



Review Paper

The brain as a working syncytium and memory as a continuum in a hyper timespace: Oscillations lead to a new model



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ABSTRACT

The aim of this study is threefold: (1) we propose a new framework describing the neurophysiologic functioning and cognitive processing of neural populations, and we extend the neuron doctrine to the physiology of neural assemblies. (2) The extension from neurons to neural populations implies that the brain, with its connectivity, should be considered a working syncytium, which extends Brodmann mapping to the CLAIR model, which includes oscillatory components and their connectivity. (3) In such a working syncytium, a new description of “memory” is needed in the broad time–space continuum, which embraces all memory states. This will be called “hypermemory.”

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1. Introduction

1.1. The brain is a working syncytium

1.1.1. History

On the basis of the results of signaling analysis, Ramón y Cajal believed that the brain is an organ constructed of specific, predictable circuits. Although Cajal believed that the brain was built by neural networks with several individual and autonomous firing neurons, the connectivities between long-distance neural networks in fact cause the brain to act as a working syncytium,¹ where there is a possibility of any type of interaction occurring anywhere, which is in contrast to the

statement of Cajal. This interpretation has been clearly described in the CLAIR model by Başar and Düzgün (2016b–in this volume), which includes oscillatory activity and connectivity.

In the last three decades, another working hypothesis has been developed, which is derived from the neuron doctrine. Several investigators have shown that a brain function (except for simple reflexes) cannot be performed with a small number of neurons or only with a unique brain structure. Several areas of the brain are activated, particularly during cognitive processes (Yener et al., 2016–in this volume). Examples of this activation include the cognitive functions performed upon the oddball paradigm, event-related oscillations, and connectivity in long-distance areas of the brain, which are used for the realization of perception, sensory performances, short-term memory, and decision making. Therefore, the well-established Brodmann concept should be extended or replaced by the newly introduced CLAIR model, which should act as a transition from the neuron doctrine to the concept that neural populations are distributed throughout the whole brain. This new explanation could act as the new brain mapping model for perception, memory, sensation, and emotion.

At present, the term “mind” is often used synonymously with “consciousness.”

2. What are the conceptual essences of the EEG neurophysiology?

According to the results of the reports in this special issue, “the Electroencephalography (EEG) is a quasi-deterministic or a chaotic signal, and should not be considered as simple background noise.

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¹ Initially we have tentatively described the brain as a dynamic syncytium. This expression was criticized by Claudio Babiloni as follows:

“The concept of syncytium can be misleading. Physiologists use this term when several elements are aligned by anatomical features: skeletal muscle is composed by several cells sharing their nuclei and the action potential run along the fibers without any barrier formed by the separation of the single cells. I think that the main feature of the brain neural networks is that they are not syncytium. They are anatomically and functionally formed to allow functional synchronic co-activation (on mode) and asynchrony for de-activation. They can integrate and dis-integrate different nodes and modules on the basis of different functional states and inputs. Integration and dis-integration is a different concept of ‘syncytium’ implying ‘all or none’ behavior of several functional units.”

The working brain is anatomically not a syncytium in the classical sense. The axonal communication between separate cells causes the brain work as a syncytium.

The information in these reports leads one to the conclusion that the oscillatory activity, i.e. EEG, governs the most general transfer functions in the brain” (Başar, 1990).

“The theory that the brain works as a syncytium proposes that integrative brain function is based on the coexistence and cooperative actions of many interwoven and interacting submechanisms. This theory also includes mechanisms that consist of supersynergy, superbinding, and reciprocal interactions of attention, perception, learning, and remembering (APLR-alliance).”

In this study, we will outline a summary of structural evidence collected from earlier special issues (Schürmann et al., 1997; Başar-Eroğlu et al., 1991; Başar et al., 2013; Başar, 2008; Başar et al., 2001a,b,c,d). The functional properties of the brain give rise to a new concept: EEG-brain function. This new branch needs a series of new rules which we call EEG-neurophysiology. Başar et al. (2001a,b,c,d) described the elements of an EEG-related neurophysiology as follows²:

2.1. From neurons to neural networks

The oscillatory activities of the neural assemblies of the brain consist of the alpha, beta, gamma, theta, and delta frequencies. These are natural frequencies, and therefore, the real responses of the brain (Başar et al., 2001a,b,c).

The type of neuronal assembly does not play a major role in the frequency tuning of oscillatory networks. This is because morphologically different neurons or neural networks are excitable in similar frequency ranges. Research has shown that neural populations in the *cerebral cortex*, *hippocampus*, and *cerebellum* are all tuned to the same frequency ranges, despite their different neural organizations (Başar, 1998, 1999; Eckhorn et al., 1988; Steriade et al., 1992; Singer, 1989). Therefore, it has been suggested that all brain networks communicate by means of the same set of frequency codes from EEG oscillations.

In an attempt to describe the integrative functions of the brain upon complex stimulation, prior studies have replaced the functional role of the single neurons with neural assemblies (Başar et al., 2001a). The major point that differentiates the described results in this special issue from Sherrington's “neuron doctrine” and Barlow's “new perception doctrine” is the emphasis on neural assemblies (Barlow, 1995).

The brain has *response susceptibilities*. A neural population responds to external or internal stimuli with EEG responses or frequency components that are among its intrinsic (natural) rhythms. Similarly, if a given rhythm does not exist in a neural population's spontaneous activity, it will also be absent in the evoked activity. On the contrary, if activity over a given frequency range does not exist in the evoked activity, it will also be absent in the spontaneous activity (Başar, 1972, 1980, 1983a,b, 1992; Başar-Eroğlu et al., 2001; Narici et al., 1990).

There is an inverse relationship between EEG and event-related oscillations. Therefore, the amplitude of the EEG serves as a control parameter for brain responsiveness, which can be obtained in the form of evoked potentials or event-related potentials (Barry et al., 2003; Başar, 1998; Başar et al., 2003; Rahn and Başar, 1993).

Different tasks and their functions are represented by different configurations of parameters. Because of this, the brain uses the same frequency range to perform not just one, but multiple functions. The response parameters of the oscillatory activity are as follows: enhancement (amplitude), delay (latency), blocking (or desynchronization), prolongation (duration), and degree of coherence between different oscillations (Başar, 1980, 1998, 1999; Başar, 2004; Başar et al., 2001a;

Başar-Eroğlu et al., 1991; Kocsis et al., 2001; Miltner et al., 1999; Schürmann et al., 2000).

2.2. Superposition and connectivity are shaping the brain's functional response

The theory of the brain as a syncytium by Başar (2011) is supported by the following points:

- Several authors have demonstrated that temporal coherence exists between cells in cortical columns (Eckhorn et al., 1988; Gray and Singer, 1989; Herrmann et al., 2002).
- Each function in the brain is represented by superposition of the oscillations in various frequency ranges. The frequency of the oscillations varies across a number of response parameters. Neuron assemblies do not obey the all-or-none rule that is valid for single neurons (Chen and Herrmann, 2001; Karakaş et al., 2000a,b; Klimesch et al., 2000a,b).
- The superposition principle indicates that there is a coexistence between the alpha, beta, gamma, theta, and delta oscillations during sensory-cognitive tasks. According to the superposition principle, integrative brain functions operate through the combined action of multiple oscillations (Başar, 1980; Karakaş et al., 2000a,b).
- Coherence is a measure of phase consistency, and therefore, two signals that remain in phase over time (synchronous) are coherent (coherence equal to one). However, the opposite may not be true. Because EEG is generally composed of multiple frequency components, any pair of signals can be synchronous or coherent in some frequency bands and asynchronous or incoherent at other frequencies.
- Parallel processing in the brain is selective. This selectivity is produced by variations in the degrees of spatial coherences that occur over long distances between brain structures/neural assemblies (Başar and Ungan, 1973; Başar, 1980, 1983a,b; Başar et al., 1999; Kocsis et al., 2001; Miltner et al., 1999; Schürmann et al., 1995; Schürmann et al., 2000).

2.3. Integrating attention, perception, learning, and remembering

The extension of the theory of the brain as a syncytium to cognitive processing is governed by the following principles:

All brain functions are inseparable from memory functions (Fuster, 1995a,b, Fuster, 1997; Hayek, 1952). As in all integrative brain functions, memory is manifested as multiple and superimposed oscillations.

Attention, perception, learning, and remembering (APLR-alliance) are interrelated. Memory states have no exact boundaries along the time-space continuum. There is a hierarchical order on a continuum, but the boundaries of memory states merge into each other. Memory functions, from the simplest sensory memories to the most complex semantic and episodic memories, are manifested in multiple oscillations, which are distributed throughout the whole brain.

2.4. Genetically fixed causal factors

Begleiter and Porjesz (2006) have recently reported a fundamental approach to examine the genetic underpinnings of neural oscillations. They proposed that the genetic underpinnings of these oscillations are likely to stem from regulatory genes, which control the neurochemical processes of the brain, and therefore influence neural function.

It is well known that the present behavior influences immediate future behavior. The plasticity in this adaptive behavior is demonstrated in oscillations. The oscillatory plasticity is an additional causal factor in brain responsiveness. EEG oscillations manifest a high degree of plasticity in auditory and visual memory task experiments. The reciprocal

² Section 2 is significantly modified from Başar “Theory of the whole brain work”: Başar (2006), Int. J. Psychophysiol vol. 60 pages 133–138

activation of the APLR alliance (Başar, 2004) also affects the future responsiveness of the brain, which confirms the presence of *oscillatory plasticity* in higher cognitive processes.

2.5. Is the brain a working syncytium? The web of oscillations and neurotransmitters in “brain, body, and mind integration”

The words of René Descartes – “Everything in the universe could be explained in terms of a few intelligible systems and simple approaches...” – are supported by the results and hypotheses described in this special issue. Oscillations, neurotransmitters, the resonance principle, and entropy factors belong to governing intelligible systems in the integration of the brain, body, and mind. In the “Introduction” section of this article, we provided a definition of the concept of the “mind.” In the following section, we extend this concept according to the papers in this special issue.

“The Functional Syncytium Brain–Body–Mind” originates from results related to EEG oscillations, ultraslow oscillations, and neurotransmitters, which are quasi-invariants, as described in Chapters 9 and 22 A by Başar (2011). The overall myogenic system (OMS) and the vegetative system (including the heart, kidneys, and lymphatic system) function in an interwoven way, which (see also electrocardiography (ECG) by Triggiani et al., 2016–in this volume) lead to multiple causalities in the machineries of brain–mind.

Each oscillatory activity represents multiple functions. In addition, the contrast is true, where each function is represented by multiple oscillations.

The functioning of all physiological and biochemical pathways is governed by quasi-invariant natural frequencies and neurotransmitters of brain–body functioning (Koch et al., 2016–in this volume). This is similar to Descartes' view on the governing role of a few intelligible systems.

The principle of frequency coordination can be found not only in the brain but also in brain–body integration. According to previous studies (Aladjalova, 1957; Barman, 2016–in this volume; Gebber et al., 1995a, b; Ruskin et al., 2001a,b), structures in the vegetative system are tuned to the same frequencies. Transmitters, such as acetylcholine or norepinephrine, are also excellent vehicles for general tuning in brain–body interactions. The body and the brain use the same neurotransmitters and frequencies for the general tuning of brain–body interactions. Oscillations and neurotransmitters work together to form one combined activity. Therefore, the web of “oscillations and neurotransmitters” can also be considered as building blocks for function.

Spontaneous and event-related oscillations in the CNS and vegetative organs are all embedded in biochemical pathways (neurotransmitters). These oscillatory processes can be considered as manifestations and building units for brain–body functioning. (See papers by Koch et al., 2016–in this volume; Sanchez-Alavez and Ehlers, 2016–in this volume).

In pathology, oscillatory dynamics and the coherence between various parts of the brain determine the breakdown of the cognitive functions. As the brain matures, an enormous change in alpha activity is observed. Therefore, the mind of a child is completely different from that of a dementia patient. Creativity is not excluded in psychiatric disorders (Andreasen, 2005).

Bergson states that intuition requires an accumulation of knowledge and/or the “transition of unconsciousness knowledge” to “conscious experience.” Therefore, “intuition” plays a crucial role in the machineries of mind, particularly in creative states.

The ability to measure episodic memory and episodic emotions can also provide important opportunities for the interpretation of “the creative mind” in those with clinical disorders.

We emphasize that neither episodic memory nor intuition can be measured with physical clocks. As Bergson explained, both these processes (as known by subjective experience) occur in nonmeasurable, heterogeneous time–space continuums (Section 5.2).

Event Related Oscillations (EROs)

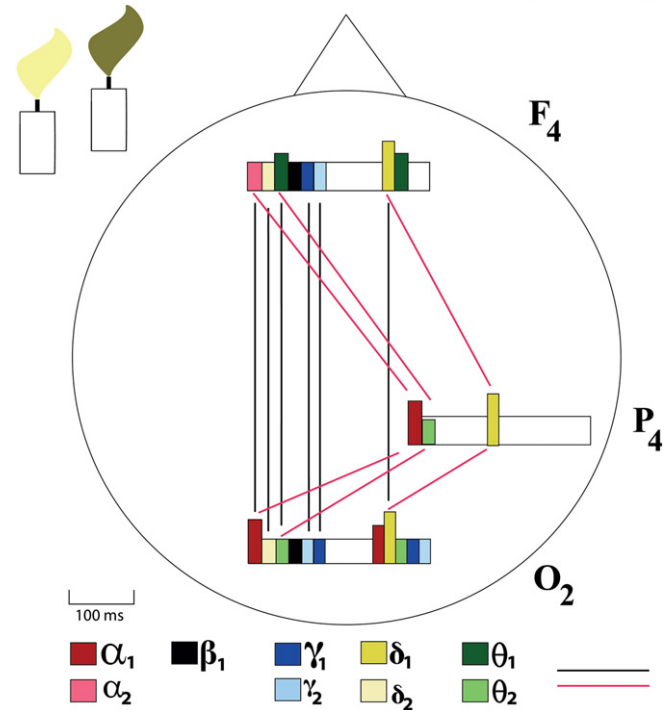


Fig. 1. In an oddball paradigm, the brain is stimulated with two different stimulations using slightly different visual stimulation. One type of stimulus is applied more frequently, while the second one is the rare stimulation to which the subject is supposed to pay attention. This rare stimulation is called “the target.” In response to target stimulation, the brain reacts with alpha, beta, theta, gamma, and delta oscillatory responses, which typically occur within a time period between 600 and 800 ms. In the configuration of the present figure, we show only the approximate/relative responses in the time sequence with rectangular boxes. The frequency codes are indicated with different colors. The heights of the bars that present oscillatory responses approximately conform to the amplitude of responses. These three brain structures also have functional connections, which are shown by the spectral coherences (Güntekin and Başar, 2010). The strength of connectivity is indicated by bold or dashed lines. Bold lines indicate coherence higher than 0.5, while dashed lines represent coherences under 0.5. In the future, more exact CLAIR experiments will be performed. This differentiation is shown by (Başar and Düzgün, 2016b in this volume). In the present paper, we emphasize the importance of the new concept, which is not included in Brodmann Models.

2.6. The CLAIR model (cortical, links, association, integrative, response)

In a recent study on the CLAIR model³ (Başar and Düzgün, 2016b–in this volume; Başar et al., 2014), the authors have explicitly described the multiple oscillatory responses that are selectively distributed in cortical areas. Moreover, the connectivity (i.e., coherence) is also embedded in the CLAIR model. The description of CLAIR functional areas will, in the future, most likely be an extension of the functional interpretation of the Brodmann model. Further, the CLAIR model will allow them to search for new measurements. This model can be also considered as a framework that indicates all complementary research to be performed (Fig. 1).

2.7. Previously undiscovered properties of the brain (the dark side of the brain)

In the previous section, we briefly described some features of the uncertain and intuitive brain, which are both strange and inexplicable. During dreams, intuitive decisions, or by remembering of episodic elements (by means of episodic memory), the brain is processing in

³ Cortical-coherence, links, associating, integrating, and responsive-areas

an inhomogeneous time–space continuum. This continuum can only be explained by the rules of general relativity theory by A. Einstein. In this special issue, we include a review related to the quantum brain, which is a newly launched area of research. This new type of off-take was explained by Başar (1983a,b,c) and detailed by Başar (2011). (See also Tarlacı, 2014; Tarlacı and Pignatelli, 2016–in this volume.)

We attempt to understand “how does the mind work,” but we cannot yet come up with a definite answer. The answer to this question requires multifold functional implications in the brain and body, as the brain, body, and mind are inseparable entities (Başar, 2011; Triggiani et al., 2016–in this volume).

3. A new memory concept: memory in a time–space continuum

3.1. What is the Brain's time?

Because the authors of the papers in this special issue discuss physiological problems, and because one paper also aims to describe the quantum brain, it is necessary to mention the importance of time concepts in the brain. As explained by Başar (2011), there are different types of clocks in the brain. Physical and homogeneous clocks as well as inhomogeneous clocks, which reflect the measurement of innate and intrinsic processes of the brain related to dreams, have been described. In addition, episodic memory, with theories from the psychological world and biological world, has not yet been completely analyzed or sufficiently described. Any theory that is not experimentally supported belongs to metaphysics. An example of this is given by Karl Popper, who described quantum mechanics in 1938. The application and boundaries of quantum mechanics could not be perfectly described at that time, although in our century, quantum mechanics is a very significant branch of physics. When we deal with the definitions of mind and memory, it is difficult to use tools, expressions, and definitions that are not yet completely understood, or their existence not yet demonstrated. In order to try to approach the mind and memory problem, we first have to describe two different definitions of time, both tentatively and globally (Fig. 2).

The reports and reviews in this special issue are aimed to propose new and essential steps for understanding brain function and dysfunction. Dysfunction in cognitive processes is mainly associated with memory loss. Attention and learning are inseparably included in memory. Further, new strategies regarding the application of brain oscillations opened the possibility of learning from diseases. In turn, important changes in the brain and body are caused by changes in the release of transmitters. A more sophisticated explanation of the mind requires a new type of thinking. This is the reason why many papers about neurotransmitters are published in this special issue. Although electrical oscillations and biomedical substrates constitute the core machineries for brain functioning, they are not satisfactory for providing a deeper understanding of the mind. An important question is “Do functional processes in the brain obey some mathematically predictable rules?” Among the new trends in neuroscience, research scientists discuss the expression “quantum brain.” They wonder if it is possible to observe quantum dynamics in the brain. According to Einstein, quantum theory deals with the population of elementary particles, and not with the dynamics of a simple particle. In studying the cognitive processes of the brain, we do not deal with single neurons, but we observe populations of neurons. Accordingly, we are confronted with the concept of the quantum brain. In the last two or three decades, four scientists approached this problem with different aspects of quantum theory (Başar, 1983a,b,c; Eccles, 1990). In this special issue, there is a short review related to the quantum brain by Tarlacı (2014) (Tarlacı and Pignatelli, 2016–in this volume).

In this study, we refer the work by Henri Bergson, who introduced the importance of “intuition” and “intuitive mind” for a transcendental explanation of brain behavior (Section 5.1).

3.2. The mind as an integration of several physiological and psychological entities

Fuster (1995a,b) and Başar (2011) explain “mind is inseparable from the psychological and physiological functions of the body.” They argue that the physiology of the brain–body and psychology are interwoven

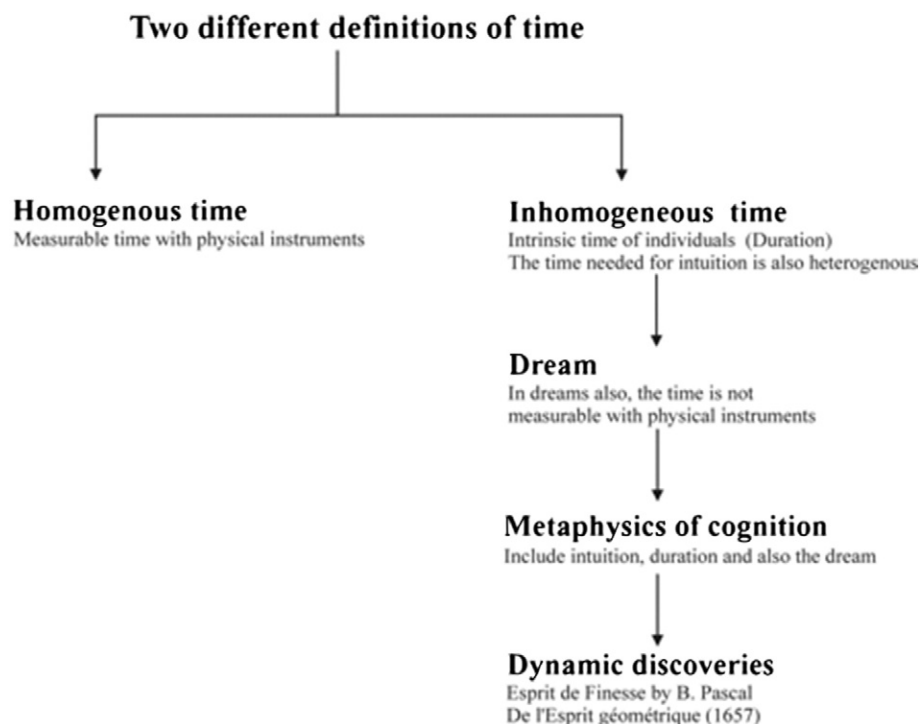


Fig. 2. Two different definitions of time. Notes: The period of the dream can be measured by rapid eye movement (REM). However, the period of the events in the dream cannot be measured. Despite the measurement of several experimental results, the fundamentals of dreams are not yet clarified. Therefore, we still as the expression “metaphysics.”

and are inseparable. Hayek (1952) raised the question “what is mind?” and discussed the relationship between mind and body (or between mental and physical events) as follows: “What we call ‘mind’ is a particular order of a set of events taking place in some organisms and in some manner related, but not identical, to the physical order of events in the environment.”

Hayek’s most important conclusion is summarized in his following statement: “we shall find that the same set of external stimuli will not always produce the same responses, but also, that altogether new responses will occur.”

Hayek excludes the possibility of finding physical elements or forces corresponding to a particular mental event, which corresponds with the context of what we call intuition.

4. The role of temporal structure in memory models

Several papers in this special issue outline the analysis of brain oscillations, which has gained importance in the last decades. However, in the development of such fast-growing trends, there is often a crisis in the causality of research results, which leads to controversies between them.

4.1. Bergson’s concept and memory models

In this study, we aim to develop an approach for the new concept of memory function based on the important concepts of a few philosophers and neuroscientists. We start with the important idea of Henri Bergson (1920), according to whom “mind is consciousness.” He does not provide a definition, but characterizes consciousness by its most obvious feature: *Before everything else, “memory embraces a feeble part of the past, but it may retain only what has just happened. A consciousness is unable to conserve its past, forgetting itself unceasingly, but then memory is conserved, with an accumulation of the past and present.”* Further, Bergson says that consciousness is also an anticipation of the future.

When we recall past deeds, interpret present actions, understand a discourse, follow someone’s train of thought, or attend to our own thinking, whenever, in fact, our mind is occupied with a complex system of ideas, we would feel that we can take up two different attitudes, one of tension and the other of relaxation, which are mainly distinguished by the feeling of effort that is present in one and absent in the other.

In his description of memory, Bergson does not define memory as a juxtaposition of several fractions or compartments of the memory, but describes it as a continuum in a broad time and space, where the “past,” “present,” and “future” are acting almost in parallel. In addition, the memory is a continuum resulting from several types of acting memories. This continuum is a metaphor used to compare Brodmann areas and CLAIR areas, as explained by Başar and Düzgün (2016b–in this volume). According to CLAIR, the brain is a working syncytium and the memory present acts as a holistic functioning system, where subfunctions are linked together due to the connectivity of structures.

4.2. Tulving, Atkinson–Shiffrin, Baddeley, and Cowan’s model

According to Bergson (1920), the mind is nothing more than consciousness and memory. The fundamental philosophical thoughts used to construct a framework for brain function and memories were discussed at the beginning of the 20th century by several neuroscientists. Again, according to Bergson, memory is not caused by the brain having distinct components. In the models of Tulving (1972) and Atkinson and Shiffrin (1968), episodic memory, semantic memory, and other types of memories are described as separate entities. However, the comparison of event-related oscillations reveals that memory function acts as a “continuum” in a broad time and space (Fig. 3). This is explained in Fig. 3.

Working memory can be defined as the process of storing, and then processing or using information. Working memory is necessary for

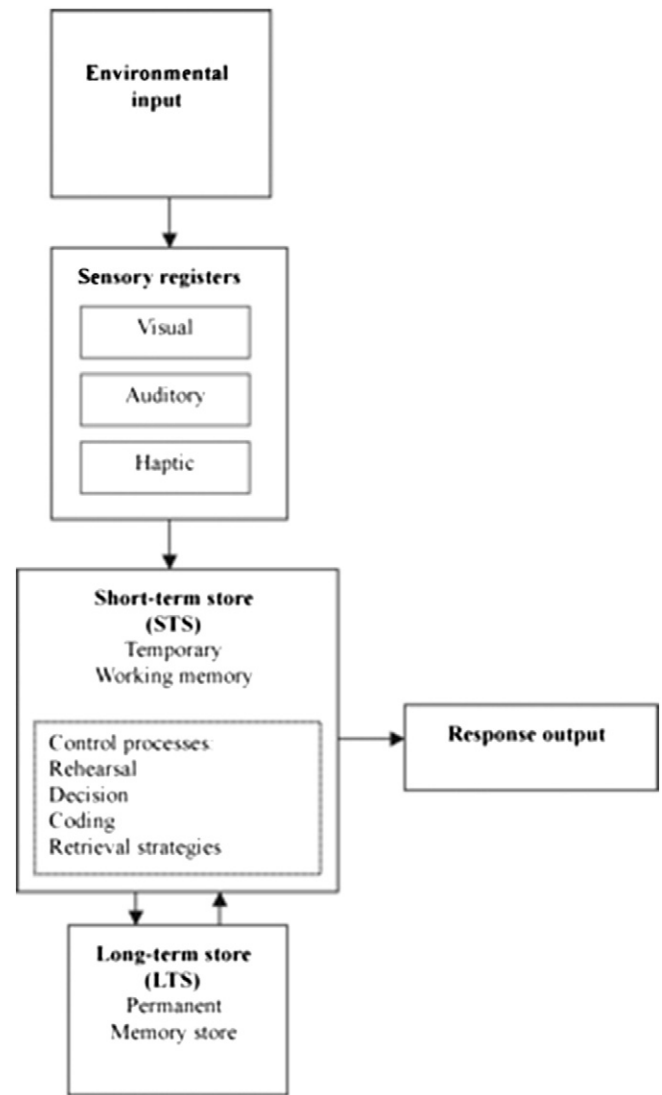


Fig. 3. Structure of memory. (Modified from Atkinson, R.C. and Shiffrin, R.M. (1968), in *The Psychology of Learning and Motivation: Advances in Research and Theory*, Spence, K.W., Ed., Academic Press, New York, p.195).

learning, comprehension, and reasoning. Several cognitive processes are involved with the working memory. Current working memory models are theoretical, and different models are based on neuroscience and cognitive psychology research (Wikipedia).

The Atkinson–Shiffrin multistore model for memory involves three different stages: sensory memory, short-term memory, and long-term memory. This model describes how memory actually works. First, any of the senses detect and process the information. This information may be stored in short-term memory, passed into long-term memory, or displaced and removed from memory. Several types of important factors, such as the type of information and the cognitive abilities of individuals, are not considered in this model (Atkinson and Shiffrin, 1968).

Baddeley’s working memory model for short-term memory was developed in 1974, which provides an alternative to Atkinson–Shiffrin’s multistore model. Three main components of Baddeley’s model include a central executive that controls the flow of information to two short-term storage systems known as the visuospatial sketchpad and phonological loop.

Cowan (2008) assumes that working memory is in fact a part of long-term memory. Further, working memory consists of long-term memories that have been activated, and depends on the ability of the individual to focus on these activated memories.

In a companion report (Başar and Düzgün, 2016b—in this volume), the model of “present,” in which Brodmann areas are replaced by CLAIR areas, the brain is described as a working syncytium. There is evidence that connectivity contributes to brain function, as several

oscillatory components are linked within several distant structures of the brain. This type of syncytium could also work efficiently in a continuum in a broad time and space. Only the joining or connecting of several brain oscillations can lead to their function. Fuster (1995a,b)

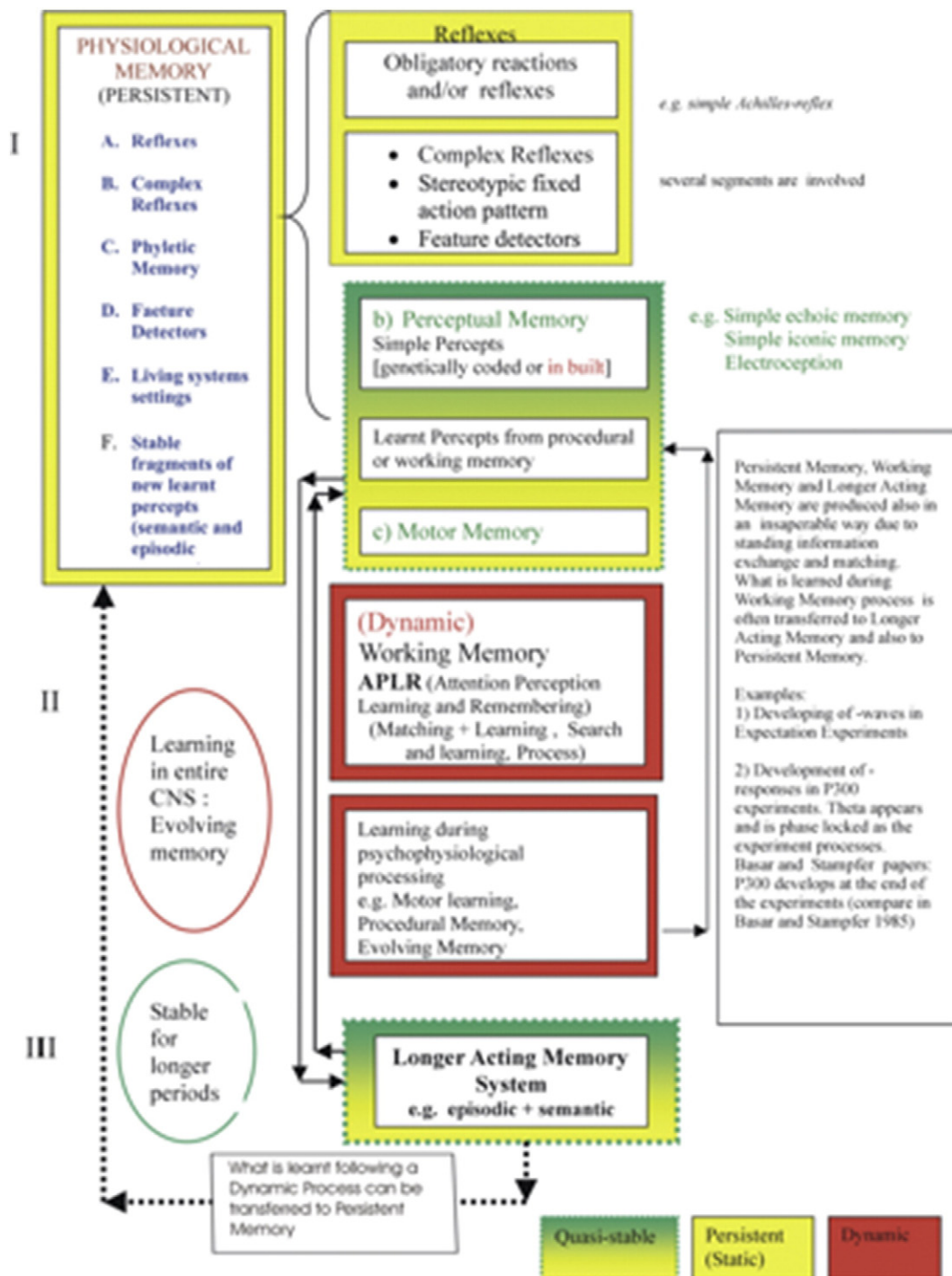


Fig. 4. A draft for a detailed scheme of memory levels, including the hierarchy and transitions between memories. Level I: At the top of the illustration is the persistent memory, of which the essential part is the physiological memory (or fundamental memory), which is composed of inborn (or built-in) memories. These inborn memories include (1) *Reflexes*, which can be (a) monosynaptic, simple reflexes, such as the Achilles Reflex, or (b) *Complex reflexes* involving multiple segments in the spinal cord; (2) *Stereotypic fixed action patterns* (example: flight reaction of *Aplysia*). Phyletic Memory (echoic memory, iconic memory, electroreception memory also belongs to physiological memory. The blood pressure of healthy living beings, smooth muscle reactions, and the beating heart contribute to physiological memory. Motor memory is classified as stable physiological memory. In this illustration, the yellow background is used to represent static components. Such memory types are persistent. In this illustration, the green-yellow background is associated with quasi-stable and longer-term memory states. Newly learned percepts, which are acquired after the activation of for example procedural memory or working memory, are quasi-stable. New percepts can be learned throughout the lifetime. These are not inborn, but they can remain over very long periods as quasi-stable memory states. With time, they can be replaced or forgotten. Accordingly, in this illustration, the background is green-yellow. Perceptual memory is categorized between Levels I and II. Level II indicates the level of Dynamic Processing and the working memory state.

reported that all brain functions are memory, and Bergson reported that memory is the mind itself. According to these statements, it is evident that the memory is a property of the whole brain, which is a working syncytium. Memories are also embedded in the working syncytium of brain and act in a continuum in time. This concept of continuum is also in accordance with the statement of Bergson that we immediately remember all possible events jointly in the past, present, and future.

4.3. Hypermemory as a continuum in hyper timespace

According to literature related to memory function, we emphasize the models of Tulving, Atkinson, and Shiffrin in the psychological context, where there are distinct and separate memory strategies for semantic and episodic memory. However, these models do not describe other types of memory that occur in parallel, such as physiologic memory, which include all types of reflexes and vegetative functioning. Başar (2005, 2011) described a more comprehensive memory model. He indicated that the memory builds a type of continuum, which is transferred from one memory type to the other. There is a continuous transfer between memory states.

In all living beings, memory function comprehends survival functions, ranging from the simplest reflex to a higher nervous activity, including “episodic” and “semantic memory” (Başar, 2011). According to this, within the hierarchy of memory functions, we categorize all levels of living and survival processes. Therefore, we tentatively introduce three different levels of memory states in Fig. 4.

Dynamic changes in the *Attention–Perception–Learning–Memory alliance* are associated with *evolving memory*. Following motor learning or procedural memory, new engrams can be created. As indicated by an arrow, these are then transferred to perceptual or motor memory. Following learning during procedural or evolving memory states, the new memorized information is transferred to longer-term memory state III. Semantic and episodic memory is categorized at this level (III), which is a *quasi-stable* level, marked with gray and yellow. “The newly learned material” following a dynamic process is sometimes also transferred to persistent memory (from level III to level I), as indicated by the arrow.

Persistent memory is not explicitly positioned in this illustration, and is solely indicated by pure yellow. In Fig. 4, persistent memory is indicated as a separate block and colored yellow.

4.4. The description in the time frame: what is the memory continuum in time space

In this study, we consider the time and space of the memory. The “hyperneuron” described by Roy John and Cognits (Fuster, 2013) includes relevant steps indicating the collective activity of the neural populations in brain function and general memory function. The CLAIR model presented by Başar and Düzgün (2016b–in this volume) describes the necessity to accept the brain as a working syncytium when performing different functions. In such a model, phyletic memory, working memory, and all memories related to functions are explained as parallel structures. In addition, several types of memories (Fig. 5) can be used to explain the boundaries of hyper timespace. In the memory storage, there are states called semantic memory and episodic memory, which are used for remembering past events, also known as “the flying back in time.” Sometimes, this travelling back goes to episodes that took place 20 years ago and more.

The “present memory” takes into account all the events occurring at present. Another memory travel is the future (prospective) memory, which needs the vision or creativity of the individuals. Then, the function performed is a type of flying forward in time. According to Bergson, “past,” “present,” and “future” memories occur in a “reverberating” manner, which indicates that there is webbing and reverberations between memories. We call this type of general memory

“hypermemory in the continuum of a timespace, which can be denoted as hyper timespace.”

4.5. The role of temporal structure of memory

According to Henri Bergson, “all consciousness is memory,” and memory is associated with events in the past, present, and future. Although there are several theoretical models describing semantic, episodic, and working memories, there is no model that takes into account the temporal structure of these different types of memories. In the light of the reports in this special issue, particularly in the framework of the CLAIR model, we have extended the earlier model of Başar (2005, 2011) to a new model, which describes the dynamic continuum in different types of memory as a parallel interaction of semantic, episodic, iconic, and emotional memories. Three types of memories are related to experiments described in the report by Başar and Düzgün (2016a–in this volume-a). Authors of the special issue show that semantic and episodic memories do occur in a parallel and integrative way. In addition, it is possible that they share the same neural structures. Cognitive events, emotional memory, semantic memory, and episodic memory are functioning interactively in a reverberating manner. The timespace of all of these memories occur in a timespace of almost 500 ms. This model leads to the development of a mental construct, which should be considered only in cases when one wants to open a new avenue for analyzing the temporal structure of memory. Certainly, this model is not the final model, as the analysis of the time structure of memory is indispensable for understanding the functioning of memories.

4.6. Transition and progressing of signals in the brain

Barlow (1961) revealed the principles that may underlie the transformations of sensory messages in the brain. He discussed the following hypotheses:

1. Sensory relays are detected in incoming messages, such as certain “passwords” or “codes” that have a particular significance for animals. We expand the passwords by indicating that passwords are a possible superposition of letters, which include the alpha, beta, gamma, delta, and theta oscillations in the brain.
2. They are filters or recording centers whose “past characteristics” can be controlled in accordance with the requirements of other parts of the nervous system.
3. Centers with given characteristics record sensory messages, which are signals of high relative entropy from the highly redundant sensory input. In a parallel publication, we have explained in more detail that the transfer of information in the brain takes place by means of similar codes, which we termed “brains alphabet” (Başar and Düzgün, 2016b–in this volume-b).

According to Barlow, the “password hypothesis” indicates that, since animals respond to specific stimuli, their sensory pathways must possess mechanisms for detecting such stimuli and discriminating between them. Therefore, one might look for such mechanisms in neuro-physiological preparations.”

“However, it is quite clear that the brain, even when studied from the restricted point of view of sensory communications, must not be considered simply as a juxtaposition of private lines, leading to a mosaic of independent cortical territories, one for each sense modality, with internal divisions corresponding to topical differentiations” (Fessard, 1961).

It is well known that the “reticular formation” might be or is one of the most powerful neuronal networks for sensory-cognitive communications. Fessard states that the track of a single-neuron message is damned to be rapidly lost when one tries to follow it through a neuronal network within which the elementary message readily interacts with many others. Fessard (1961) interpreted the theory of Horace Barlow described above in a similar manner. According to Başar (1980, 2011), the most general transfer functions are shaped by EEG oscillations.

HYPERMEMORY

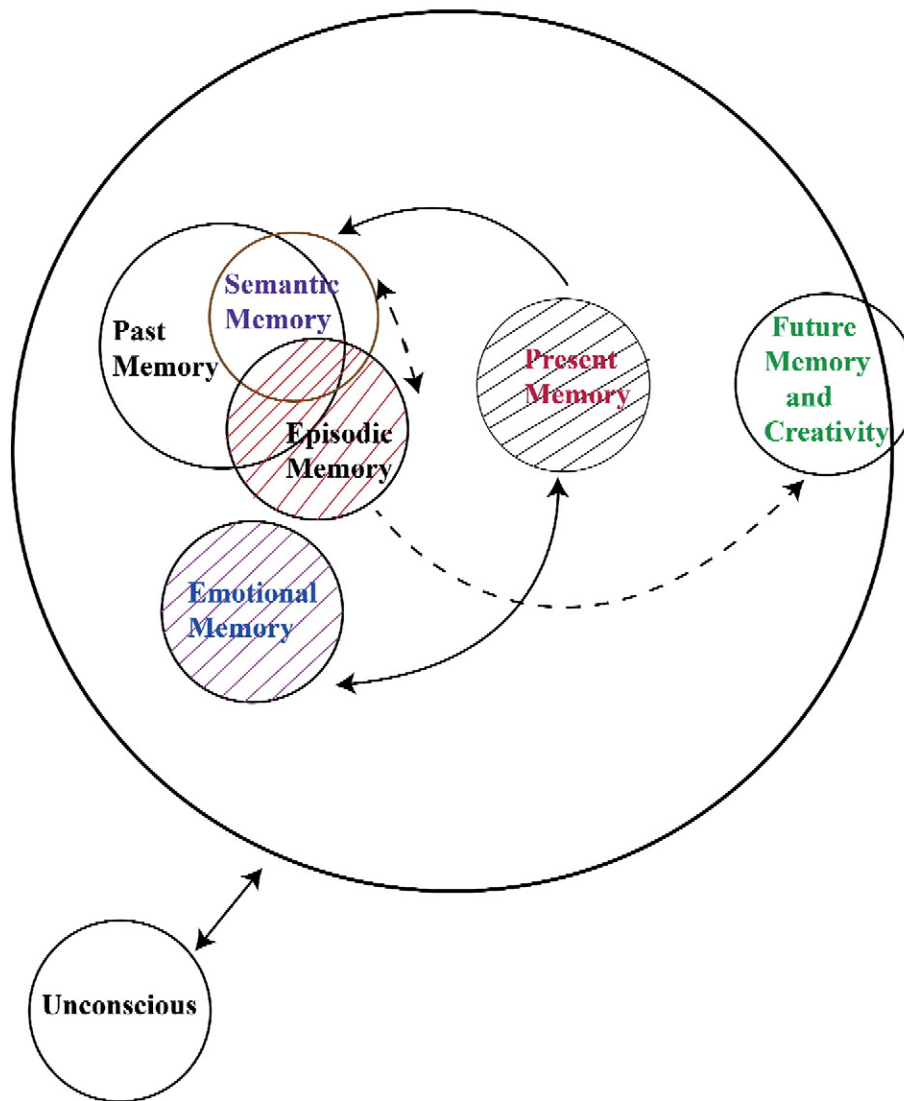


Fig. 5. In this illustration, past memory includes semantic memory and episodic memory. Semantic memory and episodic memory are mostly overlapping in time, and possibly, they share similar neural networks. Emotional memory is also based on our past memory. Therefore, it is designed in an adjoining way to episodic memory. The illustration also indicates that present memory relies on past memory, and that possibly are links from past memory to future memory and creativity. As stated by Bergson (1920), the consideration of future events requires past and present memories. As stated in the text, the time space, which we call hypertime space, requires a physical time period of approximately 0.5 s. In this illustration, the functioning of working memory and implicit memory are not yet incorporated.

According to Fessard (1961), "it seems that we should attempt to learn such principles, which govern the most general transformations-or transfer functions-of multiunit homogeneous messages during their progression through neuronal networks."

A certain amount of speculation has already been applied by different authors to the question of progression and transformation of messages through networks. Obviously, the answer requires some knowledge of the "connectivity," and the arrangement and relationship of its component neurons, within the network under consideration.

During the process of remembering, the working syncytium nature of the brain operates, whereas in reverberating, recurrent oscillatory activity occurs between the relevant structures of the brain. In such a "dynamic memory," the time history develops as a multidirectional process in timespace. In other words, the time projection of such a working syncytium can be denoted as a memory continuum in a hyper timespace. In such a model, past, present, and future memories are superimposed, and the current memory state jumps in all directions.

Başar (1998, 1999) extended and redefined the "passwords hypothesis" of H. Barlow.

Barlow (1961) described the necessity of defining the structure of a password, as mentioned in the paper by Başar and Düzgün (2016b). Later, such an alphabet enables and/or facilitates the transmission and communication of electrical signals between brain functions. The CLAIR model was constructed based on such a principle, in turn, also confirming Fessard's most general transfer functions or passwords hypothesized by H. Barlow.

Further questions are:

1. Does a general coded signal transmission by means of letters or passwords during performing of memory function really exist?
2. What is the magnitude of the timespace used to describe such a hypermemory embracing past, present, and future memories?

Both questions will be answered in the following sections.

4.7. What is memory in hyper timespace?

The memory of hyper timespace is a mental construct, including the phyletic, semantic, episodic, and working memories in a “superimposed” and “reverberating” manner. We ask “what is the timespace of such a hypermemory?” This timespace may include events of 20 years ago and contain fragments of events that are planned in the future. In fact, the introspection usually indicates that by memorizing the present event, we may remember earlier events in combination with possible future events.

4.7.1. Recognition of a known and unknown face: episodic memory response versus semantic memory

In the model of Tulving, Atkinson, and Shiffrin, and in the model of Baddeley, semantic, episodic, and working memories occupy a major part of the entire memory system. According to Tulving, episodic memory and semantic memory are separable and serial. Başar, (2006) designed a special experiment, in which a group of 20 individuals was stimulated with three different types of specific stimulations:

1. A simple light stimulation (iconic memory).
2. The picture of the subject's own grandmother.
3. The picture of elderly persons similar to the grandmother (semantic memory).

The results of the experiment are presented in Fig. 6. The oscillatory responses are compared over the frequency ranges of alpha, delta, and theta. The delta response in occipital areas does not show differences in response to semantic and episodic stimulations. However, delta responses were highly increased during episodic and semantic responses in comparison to simple light stimulation.

Fig. 7 further explains the results of the experiments comparing iconic memory, episodic memory (own grandmother), and semantic memory (picture of the elderly person). This illustration indicates the following:

Delta and theta responses react to different types of memory stimulations over short periods of time (0.5 ms). This indicates that they occur in a parallel way, and not in a serial way. The brain responds immediately to episodic stimulation. It is possible that similar neural populations are activated. However, the theta responses are more highly activated in response to the picture of the grandmother (Başar, 2005; Başar et al., 2007a,b).

4.7.2. Recognizing the face of a loved one

“Although fMRI studies merit important consideration, they should be cautiously interpreted because of the very low temporal resolution of the fMRI” (Grill-Spector, 1999). Therefore, Başar et al. (2008) used EEG strategies. In their measurements, pictures of a “loved person”

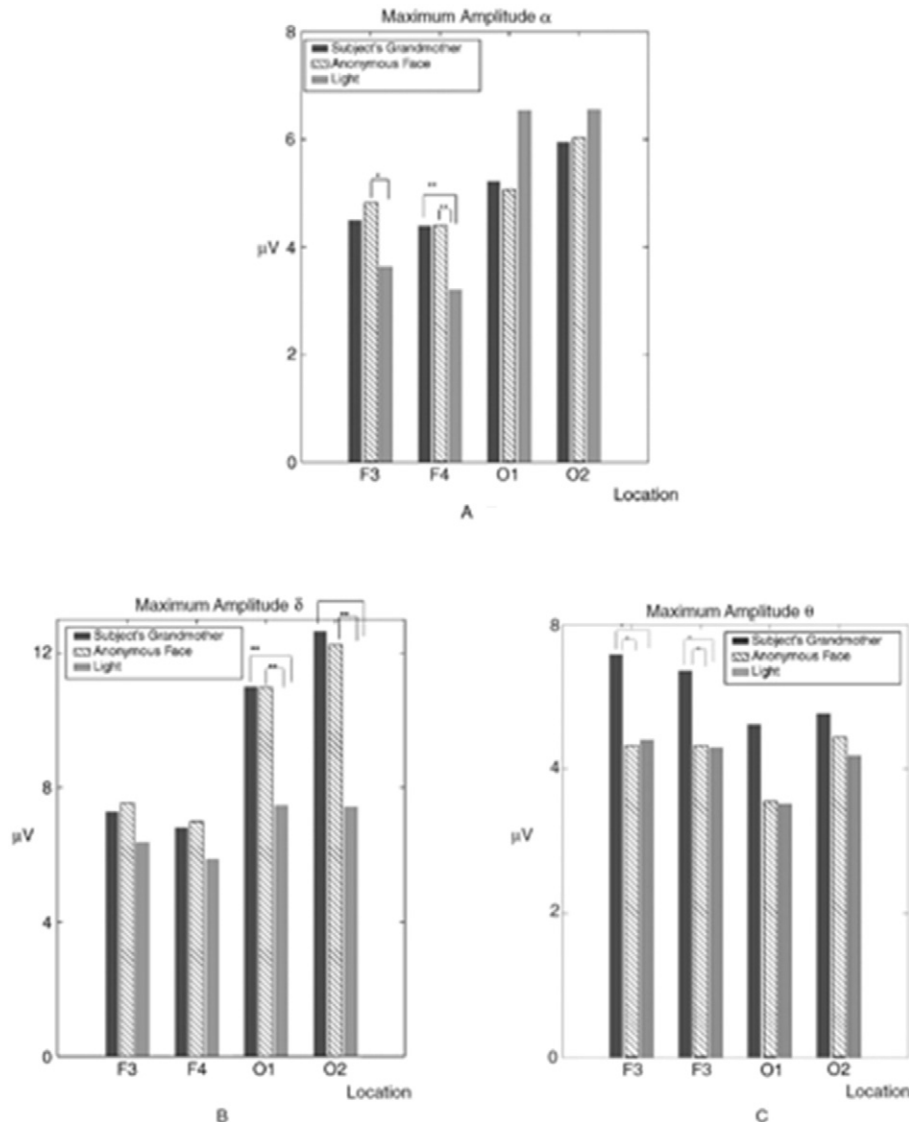


Fig. 6. The first statistical evaluation: a) alpha responses; b) delta responses; c) theta responses.

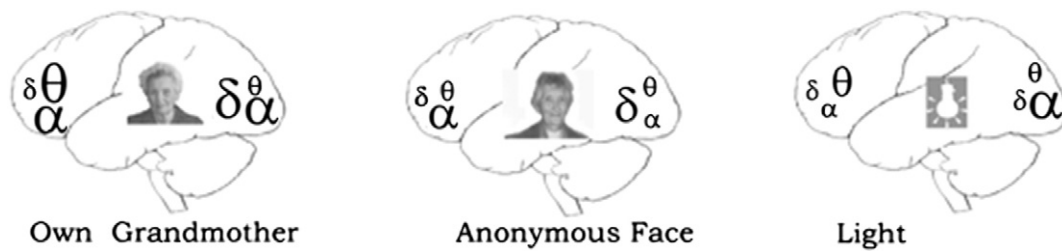


Fig. 7. A qualitative overview of the different global responses to three types of stimuli. Note the large occipital alpha and large frontal theta activity.

were presented to 26 female individuals, and the elicited responses were compared with the responses to pictures of faces of a “known and appreciated person” and of an “unknown person.” Başar et al. (2008) presented each stimulus type (i.e., a picture of “boyfriend,” “a close friend,” and an “unknown male” and “pure light stimulation”) in a single experiment.

In the second experiment, the stimuli were randomly presented to determine the possible effects of strong adaptation or habituation. The persistence of emotional states was also taken into account by using relatively long interstimulus intervals (ISIs). Light stimulation was used as a control. The faces were presented randomly and in block design. EEG data were analyzed with consideration for the maximum amplitudes and topographical differences within the conventional frequency bands of delta, theta, alpha, beta, and gamma oscillations. There were differences between light and facial stimuli in the delta and theta bands, and there were differences between face types and the two designs in the delta band. The delta response to the picture of the “loved person” elicited significantly higher amplitude values than that of the “unknown person” and “appreciated person.” These results indicate that frontal lobes react to different types of facial stimuli with specific increases in delta responses. The difference between the responses to the “loved person” and to the “known and appreciated person” reflects the component of the emotion denoted as “love.”

Fig. 8 illustrates the differences in delta responses to the four different types of stimulation presented randomly and in block design. According to Başar et al. (2008), “only the random of facial stimuli appeared to produce a differentiation of the facial processing in the brain responses.” This suggests that a habituation or adaptation effect occurs during the block presentation of the stimuli. Therefore, the results indicate that block designs may lead to false-negative interpretations, that is, there are no differences in the brain activity associated with the three faces, and induced emotional responses are assumed.

In earlier studies, occipital delta responses elicited by presentation of anonymous faces and faces of grandmothers were higher than those elicited by light stimulation (Başar-Eroğlu et al., 1993; Başar et al., 2007a,b).

4.7.3. Interim summary of face experiments

In a previous section of this report, we mentioned the importance of the general transfer functions of the brain according to the suggestions of Fessard (1961). In the concept of general transfer, functions can be understood as letters that operate as “passwords” in different neural populations of the brain. These, in turn, correspond to the alpha, beta, gamma, theta, and delta responses of the brain. Such passwords do exist. We mention the following examples:

1. During the oddball paradigm, the brain reacts with a delta response to the target signal, a sensory stimulation to which the subject has to pay attention. Thus, the delta response is a signal containing such functions as attention, perception, learning, and remembering (Karakaş et al., 2000a,b).
2. During the face recognition experiment, individuals are stimulated by three types of stimulation: simple light, the picture of an aged female subject, and a picture of the individual's grandmother (Başar, 2005; Başar et al., 2007a,b). Results indicate that theta and delta responses to faces are higher than that to simple light.

Further, the delta response of the subject upon seeing his/her grandmother's picture is higher than that to an anonymous face. The face of the individual's grandmother evokes episodic memory, whereas the anonymous face elicits semantic memory.” Although amplitudes of the delta responses are slightly different in the case of iconic memory, delta responses of semantic and episodic memories are the same, which proves that oscillatory signal transfers between memories and that the episodic and semantic memories have the same frequency composition. It should also be emphasized that the transitions between

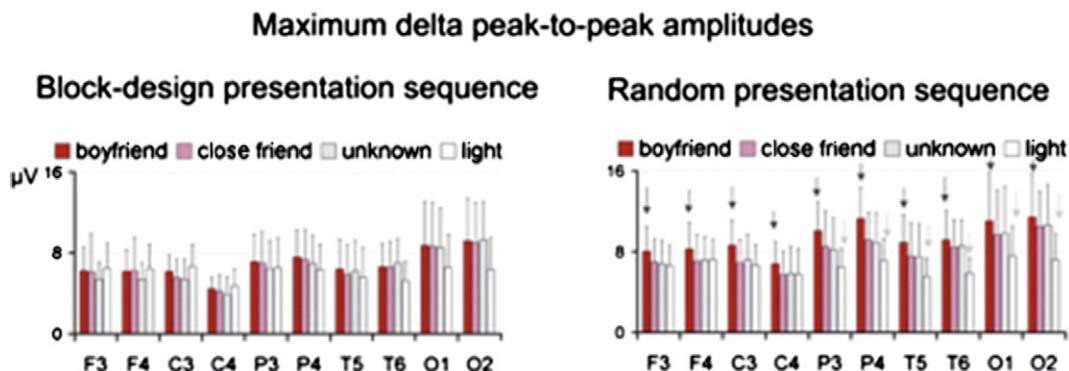


Fig. 8. Mean values and standard deviations of the maximum post-stimulus peak-to-peak delta amplitude values in the four conditions within the block-design (left column) and the random (right column) presentation experiments.

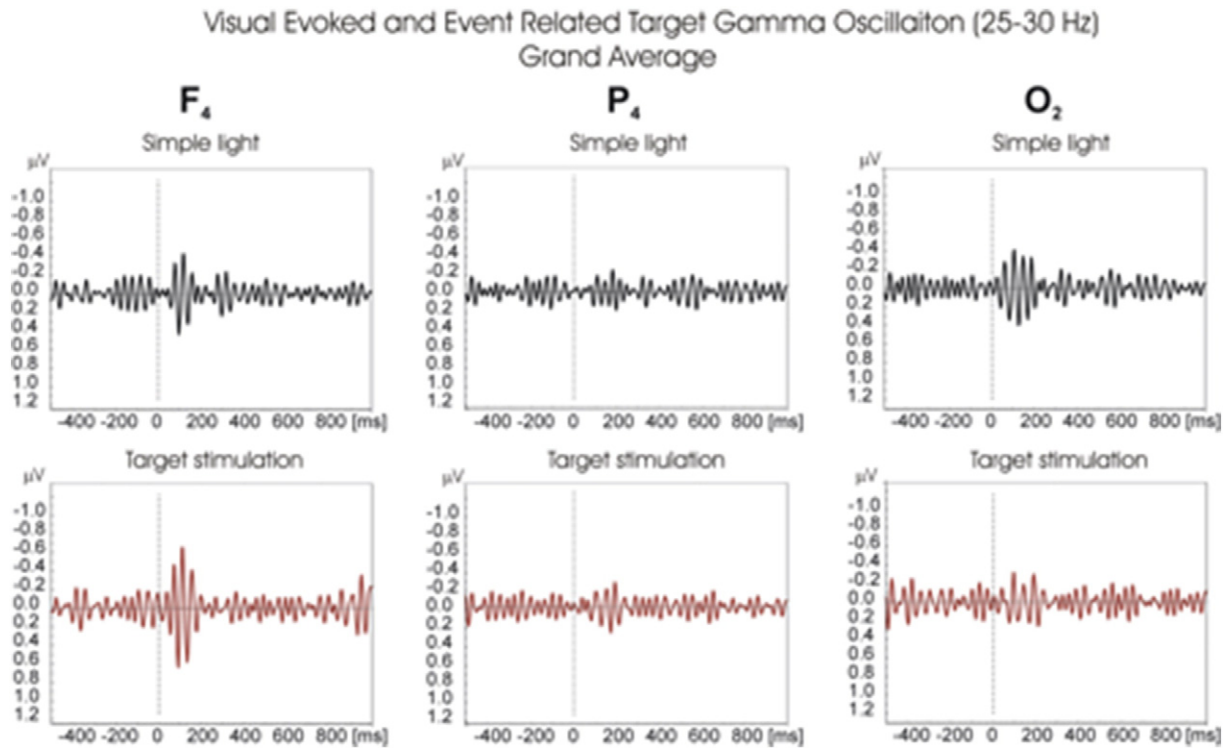


Fig. 9. Grand average of filtered (25–30 Hz) gamma oscillatory responses of 13 subjects for F₄, P₄ and O₂ electrodes upon application of target (red line) and simple light (black line) stimulation.

memories are most probably facilitated by means of the *delta password* between three types of memories.

The aforementioned results of both experiments demonstrate that the delta frequency is a common component for the electrical

formation of iconic, semantic, and episodic memories. This indicates a facilitating mechanism which differentiates these types of memory states. In addition, this leads to the expression of hypermemory.

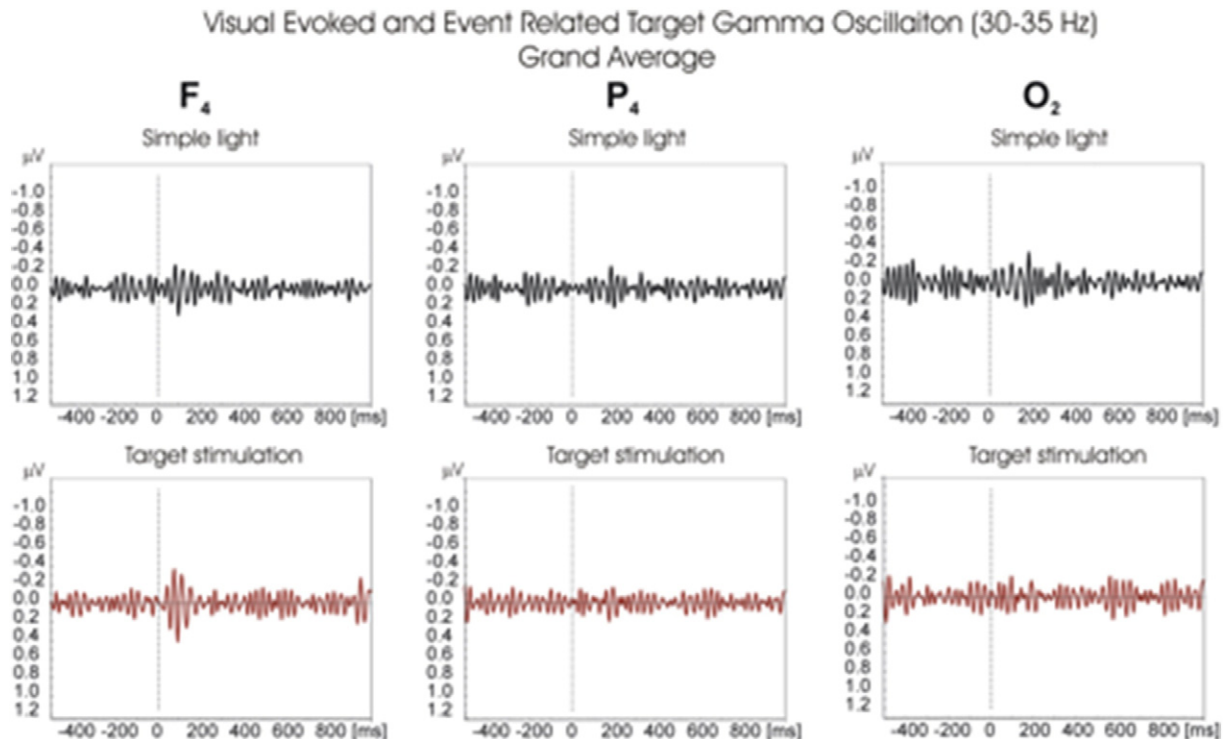


Fig. 10. Grand average of filtered (30–35 Hz) gamma oscillatory responses of 13 subjects for F₄, P₄ and O₂ electrode upon application of target (red line) and simple light (black line) stimulation.

4.7.4. Working memory in the gamma-frequency window

We now provide another type of example showing that both iconic and working memories have a type of reverberation mechanism in the gamma-frequency window. We will explain the measurements related to gamma responses in the frequency window between 25 and 48 Hz. We will also compare the responses of healthy subjects with simple light and the target responses in three distinct frequency windows. This strategy has been explained and justified in a recent study by Başar et al. (in press).

Gamma responses in three different frequency windows are illustrated in Figs. 9, 10, and 11. It is clear from Fig. 9 that simple light and the cognitive target stimulation evoke 25–30 Hz oscillatory responses in the first 100 ms in the frontal cortex. The cognitive responses are less distinct in the parietal and occipital locations. However, late responses (~400 ms) are more marked. Fig. 11 shows simple light evoking oscillatory responses in the frontal and occipital areas in the first 200 ms. The frontal gamma responses are again ample in the first 100 ms after stimulation in the occipital location. The frequency response is at approximately 600 ms in the frequency range of 40–48 Hz. We do not see such dominant responses in the first 100 ms upon target and light stimulation. Most of the larger oscillatory responses occur later, and begin and reach maximum at approximately 200 and 600 ms, respectively.

The description of oscillatory responses leads to the following important conclusions:

1. In the gamma-frequency window, pure sensory and pure cognitive oscillatory responses that occur in different time intervals following the stimulations are superimposed. The existence of several responses during this timescale is most likely due to recurrent reverberatory excitations in the sensory-cognitive networks of the brain.
2. Further, all the structures respond with the gamma frequency band, regardless of any difference in the quality of the impulse signal. Sensory and cognitive orders elicit responses in 25–30, 30–35, and 40–48 Hz frequency windows. In this way, mutual excitations and

reverberations between brain structures are possible (Fig. 12). Other important points to consider are the concept of passwords and general transfer functions.

In memory components in the presentation of oscillatory response in different types of memories, two important explanations are yet missing. We did not analyze the parallel processes related to attention in detail, and did not describe the space–time syncytium in this study. Furthermore, we did not yet encompass measurement in the whole cortex.

4.8. Passwords and general transfer functions in the connective brain networks

A global flowchart of neural structures is presented in Fig. 12. This neural flowchart illustrates the four major pathways by which sensory and cognitive processes take place in the brain. Sensory inputs (semantic, auditory, and visual) can reach the primary sensory cortices over the thalamus almost directly. Other secondary pathways convey sensory information over the mesencephalic reticular formation to further sensory association areas or to polymodal associated modules. Another neural information flow is conveyed from the mesencephalic reticular formation to the limbic system, frontal lobes, and parietal lobes. A more detailed description of this flowchart is presented by Başar (2011) and Başar and Düzgün (in this volume-b). In such a circuit, recurrent excitations between different structures and several reverberations are expected. Finally, the signal transmission may reach such statistical and complex signal processes that the final routes of signal flow cannot be properly tracked (Fessard, 1961).

In conclusion, it is appropriate to state that proper signal transmission can take place only if such a network exists with pass letters and passwords that, in turn, would create most of the general transfer in the brain. It is likely that without the existence of such common principles, most of the brain functions and memory processes would not be achieved.

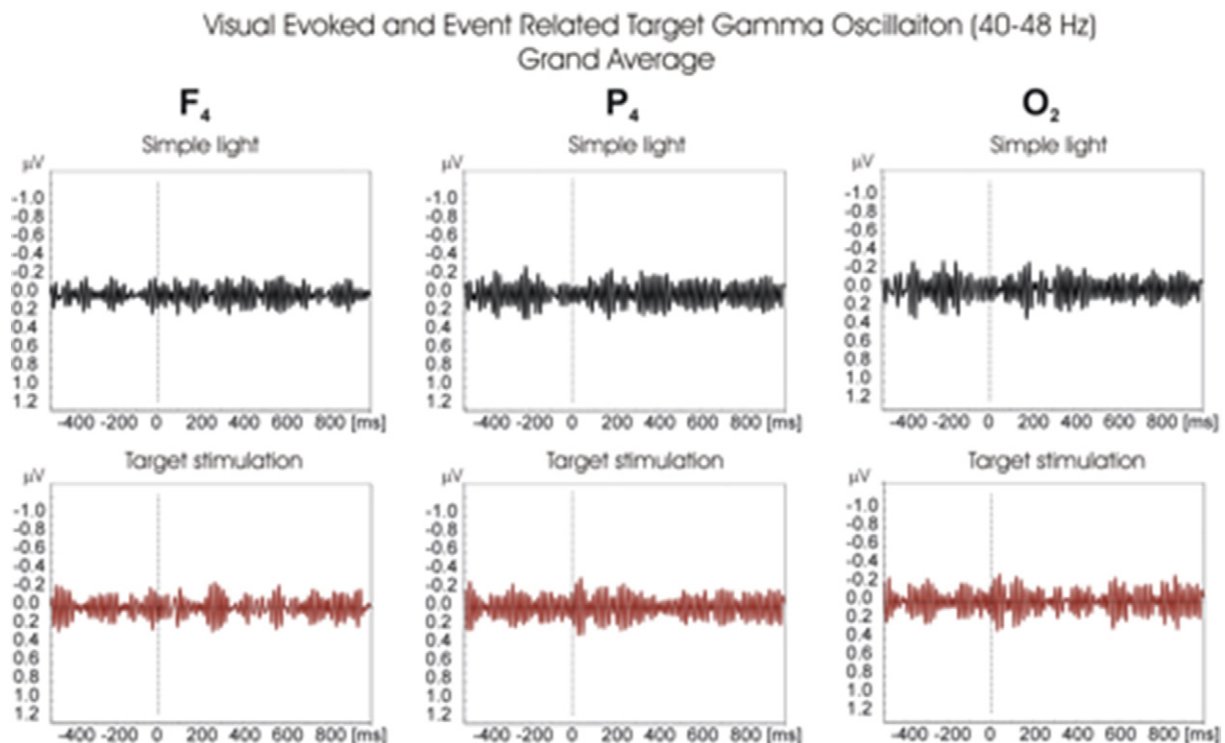


Fig. 11. Grand average of filtered (40–48 Hz) gamma oscillatory responses of 13 subjects for F₄, P₄ and O₂ electrode upon application of target (red line) and simple light (black line) stimulation.

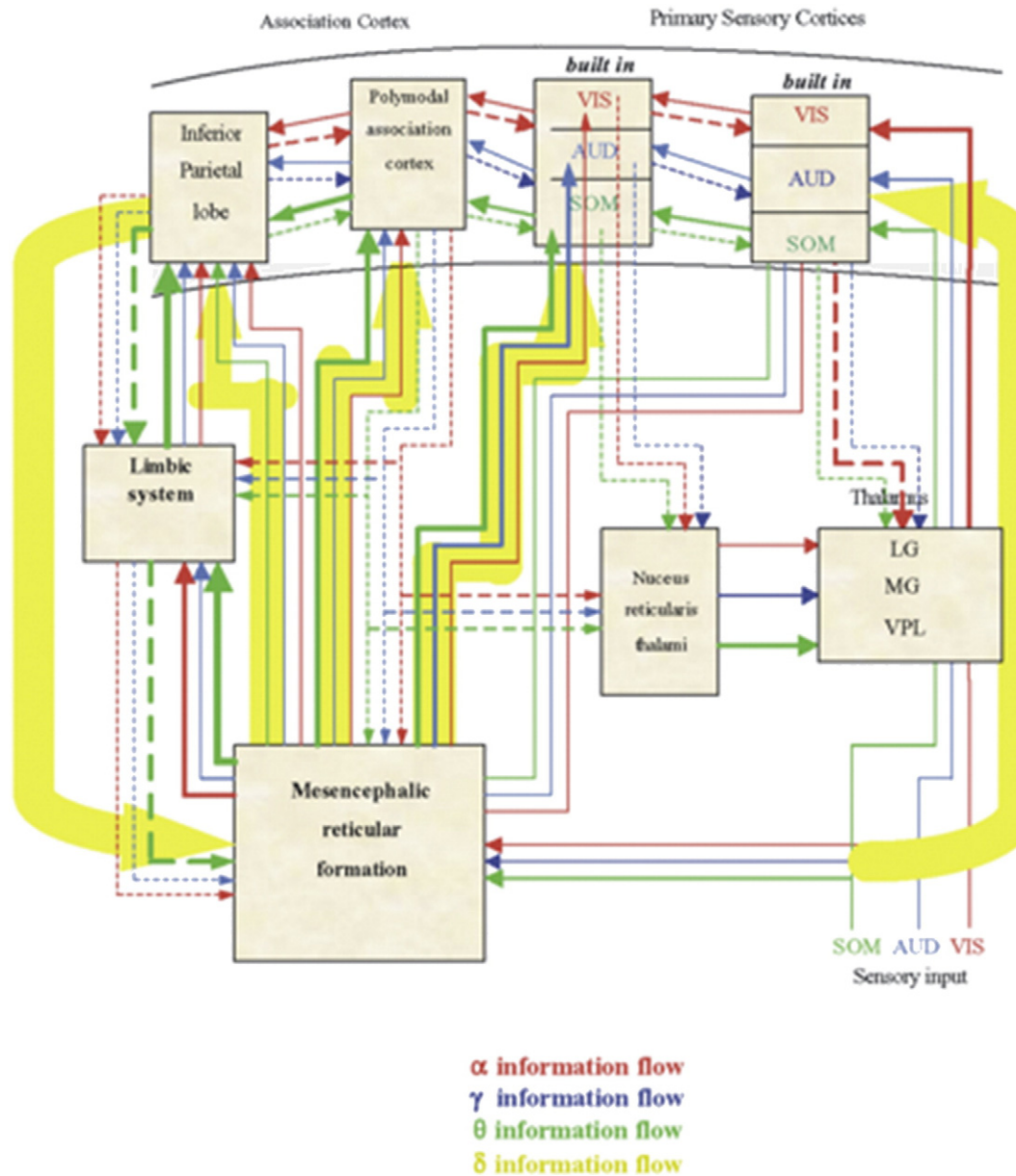


Fig. 12. A preliminary hypothetical scheme to describe the complex matching, and flow of oscillation-coded information. Alpha-code (red), theta-code (green) and gamma-code (blue). Thick line is theta (green) and very thick lines delta (yellow) representing information processing have been added in order to show the dominance of theta and delta resonance.

4.9. The continuum in the timespace

The majority of the sensory and cognitive gamma-frequency responses occur over a very short time period. Most of the responses occur within a 500-ms window, whereas few responses occur at a later time point (~800 ms). Accordingly, all memory-related responses take place almost immediately. Different types of memories, including phyletic memory, working memory, episodic memory, semantic memory, and emotional memory, occur in parallel in fractions of a second. We can combine all types of memory events in less than a second, without longer waiting periods.

4.9.1. Interim summary: hypermemory

We define the ensemble of all memory states as a “hypermemory,” which is a continuum in the timespace of a fraction of a second. The timespace is short and can be measured with physical clocks. However, the timespace can be very long when we compare all of the events

occurring in different memory states (e.g., during flying back in time, the episodic memory often covers several years).

5. Memory and intuition in a continuum of time and space

5.1. What is the intuitive mind?

Intuition is the process or the ability of knowing immediately, directly, and holistically without rational processes and without being aware of “how we know?” It has also been defined as the processing channel through which we access realms of verity and knowledge.

Intuition allows us to perceive particular relationships between representations, thereby limiting empirical knowledge to the sensible realm.

It is imperative to add that emotions, being often products of earlier experiences, influence intuitive behavior and/or our creativity. Accordingly, in cases of crucial decision-making processes, our perceptions and cognitive processes are often governed jointly by intuitive and

emotional processes. According to Fuster (2003), “memory can enter consciousness in a multitude of forms and states.” By definition, the recall of any memory is conscious. Imagining is also conscious as it consists essentially of the conscious retrieval of long-term memories and establishes cognitive networks (cognits), which are assembled and reconfigured in different ways. “Creative intelligence is the ability to invent goals, projects, and plans, or, as Fuster (2003) says, to invent the future and/or to discover not yet realized possibilities in the past.”

Currently, electrical changes in the brain's frontal and occipital lobes upon presentation of known episodes and emotional events have been measured (Güntekin and Başar, 2007, 2014). As a result, we can predict that, in the future, more refined measurements may open the way to the analysis of creative periods. At least, one may be able to detect differences between event-related oscillations in the brains of creative artists or scientists. In this study, we note that there is an evident interplay between oscillations and neurotransmitters.

Further, we point out the special emphasis of Nancy Andreasen, who studies the creativity of neuropsychiatric patients. The results and interpretation of the refined analysis of brain oscillations in this special issue may open the way for studying the changes in the “creative mind” with cognitive impairment and/or with changes in brain–body–mind integration. In addition, because there are changes in the neurotransmitter system in patients with schizophrenia, Alzheimer's disease, and bipolar

disorder, these particular types of measurements (of episodic memory/ and emotional memory) may lead to profound approaches for the understanding of creativity.

How do we travel to the past in the process of episodic memory? The answer to this question, as well as an explanation of the zipping of time during our dreams is indicated in the schematic explanation of duration (Fig. 13).

5.2. A new interpretation of intuition and duration in relation to creative processes

We take the discussion a step further in this subsection: intuitive processes in our brains require immediate access to past memories, that is, episodic and semantic memories. Further, the intuitive human brain must be able to transform events in the “episodic and semantic memory” to a type of intermediary virtual memory, which extends past events to some future projections. This may be explained with the following simple example by Başar (2011, p. 398): “We can recall the figure of our partner, and can imagine her/him wearing new clothes, which we have seen immediately beforehand in a department store. According to Bergson, this is pure imagination. Although this is a very simple example, it is suitable to explain the core of the creative memory or the necessary way of thinking. In reality, this process might require several hours.

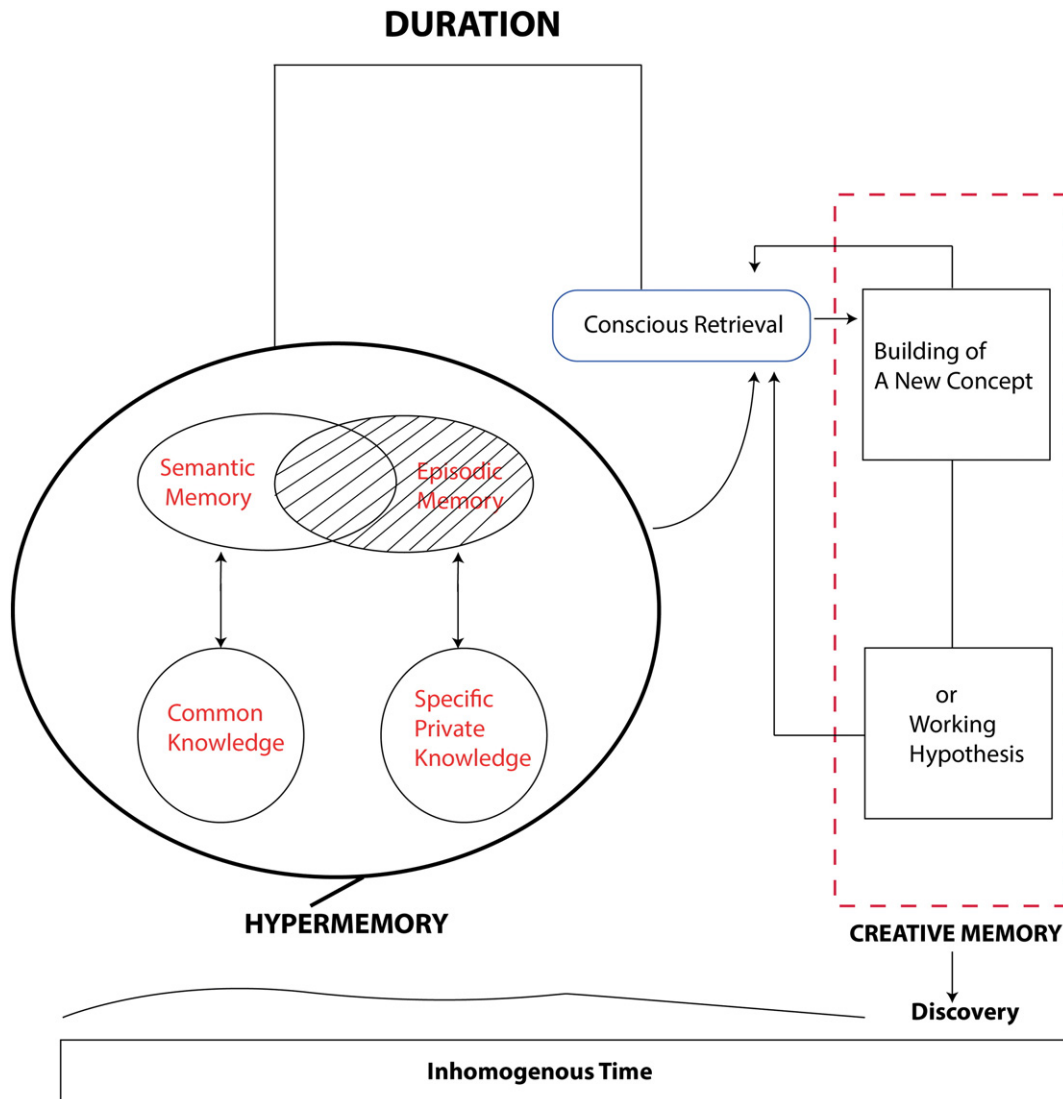


Fig. 13. A schematically explanation of links between episodic memory, creative memory by means of “duration”, for more detailed information see text.

However, this type of creative synthesis can be performed in a fraction of a second in our creative memory.” According to this explanation, this is how duration is defined in the process of discoveries in the creative mind (Fig. 13).

A more complicated or difficult example would be the application of a mathematical equation to an observed phenomenon. A mathematician can foresee the results in a very short time, which is not measurable with external clocks (Penrose, 1989). Henri Poincaré proposed a mathematical solution (which he intuitively felt to be correct) to a difficult mechanical problem that was later solved with a number of mathematical steps that took a much longer time (and was measurable with external clocks). Such an intuitive process can be dynamic or nonlinear dynamic. It may be nonlinear dynamic as the time axis is inhomogeneous, or possibly even a nebulous time axis (Başar, 2011).

In addition, memory is highly important during the duration and occurrence of intuition. Without memory, it is impossible for the past memory to evolve into creativity (Fig. 13). According to the above reasoning, memory, duration, and intuition are inseparable. This is similar to the space–time–matter continuum in physics. Our creative brain, or thinking brain, moves in a universe that consists of real life and virtual life memories, which were created upon the existence of memory.

This is manifested during dreams. The time in dreams may virtually encompass years, hours, or minutes, whereas the real time span may be only a few minutes (Fig. 13). Is the ability of our brains to be aware of very long processes over short physical time periods (that can be measured by clocks) part of creative thinking? Do creative thinking and dreaming require similar inhomogeneous time? Is the “zipping of time” during creative evolution the basic property of the brain, or must we understand the metaphysics of the brain? The elapsed time during creative processes and dreams may extend to years. In addition, we ask, is this time evolution a macro process of time expansion in Einsteinian trips to the Galaxy?

5.3. What is timespace of intuition? Can this be measured or tentatively defined?

In this subsection, we will pose a new question. “In which timespace do intuitive tasks take place?” From several publications, we have gathered information that new ideas are mostly caused by very short thinking processes. An important example is the discovery of Poincaré, related to the solution of some mathematical series. He discovered the solution within a few seconds, as he was entering a bus during travel to another city (Penrose, 1989). This is further illustrated when we compare Figs. 13 and 5.

Studies using intracranial recordings from the rat brain (Miller, 1991) and human brain (Dastjerdi et al., 2011) indicate that corticocortical interplay occurs following activation of sensory and hippocampal-cortical networks. From rat intracranial recordings, Miller (1991) calculated a hippocampal-cortical loop time in the range of 120–200 ms post-stimulation. In human intracranial recordings, upon a cognitive task, Dastjerdi et al. (2011) demonstrated the occurrence of a cortical activation in the lateral parietal cortex after approximately 300 ms. Therefore, it is reasonable to assume that the corticocortical interplay begins at approximately 300 ms post-stimulation, taking these findings of intracranial recording into consideration.

During this duration, the hypermemory is consciously retrieved, and is composed of phyletic, semantic, and episodic memories. In the previous section, we estimated the time of occurrence of the hypermemory, which usually takes place in a fraction of a second. Accordingly, it is possible that the duration will be similar to the occurrence time of the hypermemory. Once the retrieval of consciousness occurs, the subject is able to create a new working hypothesis and theories, or perform discoveries.

Although the last explanation is tentative, it can provide a starting point for which to study creativity from the viewpoint of episodic and semantic memories. It can be hypothesized that subjects having less-

powerful past memories would also have difficulty to develop a new creative memory.

6. Conclusion

1. This study began by describing the neuron doctrine of Ramon Cajal, who described the brain as an organ built of neural networks and individual and autonomic firing neurons. According to Cajal’s “neuron doctrine,” the brain is not a functional syncytium similar to the heart. Further, the functional model of Brodmann is based on the “neuron doctrine,” and does not describe brain function by considering the connectivity between various brain structures. In order to describe brain functions more clearly, the CLAIR model was developed. This model argues that brain function can be described only by the connected activity of neural oscillations in the whole brain.
2. The CLAIR model leads to the following question: Is memory activation acting in parallel with the working syncytium, which evolved during the performance of functions? Accordingly, hypermemory should embrace all different types of memories in a parallel and superimposed way. In other words, the hypermemory is not made by different compartments, but has overlapping transitions, and one can quickly transition from one state of memory to another. In order to illustrate this, we surveyed the occurrence of sensory memory, semantic memory, episodic memory, and emotional memory in Section 2. We found that the time required for responding to and/or processing reverberating memory states was 0.5–1 s. Therefore, it is possible that a memory continuum embraces all memory states immediately.

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