards that sentence. This version of computationalism based on rules and representations claims that the mind (or any adequately programmed computing device) processes the following steps: it generates symbolic sentences as inputs from sensory channels, performs logical operations on these sentences, and transforms sentences into linguistic or non-linguistic behaviours as outputs. The symbolic expressions representing LOT propositions have various *logical* or *inferential relations* to each other, and information processing therefore involves all computations of logical consequences. Therefore, processing the information contained in a mental state simply consists of *computing* the logical consequences of the propositional attitudes, using a set of inference rules. Reasoning, for example, is a process in which the syntactic properties of LOT symbols are causally determinant for organisms to produce behaviours as outputs. The syntactic or formal properties of the representations in a person or computer are interpretable as calculations, inferences, or pieces of reasoning, all of which are semantically interpretable. In this manner, semantic properties are linked to causal properties, and the content of thought is linked to causation of thought. This way of connecting the representational properties of thought (or its content) with its causal nature (or its causation) would be guaranteed by the presence of a mental syntax realized in the physical structure of the brain.

The notion of 'symbol manipulation' receives special emphasis when considered in relation to the question of how the mind, in processing information, is cognitively structured and organized. This feeds the debate within cognitive sciences about the organization of the mind and the nature of mental states. In his influential book *The Language of Thought* Fodor defined LOT as *"the only game in the town"* because it provides the best explanation for many of the familiar properties of intentional states and processes. Fodor thinks that all plausible modern psychological theories of concept-learning, decision-making, and perception are committed to LOT. There is an undeniable fact about the systematic nature of the semantic properties of thought: that mental processes exploit systematicity in the rational transitions from thought to thought, and trains of thought have rational structure and causal outcomes which are dependent on this rational structure. For Fodor, the best way to explain systematicity of thought is LOT: systematicy and other cognitive features can be explained on the basis of cognition modeling in which those regularities are explained with a certain kind of explanatory coherency in relation to LOT. In 1983 Fodor published *The Modularity of Mind*, in which he proposed one of the most illuminating psychological studies on the mental architecture as a confirmation of the framework of LOT. In it Fodor advanced an influential view in defence of LOT architecture which makes a fundamental distinction between *input systems* and the *central system*. As Fodor said, there are empirical reasons to assume that the cognitive architecture of mind is functionally divided into different parts. One part presents the feature defined by the term of *modularity;* Fodor argues that this part is substantially limited to perception and some aspects of language processing, leaving open a possible modular characterization of the motor system. In contrast, the part without this feature is mainly engaged with reasoning and higher cognitive processing. Then, explanations of mental representations may be empirically justified on the basis of an analysis of mental architecture in terms of modules vs. central system.

8. 2 The dispute between Classicists and Connectionists

Fodor's *modularity theory* represents a well worked out approach to *classical architecture*. The term *classical architecture*, or *classicism*, refers to the view that whatever the particular cognitive architecture of the brain (that is, the specific grammar of LOT) may turn out to be, there is a 'necessary condition' to be satisfied. This condition is that propositional attitudes belong to a representational or symbolic system so that:

- the representations of that system must have a combinatorial syntax and semantics, according to which the structurally complex (molecular) representations are systematically built out of structurally simple atomic constituents, and the semantic content of a molecular representation is a function of the semantic content of its atomic constituents together with its syntactic/formal structure.

- The operations on representations constituting the domain of mental processes, such as thinking, reasoning and so on, which are causally sensitive to the syntactic/formal structure of representations defined by this combinatorial syntax.

Essentially, classical architectures[114] employ rules and symbolic representations which have concatenative compositionality. On the classical view, mental architecture must include the nomological necessity of cognitive regularities such as productivity, systematic, and inferential coherence. In classical models the characterization of the notion of cognitive architecture may be reconstructed in these terms:

- Cognition essentially involves representational states and causal operations of which domain and range are examples; and consequently, any naturalized and adequate account of cognition should acknowledge such states and processes.

- Higher cognition (i.e. thought and thinking with propositional content) conceived in commonsensical terms has certain scientifically interesting properties: in particular, it is a

[114] Turing: 1950; Fodor: 1975, 2000, 2003; Fodor and Pylyshyn: 1988; Marr: 1982; Newell and Simon: 1976.

law of nature that cognitive capacities present productivity, systematicy and inferential coherency.

- Accordingly, the architecture of any proposed cognitive model is scientifically adequate only if it guarantees that cognitive capacities are productive, systematic, and inferentially coherent. This would scientifically explain how it could be a law that cognition has these properties.
- The necessary condition for a cognitive architecture to guarantee productivity (and the other essential cognitive features) is that it involves a representational system.

A defence of this general reasoning can be found in both the writings of Fodor[115] and Pylyshyn[116], and most recently in their joint article Fodor and Pylyshyn:

> "The architecture of the cognitive system consists of the set of a basic operations, resources, functions, principles, etc. (generally the sorts of properties that would be described in a 'user's manual' for that architecture if it were on a computer) whose domain and range are the representational states of the organism."[117]

In principle, we can assert that in classical models information tends to be processed *serially* (given that these models employ *rules* and *symbolic representations* which have *concatenative compositionality* in a linear sequence, like in the case of sentences) and takes place at *symbolic level*. As opposed to classical architectures, *connectionist neural-network architectures* do not require any role-governed reasoning in a language of thought but rather provide explanations for mental phenomena on the basis of neural network models. The approach held by the connectionist models the dynamics of psychological processes and phenomena at the level of neuron networks, rather than at the level of symbol manipulation. This approach has been formally pursued since the early work of Wiener and Rosenblatt in the early 80s, who proposed a model of cognitive architecture radically different to that of LOT. According to connectionists,[118] the realization of personal-level representations (thoughts) and processes (inferences) has to be implemented in the brain and central nervous system, and not directly at the level of intentional states. Mental states are realized by patterns of activation within a network of simple processors called nodes, and mental processes principally consist of the spreading activation of such patterns. Unlike the classical symbolic structures, which have evaluable semantic constituents, connectionist nodes are not semantically evaluable, nor do the relative patterns have semantically evaluable constituents. Within connectionist architectures, processing information does not refer to explicit representations and rules (thus, representations do not need to be concatenative), but is *parallel distributed* (rather than 'serial') and takes place at *sub-symbolic level* (instead of at the 'symbolic level'). The connectionists advance this model of the architecture of the cognitive mind by arguing that it

[115] Fodor: 1981.

[116] Pylyshyn: 1984.

[117] Fodor and Pylyshyn: 1988, p. 10.

[118] McCulloch and Pitts: 1943; Rumelhart: 1989; Rumelhart and McClelland: 1986; Smolensky: 1987, 1988.

consists of layered networks of interconnected (abstract) neurons. The elements whose manipulation drives computations in the connectionist network are no more than the connections between these nodes, which are neither semantically evaluable nor semantically compositional. As mental representations are computational distributed (whereas, according to the classicist, they are computational atomic), then processing information is typically massively parallel.

This understanding of processing information in terms of the distribution of 'weights' among connected nodes (and not in terms of the formation of hypotheses and the relative confirmation of those hypotheses) more closely resembles the features of actual human cognitive functioning, like learning (in which the connectionist network is trained through repeated exposure to the objects which it must learn to distinguish). However, this alternative model of mental architecture was strongly criticized by defenders of classical architectures, according to whom, connectionism is just a new and more sophisticated way of reviving the old and long dead theory of associationism. Classicists argue against connectionism by appealing to the peculiarities of language. According to LOT, complex representational mental states can potentially be generated infinitely from a finite stock of primitive representational states, just by using recursive formation rules in accordance with the linguistic capacities of natural languages. The combinatorial structure of language can be explained only if we take into consideration the properties of productivity and systematicy of a given system of mental representation. Such properties of thought and thinking are explained by means of the content of the representational units, and of their compositionality within contentful complex mental representations. Semantics of both language and thought are compositional insofar as the content of a complex representation is determined by the contents of its constituents plus its structural configuration. The classical arguments of the productivity and systematicy of language are supported by the innate character of both language and thought. LOT claims that language and thought share innateness, in addition to the recursive capacities of productivity and systematicy. This line of thought is defended by Fodor and Pylyshyn in their joint article, in which they proposed an argument in defence of the truth of classical mental architectures. According to this influential argument, mental representations are explanatorily necessary and can be realized in connectionist architecture, but the reverse is not true. The most forceful criticism of connectionism concerns the fact that this account fails to adequately explain the law-like cognitive regularities of productivity, systematicy, and recursion of language, without postulating the LOT architecture. Hence, both classical or connectionist architectures need to satisfy the necessary condition for successfully explaining the typical features of language. Although the connectionist model can do so, it is, however, simply implementing the classical LOT architecture. Otherwise, we must conclude that it cannot guarantee productivity, systematicy and inferential coherency, and as a result is empirically false. In short, despite the connectionist network resembles features of human cognitive functioning, it has evident difficulty explaining properties such as productivity and systematicy, or fundamental learning processes like language acquisition. However, even if connectionist models of mental architecture could explain productivity, systematicy, and the other essential cognitive features, they would have little new to offer. Hence, connectionism could be both true as an implementation theory of the classical architecture, and false as a theory of cognitive architecture, but, even in the best case scenario it does not constitute a radically new way of modelling cognition.

9

The Theory of Modularity of Mind

9. 1 The Modularity Thesis and the notion of Module

Now I want to focus on Fodor's psychological work on mental architecture. Fodor's modularity thesis appeared for the first time in the book *The Modularity of Mind*,[119] in which Fodor advanced an interesting view of the architecture of mind, and which contains an extensive discussion of research in cognitive psychology and psycholinguistics. The question posed by Fodor about the viability of the modularity thesis is principally an empirical one which is more closely related to debates in psychological research than to philosophical speculation. However, this theory of mental architecture has significant conceptual implications, given that it goes much beyond the ideas proposed in *The Language of Thought*.[120]

The central tenet of the modularity thesis remains that of assuming the mind to be not a single homogeneous processing system, but rather a complex processing system comprising several task-specific sub-systems, which in turn operate relatively independently of one another. Fodor distinguishes between three functionally distinct types of mental mechanisms or sub-systems which give the mind its overall structure: *input/output systems* (*modules*), *transducers* and the *central system*. The central system is the domain of beliefs, desires and the like; this is the cognitive part of the mind which is concerned with belief-fixation and higher-level processing (including general reasoning, problem solving, constructing scientific explanations, and so forth). Fodor insists that the processes executed by the central system are global and holistic (which is why he thinks that such processes are not easily amenable to investigation by cognitive science). On the other hand, the second functional part is that occupied by the transducers, which are at the interface between the mind and the world. Transducers are principally divided into two types: a) *input transducers* take physical and non-symbolic inputs from the environment and produce symbols as outputs; and b) *output transducers* take symbols as inputs and transform them into non-symbolic outputs. Transducers are supposed to carry out a fundamental function: they are what prevent the mind being isolated from the world. The mind connects informationally with the external world only in virtue of transducers, which perform their job automatically and not by means of computation. In other words, to determine what output must be produced, transducers work without any application of symbols manipulating rules. Finally, the third part of the mental architecture is that functionally occupied by the input/output systems or *modules*, which stand between the transducers and the central system. Fodor defines every perceptual input system (for example, visual system, auditory system, etc.) as a relatively isolated mental module. Accordingly, mental modules are domain-specific, informationally encapsulated sub-systems of the mind which contrast with the central

[119] Fodor: 1983.

[120] Fodor: 1975.

system. Input-systems take the symbolic output of input-transducers as their input and produce representations of the external world as output; their principal function is therefore to represent the world, rendering information accessible to thought.[121] In extrapolating the required information, input-systems do their job merely on the basis of pure computation, according to inferential rules that establish how the external world must be given the deliverances of the transducers that feed them as inputs. Input-systems generate representations of the external world in the form of symbols (resulting in the tokening of a belief), and these representations are fed into the central system. In turn, output-systems take their inputs in the form of symbols from the central system, and deliver their outputs to output transducers. In principle, output systems are involved in motor coordination and control, since their function is essentially that of instructing the body to move in a specific way during the performance of an action. As Fodor does in his book, we are going to be mainly focused on the input systems, that is, on the perceptual modules.

Fodor refers to the modular part of mental architecture in terms of peripheral cognition, which contrasts with central cognition. He individuates the input-systems as the domain of the mechanisms underlying our unconscious abilities, defining them as singular and physically-structured *modules*. The idea that individual mental faculties can be precisely associated with specific physical areas of the brain originates in the ideas of Franz Joseph Gall (who can be considered the founder of the 19th century movement known as phrenology). This intuitive idea has been developed by Fodor into a theory constructed in the context of cognitive psychology and cognitive science. More particularly, Fodor claims that the inspiration for his modular thesis came from results obtained by the linguist Noam Chomsky and the psychologist David Marr. What does the term 'module' mean? Fodor uses the term 'module' to describe something that in terms of structure and function, is very similar to the *organs* discussed by Chomsky. On Chomsky's view, an organ (or module) denotes a body of innate knowledge. Chomsky proposed that there is such a module for language acquisition. He regarded the language system as a module whose development is genetically determined and which utilizes a body of innate specified information. In a similar fashion, Fodor used the notion of module to mean a functionally defined part of the mind that is, in important respects, independent from the 'central system' responsible for beliefs and reasoning. However, the acceptation of 'module' given by Fodor is different to that of Chomsky. To a large extent, the difference between their acceptations concerns the fact that Chomsky made no commitment to the fundamental properties assigned to modules by Fodor, as described in the next section. For Fodor, the functional mental architecture consists of a modular part involving relations between input-systems connected to the five senses and input-systems connected to language, together with the 'central system'. Furthermore, Fodor's modularity thesis was influenced by Marr's theory of visual systems, which assumes the visual system to be divided into a number of more specialized sub-modules.

9. 2 The Fundamental Features of Modularity

[121] Fodor:1983, p. 40.

In his modularity thesis Fodor offers a list of principal features which, taken collectively, characterize the type of input-system. These characteristics of modularity can be reported as follows:

Domain-specificity. Fodor argues that modules are domain specific, in the sense that they are only sensitive to specific kinds of inputs. A perceptual input/output system is domain specific to the extent that it has a restricted subject matter and uses information only in a restricted cognitive domain. It is specialized in that it responds to certain inputs, and usually has its own sensory transducers through which it processes information about a class of objects and properties which is circumscribed in a relatively narrow way. In this way modules are limited to a particular type of inputs, and according to Fodor this is the reason why modules are as efficient as they are:

> "domain specificity has to do with the range of questions for which a device provides answers (the range of inputs for which it computes analyses)"[122]

Domain-specificity mechanisms are typically more fine-grained than sensory modalities like vision and audition. This appears clear from Fodor's list of plausibly domain-specific mechanisms, which includes systems for color perception, visual shape analysis, sentence parsing, and face and voice recognition, none of which seems to correspond to perceptual or linguistic faculties in an intuitive sense.[123]

Mandatoriness. Fodor argues that modules are mandatory in the sense that they process operations automatically, that is to say, not under conscious control. Modules tend to be mandatory in the sense that the operations they carry out are switched on by presentation of the relevant stimuli, and these operations run to completion. Visual or auditory illusions provide perhaps the best example of this characteristic. If the appropriate stimulus is presented and seen or heard, the illusion will be seen or heard. To illustrate this characteristic of modularity, Fodor gives three examples. First, he thinks that hearing a sentence as grammatical or not is a matter of being mandatory. If someone hears a given utterance in a known language, she will hear a sentence and give it meaning. English native speakers cannot hear the sounds of a sentence in English as mere noise, rather they hear the sounds only as English. If they hear an utterance in English, they will attribute meaning to that utterance. A second example concerns the objects we perceive 'spatially'. Any object perceived is perceived in a three-dimensional space: it is not possible to see a 3D array of objects in space as 2D patches of colour. Thirdly, Fodor claims that touching a surface involves feeling it; that is to say that people can only see or touch things in a certain way. There is no way for an individual to avoid seeing when her eyes are opened, neither can she avoid feeling when touching an object. According to Fodor, various examples of this sort can be given for other types of modules (including the higher level module for speech recognition).

Inaccessibility to central monitoring. Fodor argues that modular processes are not centrally accessible, and this means that an individual cannot have introspective knowledge of their workings. As centrally inaccessible systems are those input-systems whose internal processing is

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[122] Fodor 1983, p. 103.

[123] Fodor: 1983, p. 47.

obscure to introspection, then their outputs are accessible only to other modules, or to central cognition. An input-system is *centrally inaccessible* if the intermediate-level representations which it computes before producing its outputs are inaccessible to consciousness and equally unavailable for explicit reporting. It is important to note that the mark of inaccessibility is analogous, in important respects, to that of informational encapsulation. Both characteristics are pertinent to the nature of informational flow across computational mechanisms, however, they work in opposite directions. Inaccessibility specifies that representations within a module are not accessible to central processes; conversely, informational encapsulation establishes that modules cannot have direct access to the content of either central cognition or other modules. Fodor gives the example of visual modules: they do not have access to our knowledge (or cognition) that a given picture is an optical illusion, and when such an optical phenomenon is presented to us the illusion persists. From this Fodor draws the conclusion that we cannot consciously affect the inner workings of the module, because there is no *direct* way of affecting it. In short, encapsulation entails restriction of the flow of information into a mechanism, whereas inaccessibility entails restriction of the flow of information out of it.

Speed. Speed is perhaps the emblematic characteristic of modularity. Fodor claims that all modules are fast, indeed much faster than processes in the central mind. Cognitive processes qualify as "fast" in Fodor's sense if they occur in approximately less than half a second; once activated, a module usually produces its output in well under a quarter of a second. For example, speech shadowing is very fast, with typical lag times of about 250ms. Since the syllabic rate of normal speech is about 4 syllables per second, this suggests that shadower is processing the stimulus-length parts, probably the smallest parts that can be identified in the speech stream:

> "only at the level of the syllable do we begin to find stretches of wave form whose acoustic properties are at all reliably related to their linguistic values".[124]

Remarkable results in terms of speed are also available for vision. Fodor says that the two important aspects that this reveals are the contrast between the speed of modules' processing as opposed to how slow central processes can be, and the strong link between speed and their mandatory operation.

Informational encapsulation. According to Fodor, perceptual computational mechanisms are 'informationally encapsulated' because they are insulated from the causal influence of operations carried out by other similar mental modules. A sub-system is *informationally encapsulated* in the sense that while processing a given set of inputs it cannot access information stored elsewhere. Consider visual processing: as a result of informational encapsulation a visual system can represent visually, but not auditory, perceptible environmental properties. Pylyshyn indicates this characteristic of modularity using the term *cognitive impenetrability*. Input/output mechanisms are cognitively impenetrable, in Pylyshyn's sense, if they are not penetrable by any other area of the cognitive system (in particular by beliefs and knowledge).

Shallowness. Another characteristic of modules is that they have outputs which are relatively shallow, which means that such outputs do not require much processing. Fodor uses the example of

[124] Fodor: 1983, p. 62.

the visual system which needs little processing to output representations of basic categories of objects. On Fodor's view, the acceptation of shallowness includes two properties: an output is defined as shallow if it is either computationally cheap (little computation is required to produce it), or informationally general (its informational content is not very specific).[125]

Fixed neural architecture. Besides being characterized as domain-specific, fast, automatic, innate, inaccessible, and informationally encapsulated, modules are generally realized in a *fixed neural architecture*. This means that input systems tend to be associated with localized structures in the brain.[126] This one and the next two features are considered as complementary/convergent criteria for modularity rather than essential ones.

Specific breakdown patterns. This characteristic provides empirical evidence for Fodor's modular theory. Accordingly, modules are realized in a dedicated part of the brain that, if damaged, cannot be replaced by activity elsewhere in the neuronal system. Thus, an input/output system is *functionally dissociable* if it can be selectively impaired, damaged or disabled with little or no effect on the operation of other systems. Evidence for this feature of modules has been obtained from neuropsychological research. Neuropsychological records indicate that selective impairments of this sort are frequently observed as a consequence of circumscribed brain lesions. Standard examples of such breakdowns in functioning emerge from studies on vision concerning prosopagnosia (impaired face recognition), achromatopsia (total color blindness), and akinetopsia (motion blindness); as well as in studies on language disorders such as agrammatism (loss of complex syntax), jargon aphasia (loss of complex semantics), and dyslexia (impaired reading and writing). The studies of these disorder phenomena suggest that the lost capacities are subserved by a functionally dissociable mechanism. An individual can suffer from one such condition while all her other input systems, along with her central system, function perfectly normally. The occurrence of such specific impairments to the functioning of input systems is taken as evidence for the neural localization of input-systems.

Ontogenetic pace and sequencing. This is the final characteristic of modularity. Fodor says that input-systems (and the capacities associated with them) exhibit specific ontogenetic sequencing, since they develop at a rate and in an order that is uniform across the human species (as manifested in the various *critical periods* for different abilities). On Fodor's view, this development is genetically determined, and largely independent of the specifics of an individual's experiences or her general intelligence:

> "develop according to specific, endogenously determined patterns under the impact of environmental releasers."[127]

Furthermore, modules are *innate* and not acquired; as Fodor says, we are born with them. Language acquisition may be thought of as the most emblematic example. Influenced by Chomsky,[128] Fodor

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[125] Fodor: 1983, p. 87.

[126] Fodor: 1983, p. 98.

[127] Fodor: 1983, p. 100.

[128] Chomsky: 1986.

assumes that much of the task-specific information utilized by the input systems, and more specifically by the language system, is innately specified. This assumption endorses the nativist belief that the architecture of the mind and the development of its components and modules are innately determined.

Before concluding this examination of the defining characteristics of modularity, let me say a little about an important aspect of such features. As a matter of contingent empirical fact, Fodor assumes that modules tend to share a particular collection of these properties. It is, however, important to remember that modules may lack some of these characteristics. On his view, input-systems do not need to have all or even most of the typical properties assigned to them. Rather, an information-processing sub-system is defined as "modular" for Fodor if it has most of those features to an appreciable degree, for example, visual processing and 'input systems' that process linguistic input are modular in this way.[129] However, some marks of modularity are more important than others; specifically, informational encapsulation and domain-specificity are more essential for modularity and equally explanatory to several of the other features listed above. If input-systems turned out to lack most of these properties, they would nonetheless remain modules if they were task-specific and informationally encapsulated sub-systems of the mind.

9. 3 Globality of Central Systems: Isotropy and Quineanism

As we have seen, Fodor's proposal regarding the structure of the mind is that there is a part of the mind that is *modular* and another part that cannot be divided into domain-specific and informationally encapsulated sub-systems. The human cognitive architecture can be divided into three broad categories of mental mechanisms defined in functional terms: transducers (the retina and optic nerve, the eardrum and auditory nerve, the skin's sensory nerves, etc.); input systems for low-level perceptual processing (including language perception), which mediate between the transducer and central cognition and transform the information into a format that the central system can process, together with output systems responsible for motor control; and central processors responsible for higher level cognitive processes, (such as decision making and belief-fixation). Fodor says that modularity is restricted to the domain of input/output systems, or modules, which (at least partially) possess the typical characteristics assigned to them. Modularity can explain peripheral cognition associated with perception and linguistic processes (including language acquisition and language processing), but it is not able to explain any aspect of central cognition. This is because central cognition is not modular to any extent.[130]

How does Fodor describe central cognition? As I said, Fodor sees central cognition as the primary domain of beliefs, desires, hopes, and all the other intentional states which participate in reasoning and inference, and intellectual and practical problem solving. The central system operates at the higher level of mental representations and mechanisms involved in all the relevant characterizations of our mental activities. In all higher-order processes (for example, in belief-fixation, decision

[129] Fodor: 1983, p. 37.

[130] Fodor 1983, 2000.

making, imagining, understanding, and speaking) information is 'stored' or represented in terms of symbolic strings and carried out at the level of symbolic processing: the central system. Given that the central system does not have a modular structure, it cannot be divided into domain-specific and informationally encapsulated sub-systems, rather it takes input from a variety of distinct sources. Unlike peripheral cognitive processes, central processes responsible for belief-fixation/revision and decision making are global and holistic. Consider the process of belief-fixation, which involves integrating data from various input modules to generate beliefs that square with the subject's general beliefs about the world. The process underlying the fixing of a belief is potentially sensitive to the whole set of beliefs held by a subject; the structure of the belief system allows an individual to use information in reasoning that comes from any part of her stock of beliefs and knowledge. Then, belief-fixation involves framing hypotheses and seeking confirmation of such hypotheses, using data that bear upon the truth value of such beliefs.

To confirm the globalism of central processes, Fodor focused crucially on certain claims regarding the holistic character of scientific inference. Fodor argues that there is a high degree of functional similarity between scientific inference and belief fixation/revision, since both are centrally involved in the non-demonstrative assessment of empirical hypothesis. Fodor takes them to be global in two crucial respects: *isotropy* and *Quineanism*. The confirmation of a hypothesis is isotropic if the facts relevant to that rational inference may be drawn from anywhere in the field of previously established truths. In turn, confirmation in science is isotropic because:

> "the fact relevant to the confirmation of scientific hypotheses is sensitive to properties of the entire belief system; as it were, the shape of our whole science bears on the epistemic status of each scientific hypothesis."[131]

On Fodor's account, confirming a scientific hypothesis is a global and holistic process, because it requires the whole edifice of theories held by scientists and the relationships such hypotheses have with that edifice. Confirmation in science is simply a matter, generally speaking, of taking information from any domain, however individuated, of one's background theory; isotropy then refers to the *epistemic* relations between a hypothesis and a set of background facts. From a modular perspective, scientific confirmation cannot be informationally encapsulated as it involves a whole body of scientific and epistemic commitments, instead of a restricted body of data. Equally, isotropy is a property that applies to central processes, which are processes that appreciate epistemic relations. Fodor believes that success in confirming a hypothesis depends on the capacity of that process to bring out any relevant component of the theoretical background theories with which the subject is furnished. Highly unencapsulated processes involved in reasoning are characterized by isotropy in the sense that they have access, in principle, to all the information available to a cognitive agent.

The second property of inferential processes is Quineanism. Scientific inference would be Quinean because the form of the whole theory affects the epistemic status of the hypothesis. Fodor says that scientific confirmation is a species of *abduction*. As ordinarily construed, abduction (or inference to the best explanation) involves the assessment of a hypothesis not merely in terms of its empirical

[131] Fodor: 1983, p. 107.

adequacy, but also in terms of its possession of theoretical virtues such as simplicity, conservativeness, coherence and consistency.[132] Accordingly, a scientific hypothesis enjoys such theoretical virtues only if it is coherent, consistent, etc. with all of one's background commitments. But, as Fodor claims, such virtues are not restricted to entirely scientific theories, but are also part of belief systems. Consequently, an ordinary hypothesis confirmation will be global only if it is coherent, consistent, etc., to the entire proper subset of a background theory or belief system. The argument proposed by Fodor for the globality of central processing is as follows: since scientific inference is Quinean and isotropic, and given the high degree of functional similarity between scientific inference and everyday belief-fixation, we can reasonably suppose central processing for our ordinary belief-fixation to be Quinean and isotropic. Fodor draws the conclusion that the cognitive architecture on which central processes depend must be able to subserve Quinean and isotropic processes.

9. 4 The extent of Modularity: the Massive Modularity Thesis

Since the appearance of Fodor's modularity thesis there has been an active debate about the extent of modularity. Among psychologists, philosophers and cognitive scientists who accept the theory of the modularity of mind, there is controversy about how much of the mind is modular. In principle, the modularity thesis may vary with respect to either the number or the identity of the modules in the human mind. How many modules are there and how specific are they? Fodor answers very cautiously, as he believes that there are different modules for each of perceptual modality, plus one language module responsible for linguistic processing. In contrast to Fodor, other thinkers seem more adventurous, and go a step further to propose that the mind is 'massively modular'. The thesis of *massive modularity* is the claim that there is no distinction between the central mind and modules, because there is no such thing as a non-domain specific and unencapsulated cognitive central system. On this view, the mind is made up of a number of domain-specific modules, which means that there is a distinct, more or less encapsulated, mechanism for each kind of cognitive task. For example, the tacit knowledge of the theory of other minds can be thought of as an innate module (among other modules) devoted to commonsense reasoning about physics, biology, psychology, etc. The tenet of the massive modularity thesis is that our mental faculties are much more fragmented than Fodor thought. The idea that the mind is nothing more than a collection of modular systems (as opposed to the view that there is a non-modular system responsible for integrating modular outputs) is proposed by evolutionary psychologists including Tooby,[133] Pinker,[134] Sperber,[135] and Carruthers.[136]

[132] Harman: 1965.

[133] Tooby: 1992.

[134] Pinker: 1997.

[135] Sperber: 2002.

[136] Carruthers: 2006.

Carruthers presented a sophisticated defence of massive modularity. He says that central cognition is entirely modular, because all cognitive processes are modular or emerge from interaction with modular processes. To integrate all cognitive processes and assign to them some of the characteristics of modules in a plausible way, Carruthers proposed a revision of the notion of module, and suggested removing some of its characteristics and redefining others. His weakened notion of 'module' allows a lot of variability in each of the characteristics attributed to modules by Fodor. Firstly, he eliminated some characteristics as he thinks that these are incompatible with the view that modules are part of central processing. He considered plausible domain-specificity, mandatoriness, and also the innate character of modules and the neural specificity characteristics, but he proposed to modify the notion of encapsulation and to add the characteristic of frugality. Following his modifications, modules are processing systems which are usually associated with a functional domain, are *frugal* in their operations and are encapsulated to varying degrees. According to Carruthers, only the outputs of a modular process will be available to other processes.[137] At the same time, Carruthers rejected shallowness of the output and also discards speed. Speed is rejected because if modules are fast, as Fodor says, then this characterization only makes sense when modules' speed is compared to the speed of central processing. However, if we take both peripheral and central cognition to be entirely modular, there is no sense in making this comparison. This assumption is consistent with the massive modularity thesis, according to which some of the characteristics attributed to those "strong" modules must be removed in order to include all possible processes of the mind in the set of modules. Thus, the thesis of massive modularity aims to give an account of the architecture of mind entirely based on interactions between modules, of which there could be many types.

Fodor has criticized the thesis of massive modularity because it contains an evident problem. According to Fodor, if there is no such general non-domain-specific cognitive mechanism, how does the mind decide, for any given input, which module should deal with that input? The problem with the massive modularity view concerns the exclusion of a decision procedure necessary to assign input to modules; Fodor argues that this procedure cannot itself be modular because it must select information which is going to be handled by many different modules. His attack on the massive modularity thesis appears in *The Mind Doesn't Work That Way*,[138] and also in *LOT 2*,[139] in which Fodor reiterates that the central system is non-modular, and connects this view to general doubts about the adequacy of RTM as a comprehensive theory of the human mind. Fodor's argument is centered on one principal function of the central system: the fixation of beliefs via abductive inferences. According to Fodor, the fact that a rational inference has an *isotropic* and *Quinean* character demonstrates that it cannot be realized into modular systems. These features would render belief-fixation a holistic, global and context-dependent mechanism that cannot be realized in any modular, informationally-encapsulated system. What is more, given RTM's commitment to the claim that computational processes are sensitive only to *local* properties of

[137] Carruthers: 2006, pp. 62–63.

[138] Fodor: 2000.

[139] Fodor: 2008.

mental representations, holistic features of central cognition seem to fall outside RTM's scope.[140] The syntactic properties of mental representations are local in the respect that they supervene upon the *intrinsic* and *context-independent* properties of such representations, whereas other kinds of properties are *global* and *context-dependent*. To the extent that cognition involves global properties of representations, Fodor concludes that CTM cannot provide a complete satisfactory model of how cognition works:

> "Cognitive science that provides some insight into the part of the mind that isn't modular may well have to be different, root and branch, from the kind of syntactical account that Turing's insights inspired. It is, to return to Chomsky's way of talking, a mystery, not just a problem, how mental processes could be simultaneously feasible *and* abductive *and* mechanical. Indeed, I think that, as things now stand, this and consciousness look to be the ultimate mysteries about the mind."[141]

Although Fodor has long championed CTM as the best theory of cognition available, he draws the skeptical conclusion that its application is basically limited to the portions of mind that are modular. Then, the global and holistic nature of the central system undermines the plausibility of CTM as a theory of such central processing. Computers are successful in executing the local inferential processes, but they are unfit to execute the kind of global and holistic processing we routinely perform. In order for a computer to process global and holistic tasks, it should either search exhaustively for a whole belief system, or take a whole belief system as input. But, as Fodor says, this is highly improbable, because the mind does not work in this kind of way:

> "The totality of one's epistemic commitments is vastly too large a space to have to search through if all one's trying to do is figure out whether, since there are clouds, it would be wise to carry out an umbrella. Indeed, the totality of one's epistemic commitments is vastly too large a space to have to search whatever it is that one is trying to figure out."[142]

Fodor's conclusion is that cognitive science needs a radical new theory of how the mind works; despite his commitment to CTM as the best theory of intentional states and intentional processes we currently possess (given that CTM has the capacity to explain productivity and systematicity of thought and our intentional states, along with the intentionality of sentences that ascribe intentional states to individuals), he excludes the idea that CTM can explain the global and holistic nature of central processing.

9. 5 The Adaptationist View

I want to conclude this examination of Fodor's modularity thesis by focusing on a second central issue related to the perspective endorsed by the evolutionary psychologists. The issue is concerned

[140] Fodor: 2000, chapters 2-3; 2008, chapter 4.

[141] Fodor: 2000, p. 99.

[142] Fodor: 2000, p. 31.

with the question of whether modules should be thought of in terms of *adaptations*, namely, products of selection pressures that faced our hominid ancestors. In the context of the present discussion, the term 'evolutionary psychology' should not to be confused with the general claim that human beings evolved from earlier species of apes, in a long and complex evolutionary process which started about seven million years ago. This claim is beyond debate, as it is largely accepted within the scientific community as a solid truth. What the term evolutionary psychology here refers to is a more specific and controversial claim, according to which mental capacities and related faculties are *adaptations*, in the evolutionary and biological sense. Biologists define an adaptation as a trait, or capacity, whose nature is the product of natural selection. If we endorse a modularity perspective, we might hypothesize that modules were selected through natural selection, and that such selection was specifically occurred to solve an adaptive problem. As natural selection provides organisms with evolutionary functions that cause situations that enhance their survival, modules, among other adaptations, should satisfy a specific *function* which was selected for an adaptive reason. This claim is consistent with the adaptionist theory, which establishes the general condition that if something has a function, this function must be the product of evolution by natural selection. The notion of biological function demands actual evolutionary, or causal, history, as it applies to all the biological organs which are credited with having a function with an evolutionary origin. Taken in an evolutionary and adaptionist sense, a modular mechanism is something to which natural selection has awarded a certain biological function that causes behaviour to enhance the survival of an organism and, more generally, of a species. This perspective is defended by evolutionary psychologists who treat psychological traits as adaptations in the Darwinian sense. Evolutionary psychologists search for evidence that organisms live in a type of environment in which the possession of mental organs aids their survival. In defending the thesis of massive modularity, the evolutionary psychologists individuate such mental organs in modules which are relatively isolated and dedicated to specific information-processing tasks, and which are resilient, probably innate mechanisms within the mind.

Fodor has long been skeptical of evolutionary psychology, including the claim that the mind is a product of natural selection. His doubts concern the general assumption that the knowledge of the evolutionary history of a system is really necessary to make inferences about its function, as the notion of function, which is relevant for psychology, might be *synchronic* but not *diachronic*:

> "You might think, after all, that what matters in understanding the mind is what ours do now, not what our ancestors' did some millions of years ago."[143]

In *The Mind Doesn't Work That Way*, Fodor responds to a number of arguments to demonstrate that natural selection is not necessary to underwrite claims about the teleology of the mind:

> "One can often make a pretty shrewd guess what an organ is for on the basis of entirely synchronic considerations. One might thus guess that hands are for grasping, eyes for seeing, or even that minds are for thinking, without knowing or caring much about their history of selection. Compare Pinker: "psychologists have to look outside psychology if they want to

[143] Fodor: 1998b, p. 209.

> explain what the parts of the mind are for."[144] Is this true? Harvey didn't have to look outside physiology to explain what the heart is for. It is, in particular, morally certain that Harvey never read Darwin. Likewise, the phylogeny of bird flight is still a live issue in evolutionary theory. But, I suppose, the first guy to figure out what birds use their wings for lived in a cave."[145]

The question he posed concerns the presumed necessary role of natural selection in figuring out how the mind works. But, as Fodor says, natural selection does not guarantee understanding of the work of psychological mechanisms, because to understand how a psychological mechanism functions does not require knowledge of the selection pressures that led to it. For the evolutionary psychologist, the adaptive complexity of the human mind must be treated as a collection of *adaptations*, and natural selection as the only explanation for such adaptive complexity in the living world. Fodor's response to this point is that the complexity of the mind is not relevant to determine whether it is a product of natural selection:

> "What matters to the plausibility that the architecture of our minds is an adaptation is how much genotypic alternation would have been required for it to evolve from the mind of the nearest ancestral ape whose cognitive architecture was different from ours…It's entirely possible that quite small neurological reorganizations could have effected wild psychological discontinuities between our minds and the ancestral ape's."[146]

Fodor argues that we cannot actually establish whether a small neurological change in the brain of our ancestors led to a larger change in their cognitive capacities, despite the appeal of adaptive complexity it does not warrant the idea that our minds are the product of natural selection. On his view, whether we can regard modules as adaptations should depend only on evidence recognized by empirical psychological research, and not on philosophical theorizing which tests the possible explanations available. This point is made clearer in his latest book *What Darwin Got Wrong*,[147] in which Fodor reiterates that explanations based on natural selection are both of decreasing interest in biology and actually incoherent.

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[144] Pinker: 1997, p. 38.

[145] Fodor: 2000, p. 86.

[146] Fodor: 2000, pp. 87-88.

[147] Fodor and Piattelli-Palmarini: 2010.

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Visual, Auditory and other forms of Perception

10. 1 Visual Perception

In this chapter I want to deal with the question of how the modularity thesis applies to perception. Presumably, a general and naturalistic account of perception should attempt to explain all kinds of perception (whether specifically human, more generally biological, or purely mechanical) exclusively in causal terms, that is, in terms of causal laws, structures, and functional causal dispositions. In the context of perceptual theories it is accepted that whatever else is involved in perception, it undoubtedly involves processes (relying on a collection of relevant information, or data, about the environment) in which sensors, or sensory organs, are used to provide causal inputs from the environment to organisms. A naturalistic approach to perception is represented by informational semantics as developed by Dretske and Fodor, which gives a characterization of the relevant kind of sensory information in terms of nomic covariance relations between sensory inputs and outputs.[148] Nomic covariance relations are used to underwrite a concept from the information conveyed by sensory transducers to the brain; therefore, the possession of working sensory organs, or mechanical sensors, is necessary for any kind of perception. This claim echoes the understanding of mental architecture theorized by Fodor. Thus far we have seen that Fodor made a fundamental distinction among the functional parts that compose the organization of the mind, in which a *central system* (or *central mind*) contrasts with *transducers* and *input-output systems* (*modules*). In proposing that the explanation of 'input-output systems' must be taken in the context of a modular view of perception, rather than in the context of a view which considers perception as a part of cognition, Fodor assumes that 'input systems' includes the systems responsible for linguistic inputs/outputs processing.

The power of Fodor's modularity thesis resides in the fact that it applies to a wide range of explanations of perceptual systems. Its particularly fruitful application is illustrated by the example of computational theories of vision. Proponents of the classical approach to mental architecture often appeal to computational theories of vision as illustrative of the sort of explanation they propose. Computational theorists of vision naturally treat the visual system in terms of representational processing; from the representation of the distribution of light reflected onto the retina, to the eventual construction of a representation of the objective scene around the perceiver. For Fodor, the visual perceptual system is modular and has low level cognitive activity. Consider the function of the human eye: that of a transducer that transforms input radiant energy into nomically covarying output as electrical impulses in the optic nerve. Hence, there is a sense in which visual perception is not a rational process in the same way a thought is. To confirm this assumption, Fodor recurs to the example of visual illusion, which may be simplified as the

[148] Dretske: 1981; Fodor: 1990.

phenomenon related to something that visually seems to be what it is not. What is interesting to note about this perceptual phenomenon is that the illusion persists even if we know that it is an illusion. When we encounter a situation in which we are inclined to believe something and its opposite, we tend to eliminate, as rational thinkers, the inconsistency in our thought. Although a rational agent would be inclined to eliminate explicit contradictions in his or her belief, in the case of visual illusion such inconsistency remains unchallenged. What kind of overall picture of the mind is suggested by the phenomenon of visual illusion? The case of visual illusion clearly demonstrates that perceiving is not the same as judging or believing. In fact, if perceiving were just a form of believing, this situation would lead to continuous conflict among our current psychological states, as in the case of explicitly contradictory beliefs. Let us suppose that the belief that x is the case (for example, the belief that 'stripes are uniformly coloured') and the belief that x is not the case (for example, the belief that 'stripes are not uniformly coloured') coexist simultaneously and consciously. This contradictory situation would render objectively impossible the selection of behaviors that are rationally coherent with a given belief. No rational agent could live with such explicit contradictions in his/her beliefs, because, if perception were a form of belief, this would lead to irrationality. Cases of perceptual illusion had already been discovered in the early work of Gestalt psychologists, who suggested ways in which the mind structures perceptual experiences. Subsequently, the psychologist David Marr carried out pioneering work which confirmed the hypothesis that we capture the structuring effects of perceptual experiences computationally. Marr's computational theory of vision joins Jerry Fodor's modularity thesis in providing empirical evidence for defining the visual system as a relatively isolated 'mental module', that is, an information-processing system which is in important respects independent of the 'central system' responsible for belief and reasoning.

10. 2 Marr's Computational Theory of Vision

In the literature of psychology and cognitive science, the term 'visual perception' is used for the ability to interpret the surrounding environment by processing the information contained in visible light, whereas the term 'vision' denotes the resulting perception of such processing. Generally, visual perception and the various psychological components involved in vision are referred to collectively as the *visual system*, which constitutes the object of extensive research in various fields including experimental psychology, cognitive science and AI, theories of computation, neuroscience and molecular biology, all of which operate at very different levels and use different techniques. However, in 1980 Marr proposed an innovative computational approach that led to promising advances in the scientific understanding of visual perception. Marr's computational theory of vision[149] involves a complex information processing task which attempts to capture and represent the various aspects of the environment. In a process such as vision, it is important to give a full description of the information processed by the nervous system; the central tenet of Marr's model is thus to explain how visual information is processed in a computational system which is only loosely constrained by physical properties. Marr introduces three different types of abstraction, or analysis, of informational processing systems:

[149] Marr: 1980, 1982.

- Computational or cognitively functional analysis
- Algorithmic analysis
- Physical implementational analysis

The first type of abstraction is computational analysis. This task analysis of cognitive systems serves to identify the specific information-processing problem that a system is configured to solve, and the general constraints upon any solution to that problem. If the role of the computational task is to describe what is being evaluated and why, the algorithmic analysis tries in turn to explain *how* the cognitive system performs the information-processing task. The second task principally aims to identify input information and output information and algorithms for transforming input into required output, as well as specifying how information is encoded. Finally, implementational analysis tries to find a physical realization for the algorithms developed to achieve this computation. The implementation analysis of such algorithms identifies the neural structures (populations of neurons) which realize the basic representational states to which the algorithm applies, or the neural mechanisms that transform representational states according to the algorithm (whether this physical implementation is part of the neural tissue or part of an external computer). In other words, the computational level addresses, at a high level of abstraction, the problems that the computational system must overcome; the algorithmic level attempts to identify the strategy that may be used to solve these problems; and the implementational level attempts to explain how solutions to these problems are realized in neural circuitry. To clarify these different levels of abstraction we might consider the example of a Turing machine: computational analysis represents the characterization of multiplication functions; algorithmic analysis corresponds to the Turing machine table; and implementational analysis is simply the physical construction of the machine.

After introducing these different levels of abstraction, Marr provides a general theoretical framework of vision which combines them. The computational, algorithmic and implementional tasks are employed to characterize vision from a computational perspective that involves, at each level, a symbolic representation of the information carried in the retinal image. We know that the intensities perceived by a visual system are a function of four main factors: geometry (shape and relative placement), reflection of visible surfaces, illumination and viewpoint. Then, we can think of a visual image as composed of a wide array of intensity, created by the way in which light is reflected by the objects viewed by an observer. According to Marr, early visual processing aims to create a description of external objects by constructing a number of representations from the intensity values of the image. To demonstrate that vision proceeds by explicit computation of symbolic descriptions of the visual image, Marr proposed that vision includes three stages of representation, each of which builds greater and greater detail back into the image, so that eventual recognition and response is achieved. This multi-level account of vision includes the following types of visual representations:

I. A *2D* or *primal sketch* of the scene, based on feature extraction of fundamental components of the scene, including edges, regions, etc. (Note the similarity in concept to a pencil sketch drawn quickly by an artist as an impression).

II. A *2½D sketch* of the scene, where textures are acknowledged and surface orientation is computed. (Note the similarity in concept to the stage in drawing where an artist highlights or shades areas of a scene to provide depth). A representation of distance and depth centered in the observer is achieved in this stage.

III. A *3D model*, where the scene is visualized in a continuous, three dimensional map. A representation of depth and volume centered in the object is achieved in this stage.

Marr argues that early visual systems derive representations in which these factors are separated. The *primal sketch* is the resultant description of the shapes of surfaces and objects, their orientations and distance from the viewer; the representation and analysis of local geometric structures and detection of intensity changes and illumination effects take place at this level of representation. Independent spatial organizations of the viewed intensities in a 2D scene reflect the structure of the visible surfaces. To capture these organizations, Marr's theory of vision makes use of a set of *place tokens* corresponding to *edges, bars, ends,* and *blobs*; such low level features are represented by five factors (quintuples) including: type, position, orientation, scale, and contrast. In the first stage, early vision makes local changes in light intensity explicit, locating discontinuities in light intensity because such edges, bars, ends, and blobs often coincide with important boundaries in the visual scene. The resultant representation consists of a collection of statements about the edges, bars, ends, and blobs present in the scene: where they are located and orientated, and any other information with which to define a crude initial processing. Structures like boundaries and regions can be constructed using the application of grouping procedures. The full primal sketch seizes many of the contours and textures of an image; however, this first stage is only one aspect of early visual processing. The second stage of observer-orientated representation is the *2½D sketch*, which is the consequence of early visual processing, in which the orientation and depth of the visible surfaces and discontinuities are represented. The second level of representation involves an analysis of motion, depth and shading, and further, full analysis of the primal sketch. Marr defines the 2½D sketch as composed of some local surface orientation primitives, distance from the viewer and discontinuities in depth and surface orientation. Like the 2D sketch representation, the 2½D sketch is specified in a viewer-centered coordinate system. Despite the 2½D sketch being necessary to guide any action undertaken, it does not suffice for recognition of visual objects. For that a third representational level is required. The *3D sketch* representation allows the observer to recognize what object a particular shape corresponds to. This third level of representation describes shapes and their organization using a modular and hierarchical organization of volumetric and surface primitives centered into the object.

What Marr's computational theory suggests is that vision proceeds from a two-dimensional visual array on the retina, to a three-dimensional description of the world as output. The visual system provides this description by creating a representation of the pattern of light on the retina and making computational inferences in various stages. The goal of early visual processing is to give the initial description of the surfaces present in the image; the task for the psychology of vision is thus that of explaining how our visual system produces a representation of the 3D visual environment from the distribution of light on the retina. In order to finally obtain the 3D sketch representation, the system has to build into the mind 'knowledge' of certain rules or principles in order to make the inference from one stage to the next. For Marr, such principles are not accessible via introspection; even if we know that they are in some way present in our minds, we cannot access them introspectively. Yet he suggests that it is possible to investigate vision at any of these levels independently. There are essentially two conclusions which can be drawn from Marr's multitask analysis. First, that the visual system's job is to provide a 2½D representation of the visual environment that can serve as input for recognition and classification processes (primarily information about the shape of objects and their spatial distribution). This entails that perception involves the construction and manipulation of abstract symbolic descriptions of the environment. Second, the *3D sketch* is a representational task centered on the object of the scene, rather than on the viewer-frame of reference. Marr argues that when describing an object, we do not need to know what we are looking at in order to determine some aspects of it. For him, the visual system provides information to recognition systems that abstracts away from the perspectival features of observer representation. Recognitional abilities are constant despite changes in how things look to the perceiver due to an object's orientation, its distance from the perceiver, and its partial occlusion by other objects. Edge-detecting algorithms applied to the retinal image result in a description which could be likened to a written description of which edge features are where in an image (in much the same way as programming code on a computer describes the formation of an icon on the display screen). Then, object recognition is reached when one of the reconstructed descriptions matches a stored representation of a known object class.

10. 3 Auditory Perception and the analogy with Visual Perception

When considering modalities other than vision that enhance an account of perception defined within the framework of the modularity of mind, we have to mention auditory perception. Beyond revealing new and rich territory for empirical and theoretical exploration in its own right, the study of auditory processing certainly deserves a role in the development and vetting of an adequate and comprehensive understanding of perception. The topic provides a useful case for cognitive scientists and experimental psychologists to evaluate claims about modular perception already proposed in the visual context. There is an evident relationship between visual perception and space on the one hand, and auditory perception and time on the other. Studies in cognitive sciences often focus on visual perception in relation to spatial issues, while auditory perception is more concerned with temporal aspects of perception. But what does the term 'auditory perception' mean? In a broad sense, this term refers to the capacity to perceive and understand sounds, including speech and environmental sounds. This capacity is concerned with the way the brain identifies, interprets and attaches what we hear (namely, the meaning of sound) by means of specific organ-transducers, such as the ear. We know that in nature sounds exist in the form of vibrations that travel through the air or through other substances; the ear detects such vibrations and converts them into nerve impulses which are sent to the brain, which in turn provides an interpretation of this information. But there are many processes, involved beyond simply hearing a sound, which turn a mass of incoming noise into something useful and understandable. Here I shall report some of these important processes:

Auditory discrimination[150] is the process through which people note the difference between sounds. This process plays a special role in the comprehension of language. Given that spoken words are

[150] Chermak and Musiek: 1997.

understood on the basis of different sounds, this mechanism allows us to distinguish between subtle differences in sound in words, and to identify the beginning, middle and end sounds of words. It is supposed that auditory discrimination is developed in children at a very early age; this assumption can be made based on simple considerations. If a child were not able to discriminate between sounds in words (for example, between the sounds "pat" and "bat", where /p/ is voiceless whilst /b/ is voiced), then, in perceiving a vast amount of noise, he would not be able to focus on important noises and ignore irrelevant noises as unimportant (so he will perceive and process the sounds of "pat" and "bat" as if they referred to the same word). In virtue of this mechanism, children and adults can distinguish perceived words that sound the same from perceived words that do not, such as voiced versus voiceless words (for example: "pat" vs. "bat", "tip" vs. "dip", etc.). Instead, *auditory synthesis* is the process by which the brain combines different sounds into understandable units, similar to the way letters are combined into words and words into sentences. Like auditory discrimination, auditory synthesis is necessary for comprehension of language since it is related to the ability to join or blend sounds together to create words, such as: "c-a-t = cat". On the other hand, beginning with putting units together at a syllable level teaches child that long words can be broken up into smaller constituents: as at the early stages of phonetic reading or spelling. *Auditory analysis* is therefore the mechanism by which one can break up words into their individual sound constituents. For example, to determine whether one has spelled the word "cat" correctly, we have to break the word up into its individual sound components: "cat = c-a-t".[151] In contrast, *auditory sequencing* is a process closely related to both memory and auditory perception, as it refers to the ability to understand and remember the order in which certain sounds happened.[152] Finally, *auditory rhyming* is a process that includes both discrimination and production.[153]

Having introduced those processes, we may think of the auditory system as a collection of components. This view might grant the validity of asking questions about the architecture that causes listeners to assign sources to locations and pitches to sources. Psychological studies have encouraged a modular conceptualization of auditory processing analogous to the dominant theory in visual processing.[154] Evidence for a modular system exists in the literature as regards descriptions of deficits in auditory processing (descriptions of deficits in auditory processing had already appeared in the literature by the end of the 19th century). Specifically, three major disorders were identified: cortical deafness, which describes a condition in which individuals have no auditory perception;[155] auditory agnosia;[156] and pure word deafness, a condition in which individuals are not capable of perceiving or interpreting speech sounds as words.[157] Each of these auditory disorders can be viewed as being analogous to a specific disorder in the visual domain; specifically, it seems

[151] Cooke: 1974.

[152] Martin: 1972.

[153] Coch, Grossi, Coffey-Corina, Holcomb, and Neville: 2002.

[154] Polster and Rose: 1998.

[155] Wernicke and Friedlander: 1883.

[156] Freud: 1891; Van Lancker and Canter: 1982.

[157] Bastian: 1897; Kussmaul: 1877; Lichtheim: 1885.

reasonable to contend that cortical deafness and blindness represent sensory impairments; the agnosias represent perceptual and/or semantic impairments; dyslexia and pure word deafness represent receptive language impairments and phonagnosia and prosopagnosia represent person information impairments.

Clinical descriptions of auditory disorders lay the groundwork for an ongoing debate about the underlying nature of the auditory system: whether the disorders reflect quantitative differences in the severity of damage to the auditory processing system, or qualitative differences between independent modules of that system which are susceptible to selective impairment. To the extent that phonagnosia and auditory associative agnosia are auditory analogies for prosopagnosia and visual associated agnosia, questions relating to the specificity of deficits and the number of modules that exist can be raised in the auditory domain. If we assume that pure word deafness and phonagnosia are auditory analogies to visual disorders in processing words and faces, then we can postulate two types of auditory processors: one for voices and another for words. This possibility may be seen as a modification of the theory that verbal and nonverbal sounds are processed independently.[158] However, other studies suggest treating prosopagnosia as an independent visual processing impairment associated either with damage to neural hardware dedicated to processing faces,[159] or with an impairment in the complex category processing required to identify faces.[160] In any case, a modular theory of auditory processing which allows for several patterns of deficits to be observed on the basis of the severity of damage to modules appears to provide the best explanation for the existing data. In fact, we could hardly explain how a perceptual impairment can impair the processing of one class of stimulus (non-linguistic sounds) but not another class (linguistic sounds), unless we assume that independent processing modules exist.[161] The idea that disorders reflect impairments in the operation of distinct modules provides a more coherent account of cases in which a selective impairment in one type of stimulus is attributed to a perceptual deficit. As different modules process different types of information, then a low-level impairment in one module would not necessarily affect the manner in which stimuli are processed in the other modules. In the light of the widespread support for modularity in visual processing and the strength of these analogies between visual and auditory disorders, the impact of the modularity thesis on the study of auditory perception is unsurprising.

10. 4 Other forms of Perception: Speech Perception and Music Perception

One of the most promising directions for research into auditory perception focuses on the relationships between the perceptual modalities that shape experience. A primary interest of study centered on testing language comprehension deficits in the auditory modality. It is supposed that speech perception is dealt with by a phonetic and linguistic module. The module specific to speech

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[158] Albert et al.: 1972.

[159] Seeck, Mainwaring, Ives et al.: 1993; Sergent, Ohtaz and MacDonald: 1992.

[160] Damasio and Van Hoesen: 1982.

[161] Fujii et al.: 1990.

has its own perceptual primitives, which are intended to be the articulatory gestures that constitute phonetic events.[162] The speech module is thought to be independent of the modules for pitch and timbre. When resonance is presented in isolation, the auditory module for timbre interprets its centre-frequency slope as a chirp; conversely, when this same resonance is placed in the appropriate context, the phonetic module interprets its slope together with other parts of the pattern as a phonetic event. Speech perception appears simply to use all of the phonetically relevant information in the signal, despite having its own specifically phonetic criteria which are very different from those for pitch and timbre. This suggests that there are two distinct component lexical and phonetic-processor modules. Empirical evidence for this assumption is provided by clinical studies on double dissociations in patients. It has been demonstrated that patients who are unable to identify non-linguistic sounds can understand speech;[163] and patients who are not able to comprehend speech can, nevertheless, identify non-linguistic sounds.[164] The performance of these patients clearly indicates that linguistic and nonlinguistic auditory sounds are processed by independent processing modules.[165]

On the other hand, auditory perception is connected to general issues of musical experience. Auditory experiences are critical for appreciatively listening to music, and to appreciate music is to appreciate sounds, sequences, arrangements, and structures of sounds. Listening to music requires listening in a way that abstracts from the environmental significance, and thus from the specific sources, of the sounds it includes; it is then a topic that affects the relationship between hearing a sound and hearing a source. We might question whether there is a specific module for music recognition, or general auditory recognition for both speech/music and environment/sounds recognition. Evidence for the view that there is a specific module for music perception is provided by studies of cases in which selective impairment and sparing of musical abilities are compromised by music-related deficits in neurologically impaired individuals. It has been shown that when the general auditory system is damaged, amateur abilities such as music recognition suffer more than expert abilities such as speech recognition. Accordingly, non-musicians might lose their ability to recognize spoken words yet remain able to recognize music; conversely, brain-damaged patients afflicted with verbal agnosia (namely, word deafness) can recognize nonverbal sounds including music even though they have lost the ability to recognize spoken words.[166] The study of music perception includes several theoretical issues regarding temporal processing, including the issue of the nature of timing information behind music processing, or whether our perception of rhythm must be explained in terms of modality-specific processes or modality-general processes. Time perception will be the object of the following chapters.

[162] Liberman & Mattingly: 1985.

[163] Spreen et al.: 1965.

[164] Metz-Lutz and Dahl: 1984; Saffran et al.: 1976.

[165] Albert, Sparks, Von Stockert et al.: 1972; Shallice: 1988.

[166] Godefroy: 1955; Mendez: 2001.

11

Time Perception

11. 1 The Importance of Time

Time is a crucial dimension of our perceived world, we often wonder about the fashioning and incomprehensible character of time dimension and the way it affects us. When we perform our daily tasks, it is unlikely that we pay attention to every single step in our experience. We wake up in the morning and start putting our energy into certain activities, activities that permit us to be part of the society or the world in which we live. We go to work, then we have lunch and later we go home again. At the end of the day, after dealing with our social lives or carrying out personal activities, we sleep (if we do not suffer from insomnia). In everything we do during the different stages of the day, we apparently pay little attention to what we are actually doing. We do not pay close attention to the streets we walk down every day from home to work or work to home. For instance, we do not decide whether we will walk on the pavement on the right hand side of the road or on the left hand side of the road. We just do it “automatically”, in the same way that we “automatically” use our right or left hand when we have lunch. Equally, once we have learnt to swim, cycle or to fish, etc., we do not need to remind ourselves of every step that the learned process consists of, for example every movement we need to make to perform a specific physical activity. We process these steps unconsciously and automatically, but at every step of our cognitive processing the information is elaborated at a specific rate. Timing apparently plays a key role in our functional organization, but how people experience time is still unclear. Over the past fifty years cognitive psychologists have revealed a substantial number of specific mechanisms, processes and strategies, including those concerning temporal processing; on the other hand, Fodor’s work on mental architecture has demonstrated that the mind involves a highly specialized modular structure with the presence of highly specialized functions. Fodor recognizes the existence of different modules corresponding to the perceptual modalities, plus a further module for language processing. Thus in the context of the present discussion, I wonder whether we may assume that the important part of our mind which deals with time perception is modular in nature. In other words, I am posing the following question: is there a module for temporal processing? Here I argue that such a module really exists. However, before examining the hypothesis of a module for time processing, I should offer a general overview of the main issues and strategies that apply to time perception. In introducing the topic, this and the next chapter will be centered around two general questions concerning how and where is time processed in the brain. Only after this step, in the final chapter of my dissertation, will I debate the presumed modularity of time.

11. 2 What is Time Perception

Roughly speaking, time perception refers to the ability (exhibited by minded individuals) to judge the duration of events, or to apprehend the passage of time by the order of occurrence of experiences or physiological rhythms. It is generally accepted that when people perceive temporal passage they sense the *irreversibility* of time, the feeling that what lies in the future is continually getting closer to the present, and what is present continually recedes into the more distant past. This feeling makes individuals confident of the idea that things and events change through time only in one order or direction. Time can be experienced in the way we wait for something to happen or to end, but also in more subtle ways, since the same interval of actual time might be perceived as long or short, as fast or slow. Research on time perception address a broad range of the temporal experiences we have in our daily life; this topic is very complicated and requires research efforts to be directed into different, yet interconnected areas. Among these topics, we can list five principal time experiences:[167]

- *Duration*, which assigns the moments of a time interval to real-world behaviour and processes. The ways that different intervals might be related (inclusion, succession, overlap, etc.) places independent experiences into a common context that is useful for understanding the causal dynamics of the world.

- *Simultaneity*, which addresses how events that start and end at close but different moments are experienced as occurring concurrently (i.e. we feel the present as an interval rather than a durationless instant).

- *Ordering*, that is, how we perceive precedence amongst events. Not only we perceive events one after another, but while perceiving an event as occurring after another we consider also the relationships that link them.[168]

- *Past*, *present*, and *future*, which respectively regard: (i) feelings we once sensed and we cannot experience in the same way again, but an abstract (incomplete) representation of which can be recalled; (ii) feelings that we have here and now, or during short periods perceived as present (the so-called "specious present"); (iii) feelings that we have never sensed but which it is possible to do so after some time, being capable of abstractly representing this possibility (in a different way to recalling the past).[169]

- *Time flow*, that is, the fundamental feeling of the present that is constantly changing in a unidirectional way, which makes future become present and then become past.

Topics related to the experiences of time listed above have attracted significant research interest in the literature of philosophy, psychology, cognitive sciences, biology, neuroscience and artificial intelligence, to cite just some fields. In particular, investigation into the cognitive mechanisms of

[167] LePoidevin: 2009.

[168] Husserl: 1964; Tani: 2004.

[169] Husserl: 1964; Tani: 2004; Valera: 1999.

biological agents involved in time perception and how such mechanisms could be interpreted from a computational perspective, involves two general issues: one regarding the interaction of time perception with other cognitive processes and the other regarding the presumed neural basis of time processing.[170] The former is accomplished by the question of how time is processed within the brain. Time researchers committed to this issue try to provide explanations of how people plan actions, filter information, direct attention to events, form decisions, or how they understand the common and different properties of two similar behaviours executed in different time scales (i.e. temporal compression). Instead, the latter deals with the question of where time is processed into the brain. This question is typically investigated in the context of neuroscience, in which the research aims to find the (separate) subsystems necessary for time processing on long and short scales, the dedicated or implicit nature of time representation, and the role of development in the acquisition of time perception capacity. In this chapter I examine the former issue in relation to a general introduction to the study of time perception; some of the principal recent theoretical and empirical approaches to the question of how time is processed will be summarized here. The second issue will be discussed in the following chapter.

11. 3 Two paradigms of Time Perception: Perspective Time and Retrospective Time

When we approach the literature on time perception we encounter several conceptualizations and a large variety of models used to explain *how* the brain processes duration. Experimental psychologists indicate the presence of distinct processing components involved in perception of duration or timing movements. Temporal processing and experiences relating to time interval estimation are supposed to operate across different neural systems and multiple cognitive processes. Generally, empirical studies divide the issue into two experimental paradigms: *prospective* timing and *retrospective* timing.[171] The substantial difference between these two kinds of experimental paradigms concerns the different situations in which participants are asked to judge time.[172] In the context of 'prospective time theories', time estimation is explicitly the focus of the task; essentially, it is studied in isolation or in relation to four principal paradigms:[173]

- *verbal estimation*: after exposure to a time interval, reporting how much time has elapsed;
- *interval production*: producing an interval of a certain duration, for example, 1 min;
- *interval reproduction*: perceiving an interval of a certain duration and then reproducing it;
- *interval comparison*: comparing two intervals and reporting which is longer.

[170] Droit-Volet and Meck: 2007; Leon and Shadlen: 2003; Wittmann and Paulus: 2008.

[171] Hicks, Miller, and Kinsbourne: 1976.

[172] Block, Hancock, and Zakay: 2000.

[173] Zakay: 1990.

In each of these paradigms temporal duration is considered a fundamental feature of the entire experimental procedure. In general, prospective time experiments focus on judgments made regarding the duration of an interval of time that is presently experienced. Time judgments are made after the experimental participants are alerted in advance that they will be asked to judge the ensuing time interval. Through similar experiments, psychologists seek to demonstrate that if participants are informed before they perform the task that they will have to make a time judgment, they are presumably motivated by this warning to monitor the passing of time and pay attention to any available cues.[174] In principle, models of prospective time estimation rely on the idea of an 'internal clock' (which in one dominant version involves recourse to a pacemaker device that produces a sequence of time units which are fed into an accumulator).[175] In addition to the internal clock component, prospective time models consider several processes as involved in time estimation, including working memory, long-term memory, attention and decisions.

Conversely, subjects tested under the paradigm of retrospective timing are not provided with any warning at the start of the interval that they will be required to make a time judgment. In the procedure of retrospective timing, the participants are unexpectedly asked to judge the duration of a time interval after it has already elapsed; the time judgment is made when the participant is unaware that a question about time is going to be asked. Compared to time estimation assessed using prospective timing, in retrospective time experiments temporal information is processed in a more unreliable fashion. Given that the subject receives no prior warning, the estimation of duration in retrospect is supposed to be reconstructed from memory, insofar as it is carried out based on processed and stored memory contents.[176] Then, the structure of events constitutes a critical determinant of remembered duration,[177] and memory processes also deserve attention.[178] Psychologists and time researchers agree that perspective timing and retrospective timing operate at different levels and provide explanations of different psychological mechanisms. We might very state that, in general, retrospective timing theories focus on time judgments which are made in temporal intervals ranging from a few seconds (*short-term memory*) to a whole lifetime (*long-term memory*),[179] whereas, pure prospective duration judgments are made over a limited and shorter time range where a subject devotes attention to time for a period of seconds to minutes.

11. 4 The Temporal Continuum Perspective

One interesting view in the study of time perception is that individuals and organisms naturally behave on the basis of a continuous hierarchy of biological and cognitive automatisms. Whatever

[174] Doob: 1971.

[175] Church: 1984; Treisman et al.: 1990.

[176] Ornstein: 1970; Flaherty at al.: 2005; Noulhiane et al.: 2007.

[177] Boltz: 1992, 1994, 1995, 2005.

[178] Block & Zakay: 1997.

[179] Wittmann and Lehnoff: 2005; Bisson, Tobin and Grondin: 2009; Grondin & Plourde: 2007b.

performance we observe, we note that a behaviour is the unified result of a number of internal biological processes regulated in time. In language learning, learning or performing movements, in both decision making and planning action, individuals show a certain ability to manage time information for controlling actions. For instance, timing control is necessary to regulate the following exemplary performances:

- whether a sound produced can have a semantic meaning (words, sounds, music, or language itself);
- the steps composing movement, such as walking or running;
- the bio-physiological mechanisms inside bio-masses;
- the perception/cognition of days/seasons alternating;
- the perception/cognition of changes themselves.

During these performances the brain organizes information in a unified way, comprising multiple levels of cyclic activities which extend from very long time scales (e.g., menstrual cycles, circadian rhythm) to much shorter ones (e.g., the firing rate of cortical cells).[180] This picture, sometimes called temporal continuum perspective, suggests that time serves to organize a sequence of events which are linked together. Essentially, the subjective experience of time can be individuated at either biological or psychological levels. On the one hand, there is a biological basis to time perception. Some psychologists, as Cohen pointed out,[181] propounded the idea of a *biological clock* that determines how time is experienced. According to the biological approach to time perception, people have internal cycles which are used to measure time. Humans and other diurnal species normally sleep at night and are active during the daytime; the timing of functions with prominent rhythms, such as sleepiness, metabolism, alertness, and other biological rhythms of various periodicity serves to align our physiological functions with the environment. Despite the fact that the frequency displayed might vary from fractions of a second to years, daily rhythms provide most of the information available, and by paying attention to these cycles individuals (and other creatures) can know how much time has passed. The principal idea of biological time is that there is a kind of automatic rhythm that recurs continuously and which is not directly affected by environment. The cyclic patterns recurring on a daily basis in humans are called *circadian rhythm*. By definition, circadian rhythms are biological rhythms internally generated with approximately a 24 hour period (the term ‘circadian’ derives from the Latin word ‘circa diem’, namely, ‘about a day’). Circadian rhythms serve to temporally programme the daily sequence of metabolic and behavioural changes, since they persist in the absence of temporal cues (such as the alternation of light and darkness) and are coordinated internally by the biological clock. On the other hand, the metaphor of the internal clock has been recently dominant in experimental psychology. Over the last decades empirical works on time perception have proposed the idea of an internal clock concerned with the psychological mechanism of time experience. Analogously to the biological-

[180] Buonomano: 2007; Mauk & Buonomano: 2004; Wackermann: 2007.

[181] Cohen: 1964, pp. 117-118.

circadian clock that regulates the daily rhythms of fundamental aspects of physiology and behaviour, such a *psychological clock,* or time-keeping mechanism, is supposed to form the cognitive basis for the subjective experience of time.[182] However, a similar clock for time sense relating to fractions of a second to multiple minutes has not been identified with (just) one specific organ of the brain, so it seems that no single sensory organ (or perceptual system) is uniquely responsible for encoding psychological time. The difficulty of individuating the neurobiological areas necessary for representing duration and temporal passage leads us to the second general issue of time perception (*where* time is processed), which will be discussed in greater depth in the following chapter.

11. 5 The Internal Clock Theory: Pacemaker–Counter Models vs. Oscillator Models

The internal clock theory arises from several interpretations of the psychological components for interval timing. There are a variety of theoretical models that apply the image of the “internal clock”: Matell and Meck[183] provided a general overview of the three principal models for the internal clock theory: the *pacemaker-accumulator* model, the *process-decay* model, and the *oscillator/coincidence detection* model. All the internal clock models conform to a common structure which is basically composed of: a *clock component* that starts upon the onset of a timed signal; a *memory component* that stores duration codes; and a *decision/comparison component* that compares the clock’s output to previously important duration codes held in the reference memory. The clock component is supposed to be made up of repeatable processes that can be mapped onto timing. Instead, the memory component can be thought as a long-term store of previous reinforced clock’s output values; whereas, the decision-comparison component is the mechanism that evaluates how well the current clock value matches previously stored temporal memories. Besides having an equivalent common structure, such models differ in terms of the very important aspect of the different neurobiological plausibility they involve. In this paragraph I focus on the dominant models of duration estimation in prospective time theories: the pacemaker–counter device model and the oscillatory–processing device model, while the process-decay device model will not be considered here.

The first dominant contemporary model in prospective timing is a version of the pacemaker–counter device model, known as the *scalar expectancy theory*, or SET, as proposed by Gibbon, Church, and Meck.[184] The idea underlying the scalar timing model is that there is an accumulator that counts the amount of pulses emanating from a pacemaker. The pacemaker runs continuously as pulse-generator, and the accumulator is activated by the onsets of signals to time generated by the pacemaker, which acts as pulse-counter. The sort of hypothetical internal clock based on the pacemaker–counter device is composed of three connected parts:

- a pacemaker that produces pulses or “ticks”;

[182] Church: 1984; Zakay & Block: 1997; Roenneberg et al.: 2003; Wittmann et al.: 2006.

[183] Matell and Meck: 2000.

[184] Gibbon, Church, and Meck: 1984.

- an accumulator that stores the ticks produced during a time period;
- a switch that connects the two.

Each of these parts posits a distinct stage of temporal processing. During the first stage, the internal clock, or input processing, estimates the time between two events. The 'clock stage' involves the pacemaker emitting over time a continuous stream of pulses that flow into the accumulator via an *attention-controlled switch*. When a stimulus is timed at the start of a target time interval the switch closes, allowing pulses to flow from the pacemaker to the accumulator. In turn, when the stimulus goes off at the end of the time interval, the switch opens, stopping the flow of pulses into the accumulator and cutting the connection. Then, for each time interval the accumulator is engaged with the opening or closing of the switch, and in this sense the switch behaves like an arbitrary reset signal that can be compared to the signal though which a mechanical stopwatch is reset. The basic idea of this model is that representations of duration are generated at the clock level by the pacemaker–accumulator system. As the pulses emitted by the pacemaker accumulate in a counter, then the number of the counted pulses is what determines the perceived length of an interval. Accordingly, the number of pulses accrued during a target time interval and contained in the accumulator gives a representation of duration, being used as "raw" material for time judgments. At the next stage of the clock mechanism, the 'memory stage', the temporal information is stored in the memory. Basically, SET systems involve two sorts of memory. A *working memory* for duration is essentially formed by the contents of the accumulator. This sort of reference memory stores important times, necessary to execute particular tasks. What is more, the memory stage also involves estimation of duration to be stored in a *long-term reference memory*. The next level of the clock mechanism pertains to the decision-making mechanism, which compares the stored interval of time with intervals formed by the current external onset.[185] At the 'decision stage', the current accumulator account is continuously compared to a stored duration code sampled from reference memory. The decision-processing mechanism works on the basis of a temporal criterion. When the accumulator-account reaches the temporal criterion, the current timed interval is expected to end; in virtue of such expectation, an individual can make a temporal judgment about shorter or longer duration. If the objective time interval ends before the account reaches the temporal criterion, then the time interval is shorter than expected; conversely, if the account reaches the temporal criterion before the objective time interval ends, then the time interval is longer than expected. In short, the pacemaker–counter device encodes the time it takes for two events and then compares the time information stored in memory to all future events; only after the operation of all the three levels can a time judgment be made. According to this information-processing framework, time judgments and timed behaviours derive from the sequential operations processed at these three levels.[186]

As opposed to the pacemaker–counter device, or SET, the oscillatory–processing device model is developed in the *dynamic attending theory*, or DAT, where the clock mechanism is described in terms of an oscillator that detects specific combinations of periodic neural events activated upon the onset of signals. Within this oscillator–detection account, the clock activity is encoded by

[185] Gibbon: 1984; Meck: 2003.

[186] Creelman: 1962; Rammsayer & Ulrich: 2001; Treisman: 1963.

associating the combinatorial activity of the oscillator with a particular duration. DAT focuses on the contribution of the environment with entrainment of various biological rhythms;[187] this clock model is based on the *dynamical systems perspective*, which builds on the observation that there are physical regularities within the flow of events in the environment. If we observe rhythmic phenomena in music, speech or even motor coordination, we note that such regularities mark coherent beginnings and ends for several successive time spans; therefore, due to these regularities we can predict forthcoming events and establish a state of expectation. The general idea behind DAT is that judgments about the timing sequence of physical events can be made by using an internal oscillator, which must be able to detect the synchrony/asynchrony between internal rhythms and external rhythms. While the clock model based on the pacemaker–counter device includes clock, memory and decision-making stages of temporal processing, conversely, the oscillator model is composed of two principal components: a *nonlinear oscillator*, and an *attentional energy pulse rhythm*.[188] The summation of these two components forgoes the explicit memory comparison between two coded durations in favour of dynamic information afforded by synchrony versus asynchrony, between an internal 'driven' rhythm and an external 'driving' rhythm. An internal driven rhythm can be thought of in terms of attentional rhythm. The internal oscillator changes gradually and adapts to allow the attentional rhythm to get closer to the stimuli onset. Thus, the oscillator continues to adapt the time period, or timespan, between the peak of an attentional pulse and the onset of a stimulus. In particular, the oscillator process runs until the attentional peaks are closely aligned with the expected stimulus onsets.[189] The result of the continuous adaptation of the internal oscillator to the context of environmental stimuli is a synchronization of attentional pulses and stimuli onsets.[190] Consequently, the accuracy of temporal judgments depends on the temporal coherence between internal and external events; this coherence can exist only if the oscillator mechanism has the capacity to synchronize the internal rhythmicity of waiting, or attunement, with the appropriate external rhythms of the environment.[191]

Before concluding the examination of these two internal clock models, I want to mention some distinctive features. First of all, these two approaches imply different understandings of duration. In SET, sometimes called the 'interval model', duration is explicitly represented as a 'code' that is stored in memory. Conversely, in DAT, sometimes called the 'entrainment model', duration is implicitly represented in terms of the oscillator period. While the interval model involves explicit comparison of two stored duration codes, the entrainment model involves a phase-based temporal contrast metric. A further important difference between those models concerns responses to stimulus onsets. The interval model involves the arbitrary resetting of the pacemaker-accumulator clock with the onset of each stimulus whilst the entrainment model involves more gradual correction of the oscillator phase and period. In the latter model, stimuli are supposed to

[187] Moore-Ede et al.: 1982.

[188] Large & Jones: 1999.

[189] Jones: 1976; Large and Jones: 1999.

[190] Barnes & Jones: 2000; Large: 2008; McAuley & Jones: 2003.

[191] Jones: 1976; Jones and Boltz: 1989; Large and Jones: 1999; McAuley and Jones: 2003.

synchronize neurons in a certain area of the cortex, acting as an effective starting signal. As each of the synchronized neurons produces its own particular pattern of activation over time, this unique pattern of activation is associated with a particular time interval that serves as a basis for later comparison. This oscillator-coincidence detection account is favored by Matell and Meck[192] because of its neurobiological feasibility. I will later return to these models with regards to the question of whether explanations of time perception can be given from a modular perspective. Before that, let me discuss on the second general issue of time perception: the question of where time is processed in the brain.

[192] Matell and Meck: 2000.

12

Time Perception in the context of Neuroscience

12. 1 The Study of Time Perception in Neuroscience

Thus far we have assumed that time perception is an adaptive function that facilitates the ability to make temporal judgments, predict and anticipate future events, or organize or plan sequences of actions. In introducing the topic, I dealt with the question of how people perceive time, so I focused on the perspective of the 'internal clock'. According to this view, the relative accuracy with which humans (and animals) perceive duration and the passage of time is accomplished by a complex cognitive system, which invokes multiple component processes in the representation of real-time information. However, a specific and restricted neurobiological organ for time processing has not been found, and this point alone introduces a second general question: where is time processed in the brain? In recent decades the investigation into time processing has been a neglected topic in cognitive sciences and neuroscience.

Neuroscientists indicate that several neural regions are engaged in timing, and explore issues of explicit time judgments in relation to the fundamental functionality of the principal brain structures involved. They propose that timekeeping is distributed in the brain via patterns of activity across a neural network, including specific contributions from neural activity within sensory modalities. However, explanations of time behaviour demand the construction of a wide framework that includes not only the neural timer, but also non-temporal components, such as attention, memory and decision-making. The brain regions underlying these processes are supposed to work together with the neural timer, as a part of the network subserving time perception. Neuroscientific approaches match a striking number of contributions from the fields of cognitive psychology, psychiatry, neurology and neuroanatomy; plus a wide variety of techniques ranging from psychophysical and behavioural experiments to pharmacological interventions and functional neuroimaging. Recent empirical studies, focusing on the neurobiological mechanisms underlying the experience of time, led to major progress with the realization that time perception involves distinct brain mechanisms and areas on different time scales.[193] In this collection of recent research studies, several models were presented to cover experienced time intervals ranging from milliseconds to minutes in the brain areas individuated as the active ones. These demonstrated that certain brain areas are neural substrates of potential timekeeping mechanisms, including the cerebellum,[194] the right posterior parietal cortex,[195] the right prefrontal cortex[196] and fronto-striatal

[193] Gibbon et al..: 1997; Poppel: 1997; Rammsayer: 1999; Lewis and Miall: 2003.

[194] Ivry and Spencer: 2004.

[195] Bueti et al.: 2008.

[196] Rubia and Smith: 2004; Lewis and Miall: 2006.

circuits.[197] But the question of individuating the determinant part of the brain for representing duration has not been definitely answered. The variety of timing tasks and durations observed at different time ranges are partly responsible for the complicated nature of drawing a clear and definitive account of these brain structures.

12. 2 The Role of the Cerebellum in Temporal Processing

The assumption that the cerebellum is part of the biological basis of timing was first made more than 40 years ago,[198] although its role in temporal processing has been intensively examined in the last decades. The cerebellum is active in many processes which operate based on the precise temporal relationships between events, in particular, neuroscientists believe that it serves as internal clock in both the domain of perception and motor activities. Furthermore, recent studies have demonstrated that separate neural elements in the cerebellum have different delay properties which might potentially encode duration.[199] Evidence for this assumption come from several neuroscientific methods which focus on the role of the cerebellum in various timing tasks. Clinical studies of perception suggest that the cerebellum plays a role in representing temporal information. Patients with lesions in the cerebellum were found to be impaired in either the precise timing of movements,[200] or sensory discrimination of duration.[201] It has also been shown that patients with lateral cerebellar lesions increase the variability of intervals produced with a series of taps.[202] Other studies propose that cerebellar patients have more difficulty than other experimental participants in discriminating between brief intervals marked with sounds, despite being equally efficient at discriminating between the intensity of sounds.[203] All the studies reported here suggest that the deficits observed when patients process time information are not due to general auditory processing incapacity, but rather to perceptual deficits which are apparently specific to temporal dimension (as we shall see, the results of these studies are very important in the light of a presumed module for temporal processing).

On the other hand, the involvement of the cerebellum has been individuated in a variety of tasks studied in the motor domain; in particular in the cases of movement production and rhythmic movements.[204] Evidence for the cerebellar timing hypothesis comes from research on simple forms of sensorimotor learning tasks, such as eye-blink conditioning, or speech perception/production in

[197] Harrington et al.: 2004; Hinton and Meck: 2004.

[198] Braitenberg: 1967.

[199] Ivry and Spencer: 2004.

[200] Ivry et al.: 1988.

[201] Ivry and Keele: 1989.

[202] Keele and Ivry: 1991; Keele and Diener: 1988.

[203] Ivry & Keele: 1989.

[204] Spencer, Zelaznik, Diedrichsen, & Ivry: 2003; see also Zelaznik et al.: 2008.

which the timing of brief intervals is a central component. However, either perceptual or motor studies highlight the critical role of the cerebellum in tasks in which precise representation of dynamic information is necessary. Generally, the role of the cerebellum is confirmed in the explicit timing of relatively brief intervals. In the citied timing tasks, for example, the extent of temporal processing is quite limited, spanning only up to about 500 ms; but activity in the cerebellum is also reported in timing tasks in which intervals of time are shorter than 1.2 sec.[205] Somewhat along the same line, studies using rTMS (*transcranial magnetic stimulation*) data demonstrate that the cerebellum is essential in the reproduction of brief intervals of 400– to 600-msec.[206] Although there is less evidence for the cerebellum's contribution to timing in the range of seconds to minutes, recent studies suggest that it is plausible that relatively short intervals form the building blocks for the representation of long intervals. Evidence consistent with this assumption comes from neural imaging studies of duration, in which it is demonstrated that the cerebellum provides codes for processing intervals of time lasting 12–24 sec.[207] Whether the cerebellum is involved exclusively in the timing of brief intervals, or whether it also covers a wider range of durations, is open to question; however, its role in the timing of long intervals is consistent with the central clock–counter mechanism perspective.

12. 3 The Basal Ganglia and the Cerebral Cortices

In addition to the cerebellum, neuroscientists indentify the basal ganglia as the most likely subcortical structure involved in both the early stages of time processing,[208] or the encoding of time intervals.[209] Contributions to time perception provided by the basal ganglia and the cerebellum can be distinguished on the basis of different interval ranges. In principle, the cerebellum is mainly active in timing tasks relating to sub-second intervals of time, as it provides representation of duration in the millisecond range, whereas the basal ganglia has been indicated as the neural counter for longer durations, although it plays a role in timing tasks of either sub- or supra-second intervals.[210] Recent PET (*positron emission tomography*) studies would confirm that, besides the cerebellum, the basal ganglia contributes to a network underlying perception of durations of less than 1 sec. In any case, the prefrontal and the neocerebellar regions are supposed to perform dissociable functions within the network for time perception.[211] On the other hand, even the cerebral cortex is likely to participate actively in the processing of time intervals. Recent imaging studies focused on the involvement of the frontal cortex in the processing of brief intervals of less than 1

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205 Bueti, Walsh, Frith, & Rees: 2008.

206 Koch et al.: 2007.

207 Tracy et al.: 2000.

208 Helmuth, & Ivry: 1997.

209 Rao et al.: 2001; Harrington & Haaland: 1999.

210 Malapani et al.: 1998; Wiener et al.: 2010a.

211 Jueptner et al.: 1995.

sec,[212] whereas activity of the right hemispheric prefrontal cortex has been found in both sub-second and supra-second intervals.[213] What is more, the critical role of the supplementary motor area, or SMA, in the timing of intervals shorter than 1 sec,[214] or longer than 1 sec is currently being studied.[215] Evidence for the involvement of the parietal cortex in time interval processing emerges from studies using rTMS.[216] Other studies using fMRI (*functional magnetic resonance imaging*) revealed that the parietal cortex acts as an interface between sensory and motor processes by translating temporal information into action.[217] To conclude this brief overview of the brain areas that play a role in timing, the right posterior parietal cortex is active in the timing of short intervals of less than 1 sec marked by either auditory or visual signals,[218] but also in the timing of longer intervals.[219]

12. 4 Neurological mechanisms: Intrinsic Theories vs. Dedicated Theories

As I said, neuroscientific approaches focus on several brain areas or systems underlying our perception of duration and timing of bodily movements. From the perspective of neuroscience, there is no single brain area on which the functioning of our temporal experiences is completely reliant, rather different brain regions are assigned a central timekeeping function. However, it should be said that the cognitive components entangled with time processing do not necessarily depend on a potential internal clock, since they may more likely be related to an integrative processing of multiple modules distributed throughout the brain. The idea that multiple brain regions show activation during time perception tasks, and that multiple cognitive processes contribute to perception of duration, is supported by empirical studies, such as experimental manipulations of task load (i.e. attention or working memory); clinical studies involving selected patients with dysfunctions in different brain areas (i.e. cerebellum, basal ganglia, frontal and parietal cortex); and neuroimaging studies using fMRI (*functional magnetic resonance imaging*).[220]
Time researchers claim that neural mechanisms involved in temporal processing and time experiences operate in different neural areas, some of which are not primarily related to the encoding of duration (that is, the internal clock) despite taking part in a complex timing system

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[212] Pouthas et al.: 2005; Tregellas, Davalos, & Rojas: 2006.

[213] Koch, Oliveri, Carlesimo, & Caltagirone: 2002; Lewis & Miall: 2006; Penney & Vaitilingam: 2008.

[214] Ferrandez et al.: 2003; Tregellas et al.: 2006.

[215] Jahanshahi, Jones, Dirnberger, & Frith,: 2006; Kudo et al.: 2004; Rao, Mayer, & Harrington: 2001; Smith, Taylor, Lidzba, & Rubia: 2003; see Penney & Vaitilingam: 2008.

[216] Alexander, Cowey & Walsh: 2005.

[217] Bueti, Walsh, et al.: 2008.

[218] Bueti, Bahrami, & Walsh: 2008.

[219] Koch, Oliveri, Torriero, & Caltagirone: 2003.

[220] Lewis and Miall: 2003.

involving attention, working memory and decision-making processes.[221] Evidence from neuroscience feeds the debate about whether there is a central mechanism for explicitly encoding time, or whether neural populations within each region intrinsically encode temporal characteristics of sensory events on the basis of time-dependent neural changes.[222] This question divides the issue into dedicated time and intrinsic time.

Intrinsic time theories endorse the view of distributed neural networks, in which neural populations associated to each region encode duration.[223] According to this view, the different brain areas which contribute to time perception are distributed in the neural network without incorporating a dedicated timing system with a centralized clock; activity of these areas would instead depend on the modality and the type of task processed. Thus, time is supposed to be an emergent and intrinsic property of the underlying neural dynamics, it depends not on a dedicated timing mechanism but on state-dependent neural changes, such as short-term synaptic plasticity.[224] Models based on intrinsic time consider timing to be inherent in the neural dynamics of the cerebral cortex (including the primary sensory areas), assuming that several neural units possess such intrinsic temporal-processing property. For example, in the modality-specific timing areas, visual neurons are responsible for visual timing; auditory neurons are responsible for auditory timing, and so forth; these sensory-specific areas do not need to be identified with any dedicated central clock mechanism. However, intrinsic mechanisms are generally limited to very short time intervals defined as up to several hundred milliseconds. On the other hand, the alternative view of *dedicated time* suggests that time perception is processed by dedicated timing systems. Accordingly, all time modalities draw information from a central timing module, in which the cerebellum (necessary for matching movement with events and pairing events in time to consequences) and the basal ganglia (a possible gatekeeper mechanism and long-interval discriminator) are often implicated as specialized timers. Further dedicated timers of the central timing module are likely to be distributed across the cortex, the supplementary motor area (SMA) and dorsolateral prefrontal cortex. Activation of these areas in dedicated timing processes would be confirmed by studies using fMRI (*functional magnetic resonance imaging*) and TMS (*transcranial magnetic stimulation*).

In the current debate regarding temporal-processing mechanisms involved in the milliseconds range, the *state-dependent network* (SDN) model has been proposed.[225] The SDN model claims that even though temporal processing may be dedicated to the spatial attributes of a scene, time is, however, an emergent property which is intrinsically coded. According to this view, the representation of duration depends on the neural network's initial state, in which the contextual influences of stimuli with similar attributes form the basis for time judgments. Recently, this original hypothesis has been addressed by empirical studies. In the study proposed by Spencer,[226] a

[221] Rubia and Smith: 2004; Livesey et al.: 2007.

[222] Ivry and Schlerf: 2008; van Wassenhove et al.: 2008; Ulbrich at al.: 2009.

[223] Mauk and Buonomano: 2004.

[224] Karmarkar and Buonomano: 2007.

[225] Karmarkar and Buonomano: 2007.

[226] Spencer: 2009.

randomized occurrence of an irrelevant distracter interval in a duration estimation task was introduced to test predictions of the SDN model. The results obtained in the experiment support (at least in part) the SDN model for time intervals shorter than 300ms; it has been shown that interference effects diminished with intervals of 300ms. Other research provides empirical data to evaluate the plausibility of the SDN model. One study demonstrated that, in predictions of contextual influences, interference decreased when the duration of stimuli that had to be judged had different frequencies, or when the stimuli were separated with inter-stimulus intervals of longer than 250ms.[227]

12. 5 Time Scales of Time Perception

Among time researchers the assumption that the processing of temporal information in the distinct brain areas and mechanisms takes different time scales is being affirmed.[228] Central to the literature of perception of duration is the distinction between supra-second and millisecond range intervals. Several models based on this distinction came under close scrutiny.[229] As regards to short temporal scales (expressed in milliseconds) I alluded to the contraposition between intrinsic and dedicated time theories, whose major focus is whether duration in the sub-second range is processed by dedicated systems (thus, if there are dedicated areas or circuits in the brain that control the processing of time), or whether neural populations within different regions of the brain intrinsically encode duration in consequence of time-dependent neural changes (thus, if temporal information is inherent to the neural dynamics of modality-specific areas).[230]

Conversely, the study of time perception in longer temporal scales (expressed from seconds to minutes) encounters the view of the centralized clock-type mechanism to estimate duration. In the context of prospective time theories, we saw that in one dominant version the internal clock is described in terms of a pacemaker that produces a series of pulses, taking the number of pulses recorded over a given timespan to represent subjective duration.[231] Current models of prospective timing reveal that paying attention to the flow of time increases perceived subjective duration (somewhat similarly, being distracted from assessing time results in the shortening of perceived time). 'Attention' has been viewed as an important causal agent of perceived duration in many models of time perception or estimation. The importance of allocating attention to time was recently tested in a variant of clock model experiments using a specific task: the peak interval procedure.[232] In this procedure, a rat was trained to press a level bar after a certain time interval had passed (similarly to the rat of Skinner's boxes), whereas a distracter signal was present when the interval

[227] Buonomano: 2009.

[228] Trevarthen: 1999; Wittmann: 1999; Mauk and Buonomano: 2004¸ Buhusi and Meck: 2005.

[229] Gibbon et al.: 1997; Poppel: 1997; Lewis and Miall: 2003.

[230] Ivry and Schlerf: 2008.

[231] Church: 1984; Treisman et al.: 1990; Zakay and Block: 1997.

[232] Buhusi and Meck: 2009.

had to be timed. The experiment shows that if attention is distracted from judging time, the accuracy of the timed performances deteriorates. In addition to attention, other causal agents, such as emotion and bodily sensations, have been identified as shaping the perception of time. With the emergence of experiments testing causal agents of perceived duration, new theoretical models were presented to extend (but also to challenge) the classic internal-clock view of time ranges of seconds to minutes.

13

Time and Modularity

13. 1 A further issue of temporal perception: Modularity

In the last two chapters I engaged in an examination of the much-discussed issues of time perception. The whole are of study of time perception has a long history that goes back to the beginning of experimental psychology, however, it has progressed on numerous fronts especially since the 1970s, when large differences have emerged between the prospective and retrospective findings. Time in passing (prospective estimation) and time in recall (retrospective estimation) involve distinct issues and distinct procedural paradigms, but regardless of the development of quantitative paradigms and techniques used to summarize large bodies of experimental data, the pure psychological research of timing has itself shown an important renewal in the last decades.[233] The most dominant techniques to explore the sense of time have been associated with verbal estimation, duration production, and duration reproduction.[234] Reproduction of time intervals necessarily emphasizes memory for explorations of time in passing; whereas, verbal estimation and production require reference of standard temporal units (e.g., seconds, minutes). Pure perception of duration is contaminated by the linguistic and semantic tags associated with traditional units of measured time.[235]

Thus far we have seen that an influent view takes duration to be measured by an internal clock mechanism able to provide representations of the "correct" time. The idea of the stopwatch is quite simple. Somehow the brain emits a steady stream of pulses, and subconsciously tallies how many were produced during a specific interval; what is perceived as deviate from this declared target is naturally seen as errors of estimation. The view that when we perceive durations we are endowed with the biological equivalent of such stopwatch had impact on an increasing number of theories. In the recent years, new ideas emerged about the neurobiological mechanisms underlying the experience of time, time researchers and neuroscientists claim that the brain runs multiple stopwatches simultaneously depending on the kind of task required. It is currently believed that the biological stopwatches make use of several brain mechanisms, including those that control memory, regulate metabolism or any else circadian rhythmic, and that they process sensory inputs at different temporal ranges. Thus, neuroscientists renewed the interest in time perception, accomplishing research of cognitive psychology with newly and emerging empirical data; they joined with many cognitive psychologists that understanding how the brain deals with time is important.[236] In many

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[233] Block & Zakay: 2001; Grondin, 2008.

[234] Bindra & Waksberg: 1956; Clausen: 1950; Guay & Salmoni: 1988.

[235] Zakay: 1990.

[236] Buhusi & Meck: 2005.

ways, neurological research provided innovative experimental techniques, including brain imaging techniques that are used in association with different time scales. With the advance of brain imaging techniques, it became progressively more evident that highly detailed but static representations of brain configuration could lead to important insights, nonetheless, these insights appear inevitably limited by the absence of sufficient information as to the dynamic changes occurring on differing time scales. It is now evident that the brain necessarily deals with time on a number of differing scales, and also in a number of different cortical areas (or modules) having a number of differing functions (including absolute timing, relative timing, rhythmic frequencies). In this scenario we encounter a subdivision of brain on the basis of: supra-second vs. millisecond ranges of time intervals, motor timing tasks vs. non-motor timing tasks, or sequences of intervals vs. isolated intervals. This multitude of aspects of time perception gave the rise to many distinct, and sometimes, incompatible theories of time processing, all related to the two general questions earlier discussed: how and where in the brain is time processed? As we saw, time researchers are far from reaching a consensus on these questions, and this difficulty seems importantly due to the variety of explanations of what mechanisms (how), and what neural systems (where), process duration. It is not clear, for example, what timing pulses are, or how they are produced, or still where they are managed in the brain. What is more, the number of timing pulses that the brain emits per minute can increase or decrease, as depending on other important aspects which are not intrinsically 'temporal', such as attention, emotion, mood, health, and even surroundings. A major issue is whether there are dedicated areas or circuits in the brain that control the flux of time information, or whether time information is inherent in the neural dynamics of modality-specific areas; the issue marks out the contraposition between dedicated time vs. intrinsic time. However, the questions of how and where time is processed by the brain lead to another question: is time perception, along which the other kinds of perceptions, modular in nature? To give an affirmative answer to this question is to endorse a modular view of the mental architecture of time perception, analogously to that proposed for audition, vision, speech, or other kinds of perception.

13. 2 The perceived object of Time Perception: duration and succession of events

I believe that one difficulty to endorse a modular perspective for time processing might be related to the tricky character of the objects of time perception. This simple consideration can be made from the fact that the objects of time perception cannot be compared to the physical objects that fall into the three-dimension space. Whatever timing task we perform (for example, if we try to execute a rhythmic movement, or to count the beats of the song we are listening), we cannot point the finger at a 'duration object' as we do at a sound source. Woodrow wrote: "Time is not a thing that, like an apple, may be perceived;"[237] and I think this view, and other similar views, might have disheartened the development of explanations of time processing from the perspective of the modularity thesis. If time is none physical object, what is the object of our temporal perception?

This is a much-discussed issue of cognitive psychology, but the question originated from philosophical reflections. The study of psychological correlates of subjective time experience is a

[237] Woodrow: 1951.

late development in the long history of theoretical and empirical research on the relationship between humans and time in general. Outlining the history of the philosophy of time from Plato and the Greek philosophers, to Augustine, Descartes, Kant, Hegel, Guyau, Spencer, McTaggart, Bergson, Paul Fraisse, and so many others, created solid ground for the psychology of time. Philosophers often defined time dimension as the dimension of change. The Greek philosopher Heraclitus, for example, claimed that the cosmos is endlessly changing, manifesting ongoing cyclical patterns, as one of the forefathers.[238] Sometimes the idea of temporal change recurs in terms of the metaphor of the *temporal flow*, or *passage of time*. In a general speaking, this metaphor tells us that what is in the future continually recedes into the present, and then into the ever more distant past, marking out the only one direction of time (time *irreversibility*) postulated by the second law of thermodynamics. In his famous book *The Principles of Psychology*, William James introduced one of the earliest psychological studies of the psychogenesis of time sense, discussing the perception of time duration and the passage of time as a core concept in psychology. James wrote: "the knowledge of some other part of the stream, past or future, near or remote, is always mixed in with our knowledge of the present thing."[239] introducing the foundations of conceptions that will later become the basis for time perspective theories: "there is thus a sort of perspective projection of past objects upon present consciousness, similar to that of wide landscapes upon a camera-screen".[240] Almost in the same period, in his thesis "*Essai sur les données immédiates de la conscience*"[241] Henri Bergson discussed time as intuition of duration, felt through the stream of consciousness in reference to the immediate experience. Bergson argued that subjective time is a spatial degradation of "pure" time achieved by a symbolic representation constituted by the past consisting of memory, and the future formed by expectations. However, the present, past and future that form the subjective time might be just mental constructions of our experience of changing events. Then, it is not clear what perception of time should be beyond a mere perception of things whose state is in continuous evolution. The drawback of our sense of time was well analyzed by McTaggart in his famous paper *The Unreality of Time*,[242] in which he assumed that the distinction between past/present and earlier/later positions in time underlines the profound paradoxical status of time dimension. Yet, if time does not exist in the physical reality (that is, if individuals cannot objectively perceive the present in McTaggart's sense), what is the perceived time?

Despite time cannot be perceived as we perceive a physical object, it is profoundly rooted in our mental architecture as well as the spatial dimension. To paraphrase Augustine: "time exists into our mind".[243] Somehow along this line, the Gestalt psychologists assigned to time a critical role in perception. It is evident that the perception of structure in time is absolutely fundamental to the perception of any object, such as an apple. The temporal binding of the features of an apple, both

[238] Birx: 2009.

[239] James: 1890, p. 607.

[240] James: 1890, p. 631.

[241] Bergson: 1889.

[242] McTaggart: 1908.

[243] Augustine: *Confessions*.

within a sensory modality and across sensory modalities, is what renders an apple a cognitive object. This sensory–temporal feature binding lays the ground for the cognitive realm of semantic representation and mnemonic storage and retrieval.[244] In very general terms, we could say that time is the binding between physical objects that fall under perception, and that changes in those objects have a temporal organization based on *succession* (order) and *duration* (simultaneity). From the early years the interest of psychologists was centered on the accuracy of the estimation of small time periods and on the rhythmicity of living organisms.[245] The inquiry began with 19th century research of isochronous sequences, that is, sequences of sounds separated by equal intervals,[246] but then investigation into perception of duration and simultaneity followed, changing the view of the interrelationship between time and perception in the various senses. By the mid-20th century, psychologists have began to focus on the relationships between the duration and the perceived organization of rhythmic patterns. The great pioneer of this tradition is Paul Fraisse. Fraisse who conducted an impressive amount of systematic research in the area, providing important contributions in the field. From the 1940s through the 1970s, Fraisse explored different approaches to the psychology of time, including: chronobiology, psychophysics, the Piagetian approach to the acquisition of the notion of time, philosophical approaches, as well as the application of these viewpoints to the perception of rhythm in music and in poetry. In *Psychology of Time* Fraisse proposed a general model of the developed sense of time: “Time of things or duration of me? Duration from sensations, or duration from of our mind?”.[247] Drawing from Gestalt Theory, he argued that time perception comes from a ‘bridge’ between the past, the present and the immediate future induced by the duration of perception: “as soon as we fix our attention, organization appears…distinguishing objects, isolating successive structures, which therefore are figures”.[248] Fraisse developed the idea of a “time horizon, consisting of past and future time perspectives”. After reviewing his earlier work and that of others, he discussed the fundamental distinction between *perception* and *estimation* of duration in a later paper titled *Perception and Estimation of Time*.[249]

13. 3 Is there a module for temporal perception?

Thus, understanding time, or still better what perceive or think of time, has a high degree of complexity, and this is because perceptual time is not ‘isomorphic’ to physical time. What is more, in humans experienced time might be affected by several factors, including attention, memory, emotional states and motivation, interest, context, etc., which are all potential modulators of time perception. For example, cognitive and emotional factors may affect accuracy and precision of time

[244] Boker: 1994.

[245] Fraisse: 1964; Doob: 1971.

[246] Wundt: 1897; Guyau: 1890.

[247] Paul Fraisse: 1957, p. 79.

[248] Paul Fraisse: 1957., p. 84.

[249] Fraisse: 1984.

estimation in the seconds-to-minutes range. Among our senses, the 'sense of time' is peculiar, as time is ubiquitous in our experiential world and yet nowhere can be found in the physical one. A thread of the psychological and neuroscientific research was to search for a particular time organ in the human body. Evidence shows that no single or specific organ is given for time perception, but all sensory modalities are possible entries at the interface of physical time with perceptual time. This evidence might threaten the development of explanations of time processing within the context of the modularity thesis. Consider, for example, the possession of transducers as the ear. We can understand how much the ear is important to heard sounds and process the information it contains at higher levels of processing. But if the ear is fundamental to auditory perception, conversely, there is no such specific perceptive apparatus for estimating time intervals. However, I am convinced that the tricky aspects of time do not threaten the project to develop a general account of temporal perception based on the theory of modularity of mind. Rather, in this conclusive paragraphs I try to give some reasons for endorsing the modularity view of time perception. My conviction is that time perception is part of the modular architecture in the same sense as visual perception is. To support this hypothesis, I will report a number of covering functional, biological, and neuropsychological studies that confirm this view. Let us reformulate the question posed at the beginning of this discussion in this way: is there a module for temporal processing? Before discussing the hypothesis of the modularity of time processing, some observations can be made as a way of giving some initial support to the modularity view of time processing.

- It is well-known from the behaviorist literature that animals can learn time intervals. In some of Pavlov's experiments, the reinforcement was delayed by a particular time interval. When dogs were trained with the delay, they started salivating only at the end of the interval.[250] Also, many other animal studies have shown that rats, dogs, pigeons, and other animals are capable to learn the temporal structure of tasks. Skinner's boxes experiments demonstrated that if rats or pigeons receive a reward when they press a bar, they quickly learn to anticipate this event (for example, when this reward is only given every 30 seconds, the rats will increase their bar-pressing when the 30 second deadline approaches). Those dated experiments, which clearly point out a sense of duration of time intervals,[251] inspired the research of temporal duration conducted by Fraisse. In between the 1940s and the 1970s, Fraisse carried out a striking investigation on time, rhythm, succession, and duration, spanned the transition from the behaviorist psychology (of which Fraisse believed had difficulty in including time as a variable) to cognitive psychology. On the ground of this research,[252] in the 1984 he published *Perception and Estimation of Time*. Fraisse argued that there are distinct and independent mental mechanisms which deal with succession and perception of events, and that such mechanisms operate at different time scales. Here I argue that those mechanisms individuated by Fraisse for perception of succession and duration can be themselves referred as processor subsystems forming a time module.

[250] Pavlov: 1927.

[251] Gibbon: 1977.

[252] Fraisse: 1963, 1967, 1980, 1981.

- The hypothesis that there is a module for temporal processing is consistent with a large literature concerning the internal clock perspective. Yet in 1975 by Thomas and Weaver[253] proposed an intentional model based upon a cognitive processor. The *temporal processor hypothesis* claims the existence of a 'temporal mechanism' for estimation of duration, this hypothesis was successively tested in some connectionist models[254] and confirmed in an extensive literature.[255] As it was discussed in a previous section (11.5), Matell and Meck[256] have reviewed the three versions of the internal clock theory: the pacemaker–accumulator model; the process-decay model; and the oscillator–coincidence detection model. We have seen that, in the pacemaker–accumulator model, a functional 'temporal module' is identified with a pacemaker-counter device that emits pulses that are accumulated in a counter; where the stream of pulse from the pacemaker results in a linearly increasing accumulator value, and the number of the counted pulses determines a perceived length of intervals.[257] On the other hand, in the process-decay model a decay of activation in memory is used to estimate elapsed time;[258] whereas, in the oscillator–coincidence detection model stimuli synchronize neurons in a certain area of the cortex, acting as a starting sign. Regardless of the paradigm for the internal clock we adopt, the hypothesis that the brain is provided with a time module for time processing is consistent with both prospective theories and retrospective theories. Prospective timing involves time estimation of short time intervals stored for later comparison, taking at the start of any interval the subject to already know that an estimation will have to be made; in contrast, retrospective timing involves estimation of duration when the subject is aware that the time interval to be judged has already passed. In any case, the ability to estimate time is crucial in every situations in which we observe an action and expect a response (that can be considered an account of expert behavior); or in multi-tasking situations in which we are asked to switch between tasks after specific intervals.[259] The processing of temporal intervals in real life is often implicit, automated, and tightly interwoven with other aspects of cognition such as perception, learning, and decision-making. The reason why time estimation is implicit in nature is that, for most tasks, the timing aspect is often secondary to the real task being performed. Then, I argue that these features of temporal perception are exactly the kind of features indicated by Fodor for modular systems. As in the case of the other modules, we can suppose that a separate module for time processing might be integrated in a more extensive theory of cognition. A module for time processing might form the explanatory basis for temporal perception; whereas, more complex and explicit forms of time estimation might be explained on the ground of more

[253] Thomas and Weaver: 1975.

[254] Brown: 1995; Gibbon and Church: 1990.

[255] See Block: 1989; Brown: 1995; Fortin et al.: 1995; Predebon: 1995; Zakay et al.: 1994; Zakay et al.: 2004; Meck: 2005.

[256] Matell and Meck: 2000.

[257] Gibbon and Church: 1984; Alan and Gibbon: 1991.

[258] Staddon: 2005; Staddon & Higa: 1999, 2006.

[259] Kushleyeva, Salvucci, & Lee: 2005; Salvucci, Taatgen & Kushleyeva: 2006.

general cognitive strategies, which build on the basic capability furnished by the time module.[260] In the last years, the idea of the modularity of time perception was entertained by some models proposed for estimation of time intervals in the sub- and supra-second ranges. These models suggest to explain time estimation, respectively, on the basis of the pacemaker-based internal clock, with functional characteristics similar to the internal clock accounts proposed by Matell and Meck,[261] and the oscillator-based internal clock,[262] according to the generic view of intrinsic theories that representation of temporal information is inherent in neural dynamics.[263]

- Further evidence for the modularity of time processing emerges from the study of the perception of rhythm in music. The perceptual organization of rhythmic stimuli is considered a paradigm for the perception of structure in time, since commonly associated with the perception of rhythm is a feeling of movement in time.[264] The study of the perception of rhythm deals with a general elemental problem in temporal grouping and temporal correlation with which the brain is faced; by studying the perception of rhythm psychologists try to investigate the mechanisms by which the brain solves the problem of temporal chunking and feature recognition. The fundamental characteristics of perceived temporal organization in music are linked to the concepts of grouping, beat, and meter. Psychologists observe that a basic response to music is to clap, tap, or move the body in time in a periodic fashion with a perceived pulse defined beat.[265] By definition, a perceived *beat* corresponds to a series of approximately periodic time points in music that stand out in some way to the listener; whereas *meter* refers to the temporal organization of beats on multiple time scales. Taken together the time scales form a *metric hierarchy*, such that the beats at each level of the hierarchy *periodically* coincide. *Meter perception* is then the ability to hearing beats on multiple time scales, with some beats heard as more accented (stronger) than others, on the basis of the metric hierarchy imposed by the temporal structure of the rhythm. General questions on ‘beat’ and ‘meter’ concern the *metric coding* of rhythms.[266] Psychologists interested in perception of beat and meter, and in the metric coding of rhythm, generally focus on contributions of different types of accents to perception of metrical structure, the role of tempo, and the role of listener knowledge. On the other hand, general questions on *grouping* concern the *figural coding* of rhythms; and questions on perception of grouping concern how (much) sound characteristics, such as *duration*, *frequency*, and *intensity*, affect listeners in his perceiving the grouping of notes in musical patterns, and

[260] Anderson et al.: 2004.

[261] Taagen, Van Rijn and Anderson: 2004.

[262] Gupta: 2014.

[263] Ivry and Schlerf: 2008.

[264] Fraisse: 1963; Lerdahl and Jackendoff: 1983.

[265] Parncutt: 1994; Snyder and Krumhansl: 2001; Temperley: 2001; Large and Palmer: 2002.

[266] Bamberger: 1980; Smith et al.: 1994.

why listeners tend to impose grouping structure in the case of absence of acoustic cues in the signal. Fraisse[267] noted that listeners tend to simplify rhythms as they tend to spontaneously tap two different intervals, one of which is twice the length of the other. Subjects asked to memorize and reproduce rhythms tend to simplify the intervals in the original temporal sequence into two interval sizes, one twice the length of the other. The shorter interval lends itself to separation between notes and the longer to separation between groups of notes. In the recent years, various models proposed to study musical abilities (i.e. music recognition) not as the product of a general cognitive architecture, but rather as part of a distinct mental module with its own procedures and knowledge bases that are associated with dedicated neuronal substrates.[268] Accordingly, listeners develop stable representations of auditory events on the basis of a specific processing system for music recognition, which works in parallel to a specific processing system for the temporal aspects of music perception. Generally, temporal patterning of sound involves two fundamental aspects of musical communication, *tempo* and *rhythm*.[269] Given the variety of temporal patterning of acoustic energy received by the ears, the internal representation of time organization is necessary to organization of rhythmic, a time module responsible for the processing of temporal patterning of sound is then supposed to work in parallel to the music module. In the light of the high degree of functional similarity and interactive working between music processing and time processing, we can justifiably suppose that the part of mental architecture containing time processing should be referred as modular.

13. 4 Fraisse's account of time processing: Perception and Estimation of Time

Here I suggest that there is an independent processing-system specific to the information of *duration* and *succession* of events. I argue that the modular functional architecture for time processing comprises two neurobiological isolable processing components, each having the potential to be specialized for time. The proposed time module is based on a general theory of perception drown by Fraisse in *Perception and Estimation of Time*, thus, before discussing my hypothesis I examine the argument proposed by Fraisse in that paper. I begin with an examination of the assumption that time processing provides causal relations by which the mind organizes the perceived objects coming from the external world. As James wrote:

> "empty our minds as we may, some form of *changing process* remains for us to feel, and cannot be expelled. And along with the sense of the process and its rhythm goes the sense of the length of time it lasts. Awareness of *change* is thus the condition on which our perception of time's flow depends; but there exists no reason to suppose that empty time's own changes are sufficient for the awareness of change to be aroused. The change must be

[267] Fraisse: 1956.

[268] Peretz and Coltheart: 2003.

[269] McAuley: 2010.

> of some concrete sort -- an outward or inward sensible series, or a process of attention or volition."[270]

Time perception is nothing more than perception of changes between physical objects or events that stand in causal relations to each other.[271] Fraisse referred to two fundamental concepts that can be extrapolated from our experience of changes, our possession of them would depend upon changes conceived or perceived by each of us. Thus, Fraisse focused on the fundamental aspect of experiencing temporal reality that lays the foundation for abstract representations in relation to the concepts recognizable from our experience of change:

- *Succession:* which corresponds to the fact that two or more events can be perceived as different and organized sequentially; it is based on our experience of the continuous changing through which the present becomes the past.
- *Duration*: which applies to the interval between two successive events.

The distinction between these concepts is made on the basis of phenomenological and experimental data concerning the phenomenal particularities of our perceptions:

> "Succession may be distinguished from simultaneous occurence, and duration distinguished from instantaneous…succession must be distinguished from discontinuity, which is most evident perceptually when two or more stimuli excite the same peripheral sense organs."[272]

What emerges from the series of experiments reported by Fraisse for explaining the transition from simultaneity to succession is that no specialized sensory receptor is available for time processing, but final time judgments are subjected to all sorts of stimulation bias as well as to the type of task. Fraisse observed that in multisensory perception time ties all the stimuli involved in the cognitive or neurological processes; but regardless of sensory modality the succession order threshold is constant: approximately 20ms.[273] It has been shown that reaction time to an auditory stimulation is approximately 40ms less than for a visual stimulation, giving a general idea of the size of respective latencies, despite the values obtained in a reaction time task are not directly related to the succession threshold.[274] To confirm the role of latencies, Fraisse[275] conducted an experiment focusing on *synchronization*, or simultaneity, between hand tapping and the sound of a simple repetitive auditory rhythm. Data furnished by the mentioned experiment demonstrated that on the average, hand tapping, as a tactile measure, anticipates the sound by about 30ms, and this anticipation is approximately 20ms longer when made by the foot. If a subject tries to tap simultaneously with his hand and with his foot at his own spontaneous rhythm, the foot tap will

[270] James: 1890, p. 620.

[271] McTaggart: 1908.

[272] Fraisse: 1984, pp. 4-5.

[273] Hirsh & Sherrig: 1961.

[274] Gibbon & Rutschmann: 1969.

[275] Fraisse: 1980.

precede the hand tap by about 20ms. From his and other experiments[276] Fraisse concluded that those anticipations should be attributed to the fact that the tactile stimulus must precede the sound in order to be perceived as simultaneous by the brain. This means that there must be a notable disparity between two stimuli if there is to be perception of succession and order. Fraisse said that this variability can be explained by the subjective criteria for simultaneity, this evidence was reached in a large variety of experiments:

> "A perception threshold equal to or greater than 20ms thus cannot simply be attributed to disparity between the arrival of two impulses on the brain. A decision mechanism having its own duration must be postulated. A very complex model that incorporates the largest amount of data and hypotheses has been proposed by Sternberg & Knoll (1973). A value of **Δt** possessing its own variability must be added to the possible differences in arrival of impulses from the different stimulations."[277]

Fraisse explained this *decision function* by a variety of mechanisms relating to the *attention-switching* processing. It is thought that a length of time involved in this kind of processing is necessary to focus attention on each of the stimuli that are perceived as successive.[278] The decision mechanism hypothesis is compatible with the *discrete moment* hypothesis,[279] which postulates that perception of moments is not continuous, but rather intermittent and discrete since the elements of information flow are integrated at distinct moments, whose order is distinguished only if each element is treated at a different moment from the other. Each perceptive moment can be thought as a *window* that is in continuous movement, Fraisse defined the perception of these moments with the term of *perceptual moment*.[280] Accordingly, instantaneous events must be distinguished from durable events on the basis of experiments of stimuli perception; when very brief stimuli are used, then perception of instantaneity can be obtained, because the 'on' moment cannot be distinguished from the 'off' moment. Therefore, perception of succession and duration are linked to the identification of the 'on' and 'off' effects.[281] More specifically, perception of instantaneity corresponds to the non-separation of the 'on' and 'off' components of *evoked potentials*, namely, *event-related brain potentials* (ERP); as it was confirmed by a series of experimental studies[282] using *evoked potential recording techniques* that compare measured apparent perceived duration to measured stimulus duration. In all those studies, a minimal duration of 130ms for apparent perceived duration is indicated. Fraisse argued that the organization of stimuli within and across sensory modalities creates both the perception of succession and the perception of simultaneity:

[276] Gibbon & Rutschmann: 1969; Mills & Rollman: 1980; Sternberg & Knoll: 1973; Kristofferson: 1967.

[277] Fraisse: 1984, p. 7.

[278] Kristofferson: 1967; Kristofferson & Allan: 1973.

[279] Stroud: 1955; Allport: 1968.

[280] Fraisse: 1978.

[281] Fraisse 1984, p. 9.

[282] Efron: 1970b, 1974; Serviere, Miceli & Galifret: 1977a,b.

> "This objective difficulty in perceiving simultaneity relates to the fact that there is no actual impression of simultaneity for stimuli pertaining to different sense modalities."[283]

Fraisse believed that this organization occurs in the *perceptual present* (or *specious present*), in which events and stimuli are perceived as durable and continuous, in contrast to the *perceptual moment*, in which they are perceived as discrete. For example, the syllables *bit* and *ter*, when spoken such that the time interval between the two syllables is less than about 1.5–2 seconds, are heard as the single word the word *bitter*; in contrast, when the same syllables are spoken such that the time interval between them is greater than 1.5–2 seconds, two isolated words are perceived.[284] This interval of time has been identified with the perceptual present, as opposed to the past, or long–term memory.[285] For Fraisse, duration is a construct of human mind that occurs in the perceptual present, it has no existence of itself but is the intrinsic characteristic of what endures. Having introduced the concepts of succession and duration, and specified the different kinds of perception they involve (perceptual moment and perceptual, or specious, present), Fraisse introduced the fundamental distinction between the mental procedures of *estimation* and *perception*. According to him, what people can know about time is something that is manifested through *perception* and *estimation* of succession or duration:

> "Estimation of duration takes place when memory is used either to associate a moment in the past with a moment in the present or to link two past events, whereas perception of duration involves the psychological present."[286]

This specification is drafted on the empirical basis of the three orders of duration identified in the physical continuum:

- a) less than 100ms, at which the *perception* is of *instantaneity*;
- b) 100 ms-5sec, *perception* of duration in the *perceived present*;
- c) above 5sec, *estimation* of duration involving memory.

On Fraisse's view, these orders of duration do not hold the same epistemological status. Basically, durations shorter than about 100ms are not perceived as such, whereas, the perception of a succession appears beyond the level of 20ms. At this level, human eyes perceive successions which represent the raw material of the physical world, namely, the changes that can engrave their date on physical objects. Conversely, at the level above 100ms perception of duration occurs, which refers to the ability to apprehend sets of successive events and perceived objects as simultaneous. Fraisse said that this ability is situated within the limits of the psychological present[287] as first identified by William James:

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[283] Fraisse: 1963, p. 110.

[284] Fraisse: 1978.

[285] Ornstein: 1969; Miller & Johnson-Laird: 1976.

[286] Fraisse: 1984, p. 9.

[287] James :1890; Fraisse: 1963; Michon: 1978.

> "[T]he practically cognized present is no knife-edge, but a saddle-back, with a certain breadth of its own on which we sit perched, and from which we look in two directions into time. The unit of composition of our perception of time is a *duration*, with a bow and a stern, as it were –a rearward– and a forward-looking end… We do not first feel one end and then feel the other after it, and from the perception of the succession infer an interval of time between, but we seem to feel the interval of time as a whole, with its two ends embodied in it"[288]

It should be reminded that the specious present has no fixed duration but includes a unity among the perceptive events it reveals, for example, as in the case of perception of rhythmic patterns. This means that the specious present should be identified to the duration of a experiential process, and not to the period of duration itself. Generally, we recur to this ability for perception of a sentence simple enough to be repeated, where the elements of a rhythmic pattern identified as a rhythm are perceived as linked to each other to form a unified group. In turn, perception of rhythm is disintegrated if the stimuli are spaced too far apart; in this case there is nothing more than perception of their regular successions. The capacity of perceiving duration has been sometimes defined as "capacity of apprehension," "short-term memory," or "very short-term memory;" however, according to Fraisse, it can hardly extend beyond 5 sec, having an average value of 2 to 3sec. Within these limits we can speak of the perception of duration, which thereby becomes a quantity whose beginning has not yet been stored in memory.[289]

Beyond the limits of the perceived present, there is 'estimation' of duration. Fraisse thought that at this level of the processing duration can only be estimated by the subject's construct, which brings to bear short- and long-term memory.[290] Estimation of duration is involved when the subject judges durations which are not presently perceived, at this level of the processing memory intervenes in the making of global judgments about the duration that has already passed. The estimation of time in passing (the temporal flow) may concern either a duration between the present moment and the beginning of an event that has just terminated, or a duration which ran over a period of time between two events that recede into the (ever more) distant past. Long-term memory is fundamental to estimation of duration, as opposed to perception of duration which uses only short-term memory:

> "Having studied up to now the estimation of time between the present moment and the beginning of an event that has just terminated, i. e. according to some, the estimation of time in passing, it is time to study the estimation of a duration which ran over a period of past time, i.e. between two past events. The role of long-term memory is going to be vital here whereas the durations studied previously often called upon the intervention of short-term memory."[291]

However, despite the fact that in estimation of duration the length of time becomes a quantity whose beginning has just been stored in memory, there is a certain natural continuity in the results

[288] James: 1890, pp. 609-610.

[289] Fraisse: 1978; Pöppel: 1978; Allan: 1979.

[290] Fraisse: 1984, p 27.

[291] Fraisse: 1984, p. 27.

of perception and estimation of time. Concerning durations that go beyond perception, Fraisse argued that expectations and attention play an important role, generally by producing an overestimation of the perceived duration. In one study[292] he observed that duration depends on the number of perceived changes, and when stimulus complexity is too great, individualized changes are not perceived. This hypothesis echoed that of Ornstein[293] on the role of memory in estimation of durations, according to which, the estimated duration at a given moment is proportional to the storage size. On this view, time estimation is a hypothetical variable that depends on the number of events stored and retrieved, as well as on the complexity of the coding of the events. In another study[294] conducted by Fraisse, the focus was on the comparison between temporal judgments in a duration production task and temporal judgments in a non-temporal information processing task (that is, a task in which participants divide attentional resources between two sources of stimuli: non-temporal and temporal information). Fraisse demonstrated that if a task is easy, generally the subject is able to pay more attention to the duration itself. The easier the task or processing is, the more overestimated the duration would be, because the subject would be more attentive to the duration itself. This finding was a confirm of an earlier model elaborated by Thomas and Weaver, in which attention was studied in relation to two processes: estimation of duration and information processing. The study conducted by Thomas and Weaver demonstrated that the more one pays attention to time, the longer it seems; conversely, duration seems short when the task is difficult and/or interesting.[295]

13. 5 The Time Module: the First Processor Component

The mechanisms theorized by Fraisse for time perception and time estimation are consistent with the view of the modularity of time processing. Here I introduce descriptions of a presumable mental architecture in which the operations of an information processing are specific to succession and duration of events. The proposed module is composed of two smaller processing components, each concerned with a specific information-processing operation that contributes to the overall system. The results of these operations will give the cognitive basis for our ‘sense’ of time, or as Fraisse called it, the *specious present*.

The first processing component of the time module, is a temporal processing system that takes as input any stimulus that can be attributed to an unique source, including auditory, visual, tactile stimuli, and so further. It should be said that auditory, visual or tactile segregation of sound, as well as, vision, and tactile mixtures into the respective sources, occur within their respective and independent analysis modules, whose domain is specific to auditory, visual, and tactile information. As the outputs of these information domains are processed in parallel, then it is supposed that all the information contained in such outputs (i.e. auditory, visual, tactile, speech) are sent to the first time

[292] Fraisse: 1963.

[293] Ornstein: 1969.

[294] Fraisse: 1979.

[295] Thomas & Weaver: 1975; Thomas & Cantor: 1975, 1978.

processing module. This means that we have no *gatekeeper* mechanism that decides which part of the auditory, visual, tactile, or linguistic pattern should be sent to the time processing system, and which part should be not. Rather, activation of the first processing module is determined by the temporal aspects of the inputs to which such module is tuned. The temporal module operates at short time durations expressed in millisecond, and more specifically between 20ms and 100ms (according to the temporal frame identified by Fraisse, at which the perception is only of instantaneity). Consequently, the first timing module will be specialized to extract temporal information contained in the outputs of other modules only if such information is sent within this range of time. If the information is processed and sent outside the temporal range of approximately 20ms-100ms, the first timing module will not respond to the process of information-extrapolation; in the same kind of way the retina does not respond when a sound wave passes through it, nor the cochlea responds when light shines upon it. This restriction depends on the modular nature of the first time processor, which is domain-specific only to perception of *succession* (or temporal order) of events and physical objects that falls into this temporal frame. As perception of a succession appears up the level of 20ms,[296] at which human mind is able to perceive successions of events representing changes in physical objects, then the activity of the first time processor concerns the first pole of temporal order identified by Fraisse. Beyond the limit of 100ms we can speak of the perception of duration, whose domain pertains to a second timing processor.

However, the first timing processor takes incoming inputs of sensory, or multisensory, modalities, to which the subject's perception is exposed during a very short length of time. Once processed the information contained in those inputs, it generates outputs which contain representations of the rate of change of objects and events. Such representations are supposed to be given in terms of stings of temporal relations between successive moments so-defined: "the event x *is earlier* or *later than* the event y". The philosophers of time define the kind of temporal relations among temporal points, or moments, with the term of *B-series relations* (for a more detailed discussion of the topic of time perception in the context of philosophy of mind I invite the reader to view my earlier work[297]). Generally, within the B-series relations an event/stimulus might be earlier or later than another one; whereas, within the *A-series relations* an event/stimulus might be *now* present, past, or future. B-series relations are accepted by science as the time-series representing reality, and this is because they endorse a high degree of objectivity (i.e., if 'x is earlier than y' in the present, then it will in future, as well as it always did in the past). Conversely, A-series relations are less objective since are directly implicated to the perspective of the *specious present*, in which a length of time might vary considerable for two identical individuals. Although B-series relations operate under causal laws when represent temporal change (if x is earlier than y, and y is earlier than z, then x is earlier than z), those relations do not embody change by themselves (there is no change in the claim that an event, or stimulus, is earlier than another one, this matter of fact will run the same in the future and so did in the past), so the recourse of A-series is necessary to describe temporal change because A-series embody temporal change (even if A-series relations might not exist as McTaggart argued in *The Unreality of Time*). The problem posed by the philosophers of time is that objective time-order is determined by the causal order of facts and events, but when we make our judgments about

[296] Fraisse: 1984.

[297] Gentile: 2010.

objective time-order we do it on the basis of the self-intimating time-order of our perceptions. The idea of time-order itself derives from the perspective of time's observer, that is, the *specious present,* or one's 'seeing' an event precede another, and one can only see something like this by virtue of the apparent causal relation between the perceptions involved: "memory's main job" is to let "a perception cause its content to be embodied at another time in another state of mind."[298]

But returning to our timing processor, how does it work? I propose that the first modular subcomponent might be thought as an internal "clock" used to measure time succession. The functional basis for this timing mechanism is the pacemaker-based internal clock, with functional characteristics similar to the internal clock described by Matell and Meck.[299] This processor is designed to perceive and reproduce the distribution of time successions in this way. Basically, this timing mechanism includes three components (these are the typical components of the pacemaker-counter device model): an *internal timer* (or *pacemaker*); an *accumulator*; and a *decision mechanism*. The timer starts the beginning of the information flow in response to incoming stimuli (the outputs of other perceptual modules): given two stimuli (or events), x and y, which occur at a time range defined between 20ms and 100ms, the timer explicitly times the order between them. This timing mechanism is made to process information in a manner that, when the stimulus appears, the counter is started; and as soon as the stimulus disappears, the value of the counter is read out and stored in memory. Then, a decision mechanism establishes which stimulus became for first and which for second, and generates an output expressed in terms of B-series relations: "x is earlier than y", or "x is later than y". To reproduce a time succession is therefore: starting the timer, waiting until the accumulator has reached the stored value, and then making a response as output. This general kind of processing reproduces exactly the working of a peacemaker-counter device.[300]

13. 6 The Time Module: the Oscillator Processor Component

Fraisse argued that perception of duration is situated at a level above 100ms and under 5sec, into the limits of the psychological present. Here I consider that a second time processor component is responsible for perception of duration, occurring at a temporal range between 100ms and 5sec. As I described it, the first processor component is supposed to generate as outputs temporal representations (defined in terms of B-series relations) which can be thought as 'raw' material of the physical world, these representations lay the ground for perception of duration, which occurs into the second timing processor. The second timing processor takes the first processor's outputs as inputs and, after it processes the information contained in them, generates an output that reproduces the duration of an amount of time that is presently passing. This information (the second processor's output) will be available to the central system and the other perceptual modules. I suggest to describe the second processor component in terms of a timing mechanism that resembles the

[298] Mellor: 1995, p. 240.

[299] Matell and Meck: 2000.

[300] Gibbon et al.: 1984; Ivry and Hazeltine: 1995; Mattel and Meck: 2000.

working of a self-sustaining oscillatory processing.[301] The inbuilt modular oscillator can be thought to act like a metronome that starts ticking time progresses.

Imagine to have a metronome, the ‘clack’ that sounds each time the arm hits the side is an *onset*, or event. Within the brain’s neural circuits, the simplest sort of event is the ‘impulse’, that is, an instantaneous burst of neuronal activity surrounded before and after by intervals of no activity. Basically, a sequence of impulses might have an organization in time of the most pure forms, this organization is determined by the relationship of the intervals between those impulses. The term ‘period’ denotes the times between onsets, as the metronome’s arm travels to the other side; whereas, the term ‘phase’ denotes the relationship between these successive events. The temporal expectancies for each successive onset form the ‘beat’. The beat is the perception of a regular, periodic series of events that can be of any duration. This perception is in line with the rate of change of physical event onsets, from the smallest interval in the temporal sequence, up to the full duration of the repeating sequence. Thus, the second timing processor can be thought as a neuronal oscillator, whose working is like that of a metronome. The increasing number of ticks produced by a metronome generates *temporal unit intervals*, which represent physical time accurately within the clock mechanism. When we perceive the rate of change in physical phenomena we have the feeling that physical time is a continuous flow that can be divided indefinitely into smaller units. A temporal unit interval is therefore the representational reference of relative or absolute duration, since encodes the sequence of changes that occur in the physical time. Analogously, the sequence of changes perceived in physical phenomena, to which we associated the name of temporal passage, is imported into neuronal circuits in form of neuronal temporal units via activation of neurons placed into the second timing processor. Into this oscillator module, a temporal unit interval is taken as the interval between two adjacent spikes, or bursts of spikes, that result from the regular activity of the neuronal oscillator.

To describe how the oscillator-module functions, we might isolate two steps, or levels of processing, that control its behavior. The first step is originates by the *start-pulse*, which corresponds to the event of the transfer of information contained in the first time processor’s output within the neural circuits of the oscillator processor. The transfer of information (defined in strings of B-series relations) generates changes in temporally regular activities of firing neurons which are in the oscillator’s module. The frequency, or the rate of change in frequency, resulting from modulation in activities of those neurons provides a codification of different “time intervals”. So the ‘start pulse’ initiates the activity of the oscillator-module by resetting the internal timer (that is, the cortical neurons) and setting the integer to ‘zero’. When the succession of two or more pulses (which are related to each other in terms of “x’s is earlier/later than y”) is set to the start value *t*0, then perception of duration takes place. The duration of the set of pulses x-y increases when the time interval between them is not perceived, as for example when the time interval between the two syllables *bit* and *ter* is too short to be perceived (less than 1.5–2 sec), with the result that they are heard as a single word: *bitter*.[302] Hence, the value *t*0 indicates the temporal limits of the psychological present. At *t*0 the set of pulses x-y is perceived as present and, then, as separated

[301] Large and Jones: 1999; McAuley and Jones: 2003.

[302] Fraisse: 1978.

from a previous set of pulses that were perceived before *t*0 and are currently stored in memory. Beyond *t*0 stimuli are not perceived but are estimated, to use Fraisse's words. Once the internal timer sets the integer to 'zero', the sets of perceived stimuli, whose components occur at different moments, are synchronized via activity of neurons wired in the oscillator circuit (Gupta[303] identified these neurons with *frequency modulator* (FM) *neurons*). On the ground of the synchronization activity carried out by those neurons into the oscillator module, perception of succession flows into perception of duration, giving us the feeling of presentness.

The synchronization hypothesis would be proved by several studies of stimuli latencies. In distinguishing between succession and simultaneity, Fraisse focused on the transition from succession to simultaneity when two pulses of more or less variable duration of intensity are presented.[304] Fraisse[305] and others[306] observed that, despite no specialized sensory receptor is available and our time judgments are subjected to all sorts of stimulation bias as well as to various types of tasks, the succession order threshold is constant: approximately 20ms. Fraisse[307] studied the role of latencies in cases of *synchronization*, that is, simultaneity between hand tapping and the sound of a simple repetitive auditory rhythm (he found that hand tapping, as a tactile measure, anticipates the sound by about 30ms, and this anticipation is approximately 20ms longer when made by the foot). On the basis of his and other studies, he concluded that a perception threshold equal to or greater than 20ms cannot simply be attributed to disparity between the arrival of two impulses on the brain, but there must be a notable disparity between the two stimuli if there is to be perception of succession and order.[308] According to him, the forms of anticipations in reaction time should be attributed to the fact that the tactile stimulus must precede the sound in order to be perceived as simultaneous by the brain; hence a decision time mechanism having its own duration has to be postulated.[309] Kristofferson[310] and Allan[311] explained this sort of 'decision time' mechanism on the ground of the *attention-switching hypothesis*, according to which, the time involved in this process corresponds to the length of time necessary to focus attention on each of the stimuli successively. Fraisse believed that the decision time mechanism is also compatible with a hypothesis known as *discrete moment hypothesis*,[312] because there would also be a time quantum involved that would

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[303] Gupta: 2014.

[304] Ostenbrug et al.: 1978; Mills & Rollman: 1980; Allan: 1975; Allan & Kristofferson: 1974; Efron: 1970a; Allan: 1976.

[305] Fraisse: 1984, p. 6.

[306] Hirsh & Sherrig: 1961.

[307] Fraisse: 1980.

[308] Hirsh: 1959; Mills & Rollman: 1980.

[309] Fraisse: 1984, p. 7.

[310] Kristofferson: 1967.

[311] Kristofferson & Allan: 1973.

[312] Stroud: 1955; Allport: 1968.

impose a minimum duration for this operation. The "discrete moment" hypothesis postulates that the perception of time is not continuous but intermittent and discrete, elements of information are thus integrated at distinct moments, but their order can be distinguished only if each element is perceived at a different moment from the other.

Therefore, I argue that into the oscillator module, the separation between perceptual moments, that is, the temporal interval between a set of pulses x-y, is not perceived. Conversely, what here is perceived is the separation, or temporal interval, between two sets of stimuli, *x–y* and *x'–y'*. The set *x–y* gives an amount of time of *perceived* duration, whereas the set *x'–y'* gives an amount of time of *estimated* duration, that is, a duration that has already passed and that is currently stored in memory. Within our proposed model, the interval of time between perceived durations and estimated durations is called the *a-time*. The *a-time* is the second step, or level of processing, that controls the oscillator-processor's behavior; it can be referred as the interval of time between two sets of pulses (whose one set is already passed and the other is presently passing), and occurs when the inbuilt timer of the oscillator-module is started again. Once the counter reaches the stored value (for example, when the metronome's arm has traveled to the other side to start ticking time progresses; or when the cortical neurons of the neural circuit are synchronized to produce their own particular pattern of activation in time), then the oscillator processor takes another set of incoming sensory, or multisensory, stimuli (which stand in B-relations to each other, that is, in terms of "stimulus x is earlier/later than stimulus y") and synchronizes them as if they occurred *simultaneously*.

To conclude, Fraisse individuation of *estimation* of duration involves memory up the threshold of 5 sec, therefore, we might think that the *a-time* provides the temporal limit between perception and estimation of durations. Beyond 5sec estimation of duration takes place, this timing mechanism has not to be thought as a timing module itself, but rather as the result of the activities of the central system. Central to the timing mechanism of time estimation are also non-temporal parameters, such as expectations, attention, emotions, or mental states, play an important role.[313] Since there is a certain natural continuity in the results carried out by perception and estimation of duration (since both orders of duration contribute to the extrapolation of time information from the physical continuum), and given the interaction between these different kinds of processing, then it is presumable to think that the oscillator processor responsible for time perception is partially 'open' and therefore not totally informationally-encapsulated. In contrast to the oscillator processor, the first timing processor is more closed and so impenetrable from the higher-level processes of the central system. From this it follows that the human mental architecture has a module domain-specific to time which includes two component processing systems: one is more basic, totally encapsulated, working at subconscious level and a very short temporal range, this is the first modular component engaged with perception of temporal succession; conversely, the other one is more open, partially encapsulated, operates at long time scales and might be present at either conscious or unconscious level, this is the oscillator module engaged with perception of temporal duration. One reason to think that these are distinct and independent mechanisms is provided by empirical evidence, as Fraisse reported:

[313] Fraisse: 1963.

> "The concepts of succession and duration which specify our notion of time are quite naturally empirical in their origins. This does not necessarily imply that their development is empirical. Research in this field shows that perception of both duration and succession are present very early in life, but that their joint functioning is not acquired until age 7 or 8, when the child first becomes capable of logical thinking. An abstract notion of time is gradually elaborated from that age forward (Friedman: 1982). The objective sought in presenting these generalities has been to provide a framework for the present review of contemporary research in the field of the psychology of time, rather than to end the philosophical debate on the notion of time, outlined in the introduction to the Psychology of Time (Fraisse 1963), which in any case will never find a satisfactory conclusion."[314]

To use the language of the philosophers of time, the first time processor provides representations of time successions in term of B-series relations, that is, in terms of relations that the event x, occurring at moment m, is earlier or later than the event y, occurring at moment n. Whereas, the oscillator processor provides representations of time durations in terms of the *specious present*, namely, the 'sense' of *presentness* creatures possess. The temporal reference (the *now*) provided by the framework of specious present is necessary to the successive estimation of duration in retrospect. Based on the reference of *now*, the subject is able to construct complex representations of time defined in terms of A-series relations, that is, in terms of "x is *now* past (memory)," or "x is *now* future (expectations).

13. 7 The Modularity of Timing Mechanisms

To reassume. Above I drafted a possible mental architecture for time processing which may be sketched up by this very simple scheme, whose scope is just purely exemplificative:

- a) First Timing Module: between 20ms and 100ms: very-short term memory; inputs = incoming stimuli from transducers and other modules; outputs = perception of *instantaneity* or *succession* expressible in terms of B-series relations (being earlier/later than).

- b) Oscillator-Module: between 100ms and 5sec: short-term memory; inputs = B-series relations (First Time Module), and stimuli from transducers and other modules; outputs = perception of *simultaneity* or *duration* expressible in terms of (A-series) *perceived present* (being present).

- c) Central System: above 5 sec: long-term memory; inputs = whatever; outputs = *estimation* of duration expressible in terms of A-series relations (being past/future).

Each of the two distinct modular mechanisms carries out own distinct functions and operates at specific time range, providing necessary prerequisite for extracting time information from the

[314] Fraisse: 1984, p. 3.

external environment. Findings available in the literature for the hypothesis of the time module deal with the processing of intervals lasting a few milliseconds to several seconds. Covering psychological studies and behavioral observations, as well as neurophysiologic studies, Pöppel[315] suggested a temporal segmentation model on two different time scales. There is one segmentation mechanism which derives from neural oscillations with periods of approximately 20–40 ms, which are necessary for the temporal binding of spatially distributed brain activities, and explaining detection thresholds of temporal order perception. On the other hand, there is a different temporal integration mechanism that functions with a range of approximately 2–3s, this perceptual mechanism is supposed to potentially form a temporal platform for conscious awareness. Pöppel assumes that a similar perceptual mechanism, applied to a large scale perspective, integrates separate successive events into a unit or perceptual gestalt. According to this view, the mind does not perceive individual events in isolation, but automatically integrates them into perceptual units with a duration of approximately 2–3s.[316] The duration of this temporal integration mechanism can be referred to as the *specious present*. The idea of temporal integration of time units, resulting from fusing successive events into a unitary experience of time (in which perception is processed in discrete windows or processing epochs) is also present in other authors.[317] These findings provide evidence for the existence of two independent, and highly specialized processors for time perception.

13. 8 Time Processing and the possession of Fodor's features

Now I argue that time processing captures the typical properties of modular organization in Fodor's sense.[318] Thus far we have seen that Fodor indicated that mental activity has an involved modular basis, recognizing the presence of highly specialized functions which are characteristic of the part of cognitive architecture opposed to upper-level cognition. According to Fodor's formulation of the notion of *module*, the highly specialized modules can do only one thing but do it very reliably and fast, and it is practically impossible to modify their output, also the cognitive central system will not even be aware of the activity of the modules. Fodor's characterization of modular systems describes them as being:

(1) localized: modules are realized in dedicated neural architecture;
(2) subject to characteristic breakdowns: modules can be selectively impaired;
(3) mandatory: modules operate in an automatic way;
(4) fast: modules generate outputs quickly;
(5) shallow: modules have relatively simple outputs (not judgments);
(6) ontogenetically determined: modules develop in a characteristic pace and sequence;

[315] Pöppel: 1997, 2004, 2009.

[316] Fraisse: 1982, 1984; Pöppel: 1997; Szelag and et al.: 1996, Wittmann and Pöppel: 2000.

[317] White: 1963; Pöppel: 1970, 1997; Dehaene: 1993; Schleidt and Kien: 1997; VanRullen and Koch: 2003; Fingelkurts and Fingelkurts: 2006.

[318] Fodor: 1983, 2000.

(7) domain specific: modules cope with a restricted class of inputs;
(8) inaccessible: higher levels of processing have limited access to the representations within a module;
(9) informationally encapsulated: modules cannot be guided by information at higher levels of processing.

On Fodor's view, an input-system is modular to the extent that exhibits the properties on this list. Furthermore, a module can be composed of smaller processing subsystems that can themselves be referred as modules. For example, the module for the visual system described by Marr is composed of three-level computational tasks; as well as the language module contains components lexical and phonetic-processor modules. However, a module does not need to possess all the features of modular systems, it might exhibit some of them which will result more essential to its functional organization, while others might be merely diagnostic. This allows us to regard these features as 'typical' or 'characteristic' to modularity. This condition is generally satisfied for any of the listened features, except for informational encapsulation and domain-specificity, which according to Fodor are 'essential' to modularity. For example, the module for visual sense is domain-specific only to the class of visual stimuli (as it receives from the input systems only visual stimuli); and it is also informationally encapsulated because when executes its job it is not guided by the information of higher-level processing. The module for auditory sense (and so the other modules) does exactly the same: it takes only auditory stimuli and carries out its job without the supervision of the central system. As cognitive systems have at their disposal a variety of modules, then it is reasonable to think that the mind also has a modular part for coping with specific, bio-psychologically meaningful classes of temporal information. If we admit the possibility of a module for time processing, this module will be required to have (at least) the two necessary features of informational encapsulation and domain-specificity. Conversely, it might lack the properties of innateness, or mandatoriness, or neuronal specificity. For example, the neural substrate for time processing might overlap with that used in for processing other complex patterns, such as sound, vision, or speech. However, the time module could never lack informational encapsulation and domain-specificity. Since the objects of time perception cannot be compared to any physical objects, and the time-module processes a variety of stimuli coming from other modules (especially from auditory and visual modules), the only way for a module to be domain-specific is to be restricted to temporal information. The mind encodes the temporal organization of physical phenomena that fall within perception, which have a rhythmic structure composed by different successions and durations. The mental representations expressed in terms of temporal relations of succession (B-series relations) and duration (A-series relations) of events contain the necessary information to guide the behavior of humans and other creatures. In extrapolating this information, the behavior of the time module is not guided by the central system. However, the time module is supposed to be organized in two parallel and largely (but not equally) independent subsystems, specific respectively to the 'succession' content and the 'duration' content. Despite equally specific to time information, these modular processor components do not have the same degree of informational-encapsulation. The oscillator-module will result partially 'open' to the information furnished by the part of cognition dedicated to estimation of duration, whilst the processor component dealing with the 'succession' content is presumably more closed and impenetrable. We can describe the mental architecture of the timing processors components as follows.

The 'succession' analysis component deals with the segmentation of the ongoing sequence of (perceived) change into temporal groups on the basis of 'successional' values without regard to periodicity (providing the rhythmic analysis). The temporal 'succession' pathway sends its respective outputs to the 'duration' analysis component, that deals with the segmentation of the ongoing sequence of (perceived) change into temporal groups on the basis of 'durational' values. The 'duration' analysis component extracts an underlying temporal regularity corresponding to periodic alternation between the beats of the inbuilt neuronal oscillator (providing the meter analysis). In parallel and independently, these timing modular components will feed their output into the central system via the 'time estimation' mechanism. Both the succession and the duration pathways send their respective outputs to this part of central system, which extracts time information from either rhythmic, or meter analysis, to give estimation of retrospective time. The processing for time estimation in the central system constitutes a system of representations of specific temporal patterns to which one has been exposed during a period of time. The same system for time estimation also keeps a record of any incoming input useful to process its outputs, which might feed different kinds of other modular components, depending on task requirements. The time information processed at this level can be taken from any source; if the task required retrieving non-temporal information (attention, emotions, expectations, mental states, reasoning, etc.) about a temporal selection, then the associate knowledge stored in the memory will be invoked. Hence, the sub-system components that form the time module reach a sufficient degree of domain-specificity and informational encapsulation. What is more, they also share with the other perceptual systems the residual 'typical' or 'characteristic' features indicated by Fodor.

The proposed temporal modules are mandatory since they operate in an automatic way. The attribution of mandatoriness is plausible for either the subcomponent system that deals with the succession content (which operates in the millisecond range between 20ms and 100ms), or the second subcomponent system, both processors fix *automatically* temporal relations in response to a given input. These perceptual systems are also fast. Fodor said that a cognitive process count as fast if it takes place in approximately less of half second, and once activated a module would usually produce its output well under a quarter of a second. Speech shadowing, for example, is very fast, with typical lag times on the order of about 250ms. Having defined the range of action of the first timing subsystem between 20ms and 100ms; and of the second one between 100ms and 5sec, we can suppose that they generate outputs very quickly. These two important aspects of modules, speed and mandatoriness, are in contrast to the slowness of the central system.[319] Furthermore, the time module is shallow since its subcomponent systems generate relatively simple outputs, and on the basis of this source the central system provides representations of temporal information at higher cognitive levels, involving the making of judgments about time durations, intervals, or successions.

13. 9 Evidence from Neuroscience

The plausibility of a modular architecture for time processing may be entertained in the context of neuroscience. Among neuroscientists interested in the neurobiological structure of time perception

[319] Fodor: 1983, p. 63.

someone endorses the view of dedicated neural centers or circuits for the internal clock, as opposed to the view that there is no specialized system to represent temporal information in the brain, because time is inherent in neural dynamics (that is, in the firing of neural populations).[320] Different networks of brain have been found to be active in different interval timing tasks depending on nature, motor vs. perceptual, or the duration sub-second vs. supra-second.[321] Neuroscientists generally opt for an integrative processing of multiple modules distributed across the brain in relation to the duration involved. The mechanistic neurological basis of the interval timing by the brain in the sub- and supra-second range involves the cerebellum, the basal ganglia, the insula, the right posterior parietal lobe and the prefrontal lobe.[322] Then, we might suppose that different areas of the neural system contribute to the functionality of the time module. Basically, two important circuits might likely form the neural platform for the first-level temporal module: the cerebro-cerebellar loops responsible for motor and non-motor functions such as working memory, executive tasks, and emotion,[323] and the dorsal stream responsible for sensorimotor tasks, connecting the posterior parietal cortex and the motor, premotor and prefrontal areas of frontal cortex.[324] Whereas, the oscillator module might be presumably inbuilt into the basal ganglia. These neuronal regions provide different mechanisms for the interval timing by the brain in both the sub- and supra-second range.[325]

Recent models suggest that timing in the millisecond and second range may be dissociated behaviorally[326] and neurally.[327] *Behaviorally*, timing in the millisecond range is achieved relatively automatically through direct read-out from an internal timing system. At ranges exceeding the neural limitations of this system, the contributions of other processes, such as those associated with counting and memory, may become relatively more important. It is believed that timing involved in the sub-second range plays role in the motor control and the speech production.[328] Intervals of time processed in motor activities in the milliseconds range are necessary to determining speed of various motor movements for the execution of motor tasks, they are processed automatically and subconsciously. Conversely, timing in the supra-second interval range are processed at conscious level, as in the case of decision making and time estimation.[329]

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[320] Zelaznik, Spencer, & Ivry: 2002; Ivry and Schlerf: 2008.

[321] Wiener et al.: 2010a.

[322] Harrington et al.: 1998; Bueti et al.: 2008; Coull et al.: 2011; Teki et al.: 2011a.

[323] Strick et al.: 2009; Bostan et al.: 2013.

[324] Kaas et al.: 2011.

[325] Malapani et al.: 1998; Wiener et al.: 2010.

[326] Pöppel: 1996.

[327] Ivry: 1996; Meck: 1996; Pöppel: 1996.

[328] Buhusi and Meck: 2005.

[329] Buhusi and Meck: 2005.

Neurally, timing in the range of milliseconds engaged with motor control is associated with the cerebellum. If cerebellar neocortex primarily subserves basic clock functions in the temporal range useful for motor control; on the other hand, prefrontal cortex modulates time perception through supportive functions related to sustained attention, working memory and strategic organization. Both regions contribute to time perception by managing temporal representations and actively maintaining them in working memory.[330] However, some findings suggest that the most suitable candidate for producing this primary temporal representation are the interval timers within the cerebellar neocortex.[331] Neuroscientists argue that timing intervals for motor and sensory tasks are calibrated by *feedback mechanisms*.[332] The feedback processes exercise a role in the control precise movements: the feedback mechanisms maintain the normal range of a function by transferring information about the external time into the neuronal circuits in the brain, when this transfer does not occur, a failure in control of motor movement produces an increase in the range of a given movement. The involvement of the cerebellum in the feedback processes controlling motor movements tasks is necessary to transfer information of "physical time intervals" into the neuronal circuits in the brain. For example, the act of catching a ball is a task that includes a transfer of temporal information regarding the speed of external objects. Therefore, to execute a complex set of temporally precise motor movements, these movements recruit feedback mechanisms in the cerebellum. The feedback processes must tightly couple the motor actions to the requirements of the task parameters, such as the speed through which the object moves along its trajectory. The changes needed for the smooth control of motor movements occur over sub-second durations; and this condition awards centrality to the cerebellum because of its representing short time durations. Evidence here indicates the cerebellum as the best candidate for the first-level time module, because of its involvement in the timing of intervals in the sub-second range.

There are several studies that confirm the brain uses networks of the cerebellum for tasks involving sub-second intervals.[333] Evidence for the engagement of the cerebellum with the calibration of neuronal clocks in timing intervals at sub-second range comes from clinical studies. A recent study[334] on lesions of the cerebellum conducted by Gooch has shown that lesions of the cerebellum increase variability on various timing tasks, including temporal estimation, reproduction, and production tasks. In individuals with the lesions in the cerebellum, other calibration mechanisms, such as sensory mechanisms, take over the function of calibrating neuronal clocks. Mechanisms based on sensory processing calibrate time intervals of longer durations in comparison to the shorter time of motor processing of the cerebellum. The result of this research is that cerebellar lesions result in greater variations during the processing of temporal intervals. Further finding for the

[330] Olton: 1989, pp. 121–130; L. Casini, R. Ivry: 1999.

[331] Mangels, Ivry and Shimizu: 1998.

[332] Parsons et al.: 2013.

[333] Breukelaar and Dalrymple-Alford: 1999; Ivry and Spencer: 2004; Jantzen et al.: 2004.

[334] Gooch et al.: 2010.

modular nature of the cerebellum in the neuronal clock comes from a study showing that the cerebellar lesions disrupted the precise timing, indicating an increase of variations.[335]

In addition to the cerebellum, sensory-representations in the parietal cortex were found to contribute to the feedback mechanisms that serve to calibrate the clock-module. Someone has focused on the interconnection between the cerebellum and cortical areas in the feedback processes that control motor movements. It is believed that the posterior parietal cortex has a job alongside with the cerebellum to transfer temporal information of physical time from the cerebellar circuits to the cortex circuits.[336] Other studies focusing on the brain networks engaged with the cognitive measurements of temporal intervals revealed the co-activity of the posterior parietal cortex with the cerebellum in cognitive timing tasks.[337] It has been argued that the multisensory processing in the parietal cortex also contributes to transfer external time information into the nervous system, resulting involved in the calibration of the timing circuits that control multimodal tasks.[338] The role of the parietal cortex as interface between sensory and motor processes, necessary to translate temporal information into action, would be confirmed by either studies using either rTMS[339] or studies using fMRI.[340] The right posterior parietal cortex has been demonstrated to be active in the timing of short intervals less than 1sec marked by either auditory or visual signals;[341] but also in the timing of longer intervals.[342]

Conversely, other studies indicate the neural structures of the neostriatum and substantia nigra as potential key components of a dopamine-regulated internal clock.[343] Drawing upon neuropharmacology and ablation studies with rats, Meck[344] argues that the dorsal striatum serves as a counter mechanism that accumulates the clock-pacemaker pulses generated in the substantia nigra. As a confirm of the role of nigrostriatal circuits in timing intervals, clinical studies indicate that Parkinson's disease, a neurodegenerative disorder affecting neostriatal regions via dopaminergic cell loss in the substantia nigra pars compacta, results in deficits in the reproduction of temporal intervals suggestive of an impaired clock mechanism. In one study[345] subjects suffering from Parkinson's disease were found to overestimate a target interval when instructed to reproduce

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[335] Timmann et al.: 1999; Ivry and Spencer: 2004.

[336] Lewis and Miall: 2003.

[337] Amino et al.: 2001.

[338] Anderson: 1997; Harrington et al.: 2011.

[339] Alexander, Cowey, & Walsh: 2005.

[340] Bueti, Walsh, et al.: 2008.

[341] Bueti, Bahrami, & Walsh: 2008.

[342] Koch, Oliveri, Torriero, & Caltagirone: 2003.

[343] Gibbon et al.: 1997; Meck: 1996.

[344] Meck: 1996.

[345] Pastor et al.: 1992.

a time interval by counting out intervals at a prescribed rate. Basically, the magnitude of the patients' deficits was largest when the rate of counting was faster (i.e., 5 vs. 1.6 Hz) but the actual duration to be timed was shorter (i.e., 3 s vs. 9 s.). This study suggested that the locus of the deficit was an impaired counting mechanism. The role of the dopamine and nigrostriatal circuit in the timing mechanisms was emphasized also in animal studies.[346]

However, Meck[347] and Gibbon[348] argued that the representation of temporal information up to the minutes range is subserved not by the cerebellum, but by a network involving the basal ganglia and frontal cortex. It might seem that basal ganglia and cerebellar contributions to time perception can be distinguished on the basis of interval range; as the cerebellum maintains temporal representations in the millisecond range, while the basal ganglia serves as neural counter engaged at longer durations.[349] Nevertheless, a recent positron emission tomography (PET) study[350] suggested that both the cerebellum and basal ganglia contribute to a network underlying perception of durations less than 1s. Although the cortical and subcortical regions activated in the PET study conducted by Jueptner seem to be both involved in a network for time perception, it is thought that the prefrontal and the neocerebellar regions perform dissociable functions within this network. A comparative approach was proposed to investigate the relative contributions of the basal ganglia and the cerebellum to the processes involved in time perception, with the aim of integrating functions of the frontal lobe, basal ganglia and cerebellar neocortex into a complete neural model of complex cognitive processing. By comparing neuropsychological populations with circumscribed lesions across a range of temporal and non-temporal tasks, this study suggested that the prefrontal and neocerebellar regions perform dissociable functions for time perception.[351] These findings clearly indicate that different neural circuits might play role in the neural substrate of time processing. The posterior parietal and pre-motor areas, along which the cerebellum, might provide the mechanistic basis of the first time module responsible for the interval timing by the brain in the sub-second range;[352] on the other hand, the oscillator module might be inbuilt in the basal ganglia, a neuronal region that provides different mechanisms for the interval timing by the brain, especially in supra-second range.[353] The view that the basal ganglia forms the neural basis for an oscillator timing module, helping in the calibration of the modular clock, is also defended by Gupta.[354] Despite the neural circuit of the basal ganglia provides no direct representations of physical time, its role is

[346] Coull et al.: 2011.

[347] Meck: 1996.

[348] Gibbon et al.: 1997.

[349] Ivry: 1996.

[350] Jueptner, et al.: 1995.

[351] Mangels, Ivry and Shimizu: 1997.

[352] Harrington et al.: 1998; Bueti et al.: 2008; Coull et al.: 2011; Teki et al.: 2011a.

[353] Malapani et al.: 1998; Wiener et al.: 2010a.

[354] Gupta: 2014.

engaged with the beat-based timing relative to rhythms. This view is also consistent with the presumed activation of the basal ganglia during beat-based timing tasks.[355] Further evidence for the existence of two separated neural timing systems operating at different time ranges is offered by neuroimaging data. Lewis and Miall[356] indicated the existence of two distinct neural timing systems: an automatic timing system was proposed to time shorter intervals up to approximately 1s, it recruits the motor systems of the cerebellum, the basal ganglia, and SMA; whereas, a cognitively controlled system for timing supra-second intervals was associated with the right prefrontal and parietal cortical areas. Other neuroimaging studies[357] found that similar brain areas are activated in time perception tasks employing different durations. The separation between distinct time perception systems is also present in other motor-timing studies. Madison,[358] for example, demonstrated that qualitative change in tapping performance basically occur with inter-tap intervals whose duration is approximately between 1s and 1.5s; in contrast, time intervals between 0.45 and 1.5s seem to be automatically processed and not affected by attentional demands. It was also shown that intervals in the range between 1.8s and 3.6s are affected by attention and working memory processes stimulated by secondary tasks.[359]

13. 10 A brief reassume

In this chapter I proposed a modular view of the mental architecture of time perception, analogously to that proposed for audition, vision, speech, or other kinds of perception. First I reported some potential difficulties to endorse a modular perspective for time processing. As I said, one difficulty is related to the fact that the objects of time perception cannot be compared to the physical objects that fall into the three-dimension space; while another general problem is to identify the organs for temporal processing, and thus their localization within the brain. However, I argued that these difficulties do not threaten the possibility to develop a general account of temporal perception based on the theory of modularity of mind. Despite time cannot be perceived as we perceive a physical object, it is profoundly rooted in our mental architecture as well as the spatial dimension. In fact, time has a critical role in perception since the perception of structure in time is fundamental to the perception of changes in physical objects, whose temporal organization based on *succession* (order) and *duration* (simultaneity). Then, I suggested that there is an independent processing-system specific to the information of *duration* and *succession* of events. The proposed time module is based on a general theory of perception drown by Fraisse in *Perception and Estimation of Time*. As I argued, the mechanisms theorized by Fraisse for *time perception* and *time estimation* are consistent with the view of the modularity of time processing, I therefore introduced descriptions of a presumable mental architecture in which the operations of an information processing are specific to

[355] Teki et al.: 2011b.

[356] Lewis and Miall: 2003.

[357] Pouthas et al: 2005; Jahanshahi at al.: 2006.

[358] Madison: 2001.

[359] Miyake et al.: 2004.

succession and duration of events. I proposed a modular functional architecture for time processing which comprises two neurobiological isolable processing components, each having the potential to be specialized for time. Each processing component is concerned with a specific information-processing operation that contributes to the overall system. The results of these operations will give the cognitive basis for our 'sense' of time, that is the *specious present*.

So far we have seen that the first processing component of the time-module is a temporal processing system that operates at short time durations expressed in millisecond, and more specifically between 20ms and 100ms (according to the temporal frame identified by Fraisse, at which the *perception* is only of *succession* or *instantaneity*). This processing component is specialized to extract temporal information contained in the outputs of other modules within this range of time. Once processed the information contained in those inputs, it generates outputs which contain representations of the rate of change of objects and events. Such representations (which can be thought as 'raw' material of the physical world) are supposed to be given in terms of stings of temporal relations between successive moments so-defined: "the event x *is earlier* or *later than* the event y", and lay the ground for perception of duration, which occurs into a second timing processor. I considered this second time processor component to be responsible for *perception of duration*, occurring at a temporal range between 100ms and 5sec. The second timing processor takes the first processor's outputs as inputs and, after it processes the information contained in them, generates an output that reproduces the duration of an amount of time that is presently passing. This timing processor provides representations of time durations in terms of the *specious present*, namely, the 'sense' of *presentness* creatures possess. The temporal reference of *now* is necessary to the successive estimation of duration in retrospect. Beyond 5sec *estimation of duration* takes place, this timing mechanism has not to be thought as a timing module itself, but rather as the result of the activities of the central system. Based on the temporal reference of *now*, the subject is able to construct complex representations of time defined in terms of "x is *now* past (memory)," or "x is *now* future (expectations).

To give support to the modularity view of time processing, I reported a number of functional, biological, and neuropsychological studies that confirm this view. We saw that findings available in the literature for the hypothesis of the time-module deal with the processing of intervals lasting a few milliseconds to several seconds. Several psychological studies and behavioral observations, as well as neurophysiologic studies, suggest a temporal segmentation model based on two different time scales. To conclude, I argued that time processing captures the typical properties of modular organization in Fodor's sense, and entertained the plausibility of a modular architecture for time processing in the context of neuroscience, by suggesting that different areas of the neural system contribute to the functionality of the time module. Basically, I indicated two important circuits as possible candidate for the first-level temporal module: the cerebro-cerebellar loops responsible for motor and non-motor functions such as working memory, executive tasks, and emotion; and the dorsal stream responsible for sensorimotor tasks, connecting the posterior parietal cortex and the motor, premotor and prefrontal areas of frontal cortex. On the other hand, I suggested that the oscillator module might be presumably inbuilt into the basal ganglia.

CONCLUSIONS

In this dissertation I discussed the topics of intentionality, modularity and time in relation to a number of different issues, problems, theories and explanations concerned with the view that individuals (and at least animals) have an internal 'mind' that processes information coming from the external environment, and that such information guides the behaviour of those creatures. Having introduced the idea of the 'internal mind' as regards the intentionality of mental states and processes, I turned to the concept of 'modularity', and in particular to the modularity theory advanced by Jerry Fodor, which claims that the way this information is processed in the mind depends on the way the mind is functionally structured within the brain. I thus focused on the possibility that the modularity theory applies to time perception. In considering this possibility, I explained how experimental psychologists have been tempted to identify a variety of phenomena on a temporal continuum that reflect fundamental transitions in the way the brain captures information, arguing that the range of temporal experiences reveal an underlying structure that might be characterized as *modular*. To suppose that a functional architecture for time processing captures the typical properties of modular organization is to claim that an independent module specific to our 'sense' of time (understood from an internal subjectively-real experience type) exists. To summarize the steps of the argument presented thus far:

- There is a modular functional architecture for time processing that comprises two component modules: the first modular subcomponent might be thought as an internal "clock" used to measure time succession, and the functional basis for this timing mechanism is the pacemaker-counter device model; whereas, the second processor component can be thought as an internal timing mechanism that resembles the working of a self-sustaining oscillatory processing.

- One modular processor is more basic, totally encapsulated, working at subconscious level and a very short temporal range, this is the modular component engaged with perception of temporal succession; conversely, the other one is more open, partially encapsulated, operates at long time scales and might be present at either conscious or unconscious level, this is the modular component engaged with perception of temporal duration.

- Each of the two distinct modular mechanisms carries out own distinct functions and operates at specific time range, providing necessary prerequisite for extracting time information from the external environment.

- Our 'sense' of time is the cognitive result of the functions and processing carried out by those modular components (in the same way that vision results from three complex information processing types of visual representation); descriptions of how the pathways of information flow between these component modules can be useful for explaining how the mind captures and represents the rate of change it perceives from the external environment.

- The entire processing of the time module forms a representational basis for higher level processing, which occurs at the level of the central system.

- There is empirical evidence for the modularity of time processing which comes from many fields of study, more particularly, a number of covering functional, biological, and neuropsychological studies suggest the existence of such module for temporal processing.

- Hence, this allows us to regard time perception in terms of modularity, as we do with many other kinds of perception.

I hope the proposed modular architecture for time perception can provide plausible and valid foundations for future research on the psychological and neuronal mechanisms of time processing. To conclude, I wish to make a couple of suggestions concerning my hypothesis which might be examined in future enquiries. The first suggestion concerns the idea that the psychological mechanisms by which the mind elaborates and organizes temporal information have a fundamental role in the mental architecture. Temporal processing is an important part of perception; if we accept that a range of possible types of cognitive architecture might exist among animal species, then we can conclude that different kinds of cognitive architecture involve different types of perception and temporal processing. For example, like dogs, humans perceive sounds, but dogs can nevertheless perceive very high-pitched sounds that humans are unable to perceive, and in turn dogs have a more restricted visual spectrum. Differences between auditory or visual processing in humans and dogs must therefore depend on differences between their respective cognitive architecture. Naturally, such differences among different sensory-perceptive systems are also reflected in timing processing, so a dog's internal clock will differ from ours in many important respects. It seems that animal behaviour is in general pre-programmed by time, whereas human behaviour (despite being regulated by time as well) appears more flexible and less bound than the former. We often refer to animal behaviour as "instinctive" and to human behaviour as "conscious." When a organism has a particular experience like seeing a water spring or hunting prey, its memory recalls every past occasion when it had a similar experience, so that organism, having already experienced similar environmental conditions, will be prepared to deal with the new circumstances. Obviously, this situation occurs in humans as well as other species; nonetheless, unlike humans, animals tend to reinforce their behaviour from incoming stimuli in an automatic and often unconscious way (as Pavlov and the early behaviourist experiments demonstrated). At first glance, it seems that the mental architecture of animal species has a higher degree of modularity compared to the architecture of the human mind. On the other hand, in humans time information (along with other kinds of processing) appears more differentiated between temporal perception and temporal cognition (therefore, between the modularity of perceptual processes and the intentionality of representational processes). This is not to say that animals have no timing mechanisms at the level of the central system at their disposal, rather, it means that the mental architecture of animal species is more centered on aspects of perception and instinct than on aspects of cognition.

For instance, we know that some animals hibernate, going into a deep sleep so they can survive the cold season when the weather is freezing and food sources are difficult to find. When wood frogs hibernate during the winter they actually stop breathing, their hearts stop and ice crystals form in their blood; conversely, when the winter is over and the temperature rises, they defrost and their lungs and hearts restart. Hibernation is a clever survival mechanism and it is evident that this mechanism is regulated by a series of internal biological clocks. There are numerous physiological internal mechanisms that govern this and other similar physiological and biological functions, and these reactive processes form part of the biological structure of an organism following a hierarchical order. From chemical reactions to communication times between cells, to the vital cycles of singular organisms that operate at behavioural level, inner mechanisms are hierarchically interconnected by constant timing regulation; respiration, blood circulation, digestion and other similar vital functions are mechanically involved in a process of continuous adaptation to the changes identified in the external environment. In virtue of this adaptation internal mechanisms are constantly regulated by timing organization, since they have a specific duration, occur at specific moments with adequate speed, and maintain relationships with other local times which perfectly harmonised and rhythmically adapted to achieve the organism's vital functions.

However, despite the fact that the coexistence of local natural times regulates biological and physiological structures, a wood frog does not decide whether to go into hibernation or to reproduce. These behaviours are instinctive in the sense that they are pre-programmed and presumably inbuilt in its mind. When executing those behaviours animals do not exhibit what we call *free will*, given that these acts are evidently completed due to specific circadian rhythms. However, it is not clear where the borderline between conscious and automatic, or instinctive, behaviour lies. In the study of time processing in humans, for example, some research reveals that our ability to judge duration is a consequence of physiological mechanisms, which vary in inter-subjectively predictable ways. Evidence shows that if vital functioning is accelerated by the consumption of stimulants such as amphetamines, or due to increased body temperature, this results in an overestimation of time amongst subjects.[360] Conversely, it has been shown that reduced body temperature generally leads to an underestimation of time.[361] In general, an increase or decrease in vital function consistently leads to the perception of duration elapsing more quickly or more slowly respectively.[362] In any case, what appears clear here is that from the lower molecular or cellular levels to the ever-higher levels of cognitive processes, animal species (and especially humans) exhibit a certain ability to manage temporal information.

We might ask whether this timing ability is a sort of 'adaptation' in the sense intended by evolutionary psychologists. In this sense, we may consider the timing module as the product of the natural selection of evolutional cycles, something that is inbuilt in the genetic code of species that inhabit the various ecosystems. Besides the critique applied by Fodor to the general understanding of evolutionary psychology (according to which a mechanism, or function, has evolutionary purpose only if it was *selected* to enhance the organism's survival), it is evident that a time module would play a decisive role in enhancing the survival of the organisms.

A second suggestion concerns the interrelationship between temporal perception and temporal cognition. Being interdisciplinary in nature, the study of time has been approached from various perspectives; specifically, research in philosophy, cognitive linguistics and AI is committed to exploring how time manifests itself in language and thought. Time statements qualify external

[360] Hoagland: 1933; Fraisse: 1963, 1984.

[361] Baddeley: 1966.

[362] Wearden and Penton-Voak: 1995.

representations of beliefs, desires, or intentions, and using these external representations, anticipatory reasoning about intentional dynamics can be performed. In the general formalization approach presented in Jonker and Treur,[363] the temporal aspect of the dynamics of interaction with the environment is made explicit and related to the dynamics of belief, desire and intention; in this approach, mental states are grounded in interaction histories on the one hand, and related to future interactions on the other hand. A principal issue is the conceptual dependence between time and space (I have already dealt with this issue in my earlier paper).[364] In linguistics the *conceptual metaphor theory* has provided much of the impetus for exploring this issue. As Lakoff and Johnson argued:

> "…what we call the domain of time appears to be a conceptual domain that we use for asking certain questions about events through their comparison to other events…very little of our understanding of time is purely temporal. Most of our understanding of time is a metaphorical version of our understanding of motion in space."[365]

This position argues that time arises from the abstraction of relations between events that we perceive and experience in the world "out there", and that once these relations have been abstracted, they are structured in terms of spatial correlates allowing us to conceptualize time:

> "our concept of time is cognitively constructed…events and motion are more basic than time."[366]

According to the view of Lakoff and Johnson,[367] at the representational level, time and space are asymmetrically structured: time is supported by, and arguably parasitic on spatial representation, so mappings recruited from the domain of space provide structure for the domain of time, but not vice versa. In focusing on this evidence Lakoff and Johnson posited a "passage" conceptual metaphor, in which time recruits structure from motion through space on the basis of *experiential correlations*. They argued that time inevitably and ubiquitously correlates with salient aspects of spatial experience: duration, for example, correlates with spatial length.

On the other hand, focusing on lexical concepts for time, rather than conceptual metaphors, Evans[368] has argued that time is in some ways more fundamental than space, at least at the neurological level: it facilitates and underpins our ability to perceive and interact in the world, to anticipate, and to predict. Based on neurological evidence, he considered the distributed nature of temporal processing to be critical to our ability to perceive events, assuming that event-perception is

[363] Jonker and Treur: 2002.

[364] Gentile: 2010, pp. 33-38.

[365] Lakoff and Johnson: 1999, pp. 138-139.

[366] Lakoff and Johnson: 1999, p. 167.

[367] Lakoff and Johnson: 1980,1999.

[368] Evans: 2004; 2013b.

facilitated by temporal processing. Somewhat along the same line, Crick and Koch[369] claimed that temporal processes have a critical role in facilitating our perception of sensory-motor experience. In approaching the so-called *binding problem*, that is, the problem of how percepts are formed in the absence of a central association area for the integration of perceptual information in the brain, they suggested that perceptual binding is achieved via the coordinated oscillation of neurons. Accordingly, binding may result from the temporally coordinated activities of neurons that *bind* perceptual information, rather than from the integration of information at a specific "association" site in the brain. Perception of temporally structured events facilitates perception of our world of sensory experience, so that spatial awareness would be favoured by the temporal mechanisms that control perception. Not only temporal structuring of our experience of time occurs alongside, or in parallel to, spatial perception, but it also facilitates the perceptual processes of the spatio-sensory world around us.

As I said, time itself is not the object of our perception (for the reasons I detailed in the last chapter), but is the manner whereby perception is facilitated. Conversely, the representation of time in the conceptual system is accomplished by spatial correlates, therefore we could conclude that there is an asymmetrical dependence between time and space at the perceptual and representational levels. While our experience of time and space are distinct and distinguishable at the perceptual and neurological level, on the other hand, at the representational level they appear to be largely asymmetrically organized.

[369] Crick and Koch: 1990.

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