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Chapter 5

**ATTENTIONAL STATE:
FROM AUTOMATIC DETECTION TO WILLFUL FOCUSED
CONCENTRATION**

Andrew A. Fingelkurts and Alexander A. Fingelkurts

BM-Science - Brain and Mind Technologies Research Centre,

P.O. Box 77, FI-02601, Espoo, Finland

andrew.fingelkurts@bm-science.com

www.bm-science.com/team/fingelkurts.html

Tel: +358 9 5414506, Fax: +358 9 5414507

ABSTRACT

Despite the fact that attention is a core property of all perceptual and cognitive operations, our understanding of its neurophysiological mechanisms is far from complete. There are many theoretical models that try to fill this gap in knowledge, though practically all of them concentrate only on either involuntary (bottom-up) or voluntarily (top-down) aspect of attention. At the same time, both aspects of attention are rather integrated in the living brain. In this chapter we attempt to conceptualise both aspects of attentional state within the theory of Operational Architectonics of brain and mind functioning, which provides a plausible theoretical basis for neurophysiological understanding of how attention is brought to existence in the living brain.

*“Everyone knows what attention is. It is the taking possession by the mind,
in clear and vivid form, of one out of what seem
several simultaneously possible objects
or trains of thought”*
(James, 1890/1981, pp. 403-404).

1. INTRODUCTION

It is trivial knowledge that when any human (and animals included) goes about its daily routine, he/she is constantly faced with a continuous stream of complex multimodal sensory stimuli, as well as with many possible responses to them (Seeley et al., 2007; Wu, 2011; Macaluso and Doricchi, 2013). The brain (human or animal) somehow manages this onrush of extremely diverse environmental stimuli in a flexible and rapid manner by selectively channeling them into specific spatial-temporal patterns (so-called category attractors; Tsuda, 2001; Kozma and Freeman, 2001; Perlovsky and Kozma, 2007; Chialvo, 2010) and links them to related behaviors (Schöner and Kelso, 1988; Noack, 2006; Kelso, 2012; Yufik, 2013). Environmental scene or event segmentation (structuring) is believed to be critically important during such channeling for the efficient distribution of cognitive resources and optimized organization (in space and time) of key features of perceived objects in memory (Zacks, 2010; Watzl, 2011; Marchetti, 2012). This process is intuitively understood and usually termed as ‘*attention*’ (James, 1890/1981).

Attentional process selects, modulates and sustains focus on information that is most relevant for performing a cognitive task or drive behavior at each given moment (Rabinovich et al., 2013). *Involuntary* or bottom-up attention (sometimes also called ‘external attention’ or ‘stimulus-driven attention’) refers to the selection and modulation of sensory information, e.g., extracting features from input stimuli and selecting locations in space, instants in time, or modality-specific inputs (Prinzmetal et al., 2009). *Voluntary* or top-down attention (sometimes termed as ‘internal attention’ or ‘goal-directed attention’) refers to the selection, modulation and maintenance of internally generated information (e.g., task rules, responses, long-term memory, or working memory), and in such a way it selects information for perceptual enhancement that is important to immediate task goals (Prinzmetal et al., 2005).

One of the problems in understanding and modeling attention is how both bottom-up and top-down aspects of it are combined in brain function. Usually researchers stress either bottom-up strategies like in the ‘saliency based approach’ (Koch and Ullman, 1985; Niebur and Koch, 1998; Itti and Koch, 2000) or top-down strategies such as the Corchs and Deco approach, for example (2001). We argue that such one-sided approaches are simplistic and do not adequate to a real situation in the brain, where both processes are intimately integrated and even interrelated within the same functional architecture.

In this chapter we shall analyze attention from the perspective of Operational Architectonics (OA) theory of brain and mind functioning (Fingelkurts and Fingelkurts, 2001, 2008; Fingelkurts et al., 2010, 2013). In short, OA theory is centered on the notion of “operation”. The notion of operation plays a central role in bridging the gap between brain and mind¹: it is precisely by means of this notion that it is possible to identify

¹ Humans’ struggle to understand the mind (consciousness) and its relationship to a matter (brain) – currently called brain-mind problem – stretches back to ancient times. For example, Pythagoras had the notion that “the brain served as the organ of the mind and the temple of the soul” (Hansotia, 2003). Plato argued that the soul is temporarily united with the body and would only be separated at death (Silverman, 2012). Aristotle saw the relation between soul and body as the soul is a property exhibited by the body and when the body perishes, so does the soul (Shields, 2011). Descartes believed that mind exerts control over the brain and that it is distinct from the brain (Lokhorst, 2013). This relation gets known as ‘Cartesian dualism’. Currently, this brain-mind debate is known as the “hard problem” – the problem of understanding how the brain (or, more generally, physical matter) could produce any subjective,

what at the same time belongs to the mental level and to the neurophysiological level of brain activity organization, and acts as a mediator between the two (Fingelkurts and Fingelkurts, 2001, 2008). Indeed, both, the material neurophysiological organization that characterizes the brain and the informational order that characterizes the mind necessarily involve such events as operations at their cores (Benedetti et al., 2010). Operation is broadly defined as the process or state of being in effect and it has a beginning and an end (Collins Essential English Dictionary, 2006). It should be stressed that this is so regardless of whether this process is conceptual / mathematical / phenomenal or physical / biological / physiological. In fact, everything which can be represented by a process is an operation. Understanding of the operation as a *process* and considering its *combinatorial nature*, seems especially well suited for describing and studying the mechanisms of how information about the objective physical entities of the external world can be integrated, and how unified/coherent mental objects, thoughts or decisions can be presented in the internal subjective domain by means of entities of distributed neuronal brain assemblies (Fingelkurts et al., 2010, 2013). In line with this conceptualization, simple cognitive operations that present some partial aspect of the whole object/scene/concept are presented in the brain by local 3D-fields produced by discrete and transient neuronal assemblies. More complex operations that constitute the whole object or scene are brought into existence by joint (synchronized) simple operations in the form of coupled 3D-fields – so called operational modules (OMs) of varied complexity. Further synchronization of several OMs (complex field spatial-temporal patterns) forms even more coarse scales of the nested functional hierarchy² (Feinberg, 2000) capable of cognitively and/or mentally (subjectively) presenting very complex sensual inputs as coherent perceptions of the world, and create internal complex images and conscious decisions (Fingelkurts et al., 2010, 2013). The recombination of neuronal assemblies and their operational modules in new configurations makes it possible to present a practically infinite number of different qualities, patterns, objects, scenes, concepts and decisions.

In the following sections we will discuss the place of attention in this architecture and analyze mechanisms that serve as the realization base of attention as a psychophysiological phenomenon.

2. INVOLUNTARY (BOTTOM-UP) ATTENTION

At the bottom of brain operational architectonics there is a high multiplicity of local extracellular fields that are best captured by the electroencephalogram (EEG) measurement (Nunez, 2000; Freeman, 2007). Local EEG waves recorded from the scalp are the result of self-organized integrated excitatory and inhibitory post-synaptic potentials of neuronal membranes in the neuronal mass under the recording electrodes. Since they reflect extracellular currents caused by synchronized neural activity within the local brain volume (John, 2002; Nunez, 2000; Nunez and Srinivasan, 2006; Freeman, 2007), they are expressed within local EEG signals in the form of quasi-stationary segments, each representing an envelope of amplitude modulation (so-called a ‘common mode’/‘wave packet’ (Freeman and Vitiello, 2006) or a ‘standing wave’ (Nunez and Srinivasan, 2006) in the neuronal mass. The more neurons transiently synchronize their post-synaptic potentials the higher the amplitude of a common local 3D-field, which is an indication of the collective behavior (neuronal assembly formation) at an emergent mesoscopic scale (Freeman, 1975; Nunez, 2000; Buzsaki, 2004, 2006). Such a property of neurons relies on their capability to select appropriate information

phenomenal experiences at all (Chalmers, 1995). To make progress in solving this hard problem, the neural counterparts directly constituting phenomenal consciousness must be localized and identified (Fingelkurts et al., 2013).

² In a nested hierarchy, all the elements comprising the lower levels of the hierarchy are physically combined or nested within higher levels to create increasingly complex wholes (Feinberg, 2000).

from incoming input depending on the context set by their own history and the activity of other neurons (Nasuto et al., 1999).

Because the transient neuronal assembly is formed to perform a particular operation/function of certain duration, this period (reflected in the EEG as a stabilized segment of quasi-stationary activity; Fingelkurts and Fingelkurts, 2001, 2006) corresponds to the functional duration of operation produced by the given assembly. It has been proposed that quasi-stationary EEG segments (within which the local 3D-fields generated by transient functional neuronal assemblies are expressed) are equivalent to simple mental operations (phenomenal qualities, primary cognitive operations and emotions) (Fingelkurts and Fingelkurts, 2001; Fingelkurts et al., 2009, 2010, 2013). Indeed, it has been shown experimentally that EEG segments are reliably and consistently correlated with changes in the phenomenal (subjective) content during both spontaneous (stimulus independent) and induced (stimulus dependent) experimental conditions (Fingelkurts and Fingelkurts, 1995; Kaplan and Borisov, 2003; Verevkin et al., 2007; Putilov et al., 2007; for a review see Fingelkurts and Fingelkurts, 2010). Moreover, it has been documented that different neuronal assemblies' local 3D-fields correlate with different simple conscious percepts (Singer, 2001; Freeman, 2007) and that in the absence of cognitive processing these specific transient neuronal assemblies do not appear (Pulvermueller et al., 1994) or are so small and short-lived that they are unable to support self-awareness and consciousness, as is the case for patients who are in a vegetative state (see Fig. 1; Fingelkurts et al., 2012a).

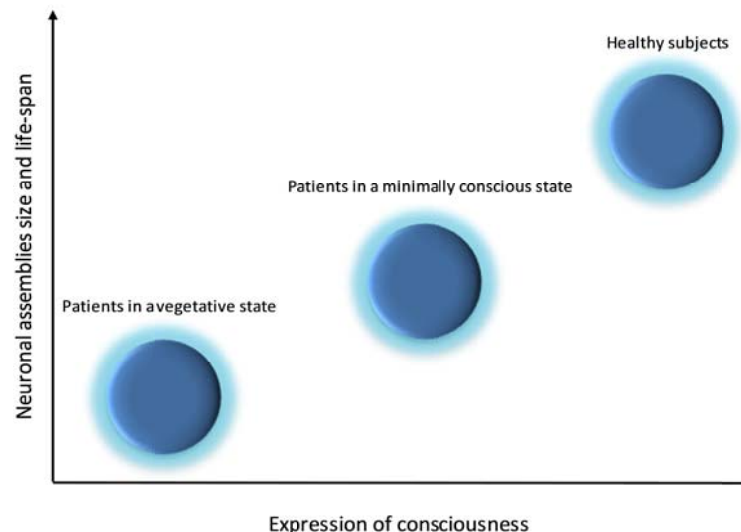


Figure 1. Schematic representation of the expression of consciousness as a function of neuronal assembly size and life-span. The size and life-span of neuronal assemblies are indicated by the Y-axis; the X-axis represents the category of subjects with different expression of consciousness. Notice that vigilance level is comparable (nearly identical) between these three conditions (not shown). The vigilance is defined as a state of arousal or tonic alertness (Head, 1923). This scheme is based on data published in Fingelkurts et al., 2012a.

The quasi-stationary EEG segments within each local EEG signal are 'glued' to one another by means of rapid transitional processes/periods (RTPs). RTPs are observed within a short-time window, when EEG amplitude changes abruptly (Fingelkurts, 1998). Each RTP has a very short duration in comparison to quasi-stationary segments length and can therefore be treated as a point or near-point (Fingelkurts and Fingelkurts, 2001, 2008; Kaplan et al., 2005; Rabinovich et al., 2008). Thus, RTPs (or abrupt jumps in EEG amplitude) are, in fact, the markers of boundaries between concatenated quasi-stationary segments. The transition from one segment to another then reflects the moment of abrupt switching from one neuronal assembly's operation

to another (Fingelkurts and Fingelkurts, 2008). As we have suggested elsewhere (Fingelkurts et al., 2013), in physics terms, one could interpret such a transition as the offloading of entropy (Bak, 1996; Jensen, 1998; Annala, 2010) and resetting of the system (neuronal assembly) memory (Allegrini et al., 2009, 2010; Paradisi et al., 2012). Neurophysiologically, RTP represents a loss of constraints among neurons constituting one neuronal assembly, followed by a rapid arrival of them at a new configuration, leading the new neuronal assembly to exhibit a different (new) structure to self-present a new simple operation (Fingelkurts et al., 2013). Cognitively, RTP could be interpreted as the *breakpoints of involuntary (bottom-up) attention* leading to an attentional disengagement, shift, and allocation to a new operation. In this sense it could be interpreted as a self-organized (Rabinovich et al., 2013) innate attentional mechanism (Mandler, 2010) that is ‘used’ by the brain to place self-presented entities of available information in relation to one another (Marchetti, 2012; Duncan, 2013). Indeed, most RTPs are seen, for example, at the boundary between perceived events, for example at the transition between one movement and the next in a visual scene or auditory stimuli (Fingelkurts, 1998; Fingelkurts et al., 2003; Kaplan and Borisov, 2003) or associated with the major change of cognitive context required in task switching (Fig. 2; for an overview, see Fingelkurts and Fingelkurts, 2013).

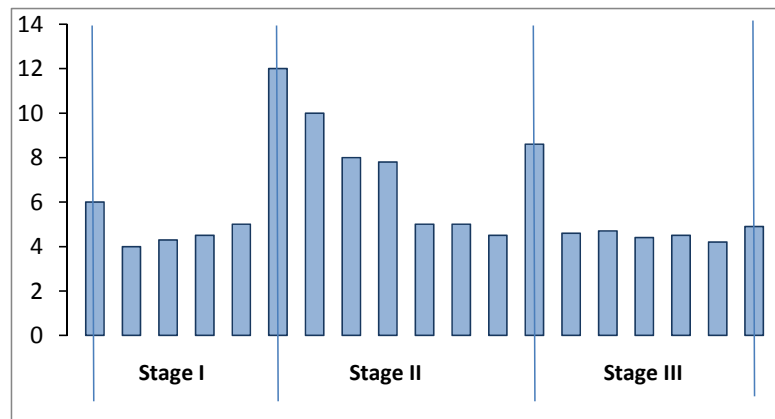


Figure 2. Dynamics of RTPs as a function of cognitive task switching. The Y-axis represents the number of RTPs in % from the total number of observations in all trials. The X-axis marks the three stages of cognitive task: Stage I – anticipation of the visual image, Stage II – presentation of the image and its memorization, Stage III – retention of the image in the mind without external presentation. RTP – rapid transitional process. The figure is adopted from Fingelkurts, 1998.

Using the conceptualization presented above we can give a more detailed description of how involuntary (or bottom-up) attention arises from self-organized behavior of neuronal assemblies. When a particular sensory stimulus appears, neurons that are sensitive to that stimulus (either due to phylogenetic or ontogenetic constrains) get self-activated and start to act synchronously (indicating emergence of a transient functional neuronal assembly), collectively forming a local common 3D-field that cognitively self-presents the perceived stimulus. This process constitutes the automatic attention and it can be experimentally assessed in the orientation reaction³ (Sokolov, 1963; Luria, 1973). The shifts between stimuli are reflected in a frame-like dynamics of the correspondent local 3D-field, where the RTPs between the frames indicate the breakpoints of automatic (bottom-up) attention. In humans such frame-like sequences (or microstates)

³ The orienting reaction or response is an involuntary shift of attention that appears to be a fundamental biological mechanism for survival. It is a rapid response to a new, unexpected, or unpredictable stimulus, which essentially functions as a ‘what-is-it’ detector (Friedman et al., 2001).

represent the basic building blocks of mentation, i.e. the basic elements of conscious thinking and imagination (Lehmann et al., 1998; Benedetti et al., 2010; Fingelkurts et al., 2012b).

Neurons within the neuronal assembly that receive a transitory suprathreshold stimulus will continue to fire for some period of time if they are properly biased (or preferentially primed) by another source of subthreshold excitatory input, – either through *arousal* (mesencephalic reticular formation and thalamus; Kinomura et al., 1996; Steriade, 1997; Kang et al., 2005; Sarter et al., 2006), or *affective reinforcement* (limbic system; Pribram and McGuinness, 1975; Damasio, 1994). It has been shown experimentally that the thalamic intralaminar nuclei and the mesencephalic reticular formation, together with their connections to the thalamic reticular nucleus, play a key role in linking arousal states to the control of moment-to-moment attentional gating (Llinas et al., 2002; Minamimoto and Kimura, 2002; Wyder et al., 2004). We argue that these brain structures (responsible for the arousal states) determine the duration of simple operations that could be executed by local transient neuronal assemblies in the cortex and thus affect the sequences of event or scene segmentation. If such durations get extremely short (leading to inattention, hyperactivity, and impulsivity) (Ivanov et al., 2010; López Hill and Scorza, 2012) or, on the contrary, very long (as during so-called ‘absorption’ or ‘attentional inertia’ – a state of attention, fully engaging one’s representational resources, which results in imperviousness to distracting events; Tellegen and Atkinson, 1974; Anderson and Lorch, 1983), one may imagine that the proper dynamics of automatic attention could not be supported and both scenarios will lead to a malfunctioning and maladaptive behavior.

As an illustration of the affective reinforcement, we bring an example from Noack (2012, p. 1058): “if an animal is hungry, its salience network sends signals to the neocortex that serve to trigger wave packets and category attractors there related to food items. If the animal is in estrus, the salience network sends signals that serve to trigger wave packets related to conspecifics, and so on. In the former example, it can be said that the animal manifests a hunger attractor landscape. In the latter example, the animal manifests a copulation attractor landscape. Thus, an animal manifesting a hunger attractor landscape will ordinarily find itself interacting with food items, such as bananas, since that interaction is facilitated and, therefore, reinforced [...]. Similarly, an animal not manifesting a hunger-related attractor landscape may find itself largely ignoring food items since their representation [...] is not reinforced. To put it simply, the current, cortical attractor landscape an animal manifests at any given moment reflects the current needs, drives, and motivation of the animal as governed by the current state of its salience network.”

Here we come closely to the next level of brain operational architectonics, where the voluntary or top-down attention emerges. This type of attention will be looked at in the next section.

3. VOLUNTARY (TOP-DOWN) ATTENTION

At the macro-level of brain operational architectonics, the electromagnetic brain field is dominated by self-organized and transitory spatio-temporal patterns (operational modules) formed by synchronized local 3D-fields that are generated by spatially dispersed local neuronal assemblies (Fingelkurts and Fingelkurts, 2001, 2013; Fingelkurts et al., 2010). As it has been mentioned in the Introduction section, individually, each neuronal assembly presents only a partial aspect of the whole object/scene/thought/concept, while the wholeness of ‘perceived’ or ‘imagined’ is brought into existence by joint (synchronized) operations of many functional and transient neuronal assemblies in the brain (for a thorough discussion, see Bressler and McIntosh, 2007; Fingelkurts et al., 2009, 2010; Baldauf, 2010). Because the beginning-and-end of discrete operations performed by local neuronal assemblies are marked by sharp changes (RTPs) in local EEG fields, the simultaneous occurrence of these RTPs throughout different local EEG signals within a multichannel

EEG recording could provide evidence of synchronization of neuronal assemblies (located in different brain areas) that participate in the same functional act as a group – operational module (OM), e.g. executing a particular complex operation responsible for a subjective self-presentation of complex objects, scenes, concepts or thoughts (Fingelkurts and Fingelkurts, 2001; Fingelkurts et al., 2009, 2010). Any single OM thus signifies the binding of multiple sensory percepts or motor programs in a context-dependent way as a function of a saliency, priori knowledge and expectancies. It somehow ‘freezes’, and ‘classifies’ the ever changing and multiform stream of our cognition and conscious experiences (Fingelkurts et al., 2010, 2013). Such classification is a signature of a *top-down focused attention* (Rabinovich et al., 2013). Metaphorically speaking, it acts as a mental magnifying lens that keeps our consciousness focused at the attended object or scene and leads to a more veridical perceptual presentation (Prinzmetal et al., 2009).

The main feature of voluntary attention is that we can attract it by will to any perceived or imagined object, scene or thought with respect to the meanings that are stored in our mind. This means that semantic orientation provides individuals with the ability to selectively attend to sensory information as well as ‘higher order information’, such as language, mathematics, and abstract categories (Klimesch, 2012). How is this process guided in the brain operational architecture?

Overwhelming experimental studies provide evidence that voluntary attention involves a particular net of cortical areas (mostly frontal and parietal areas) that together constitute the so-called ‘seat’ of top-down attentional signals (Dehaene et al., 1998; Daffner et al., 2003; Machinskaya, 2003; Posner et al., 2006; Buschman and Miller, 2007; Li et al., 2010; Tsuchiya et al., 2012). We argue that through feedback into thalamic intralaminar nuclei and the mesencephalic reticular formation, as well as limbic system, these top-down attentional signals modify the sequences of RTPs in the dynamics of the activity of local transient neuronal assemblies; and in doing so select a cortical OM that matches the working memory content and is most appropriate for performing a cognitive task or driving a behavior during the present moment. Simultaneously, top-down attentional signals dynamically and transiently block (or inhibit) formation of other OMs that are unrelated to a specific cognitive task or behavior at this present moment (Dodds et al., 2011). From this perspective, using the words of Rabinovich et al. (2013), top-down attention “can be viewed as a higher-order process that emerges from the interactions of complex dynamical modes (structures) that are functionally united by a common cognitive task”. In other words, this fronto-parietal network of brain areas serves as an order parameter⁴ (Noack, 2012).

Our own studies have shown that top-down attentional signals that serve as so-called order parameters are indeed represented by an *unique complex* OM that involves several frontal and parietal *simpler* OMs (Fingelkurts, 1998). This fronto-parietal OM was specifically presided over cortical dynamics each time a subject had to explicitly and voluntarily concentrate his/her attention (Fig. 3 A). At the same time tasks that involved attention only implicitly⁵, but were dominated by the particular cognitive task or visual image, were characterized by multitude of different OMs that were specific to these concrete cognitive tasks or images (Fig. 3 B; Fingelkurts, 1998). These data confirm the governing role of the specific top-down attentional OM in the voluntary shifts of attention.

Importantly, the frontal component within this unique complex OM was always dominant in comparison with other cortical areas that constituted this OM (see thick-lined frontal simple OM in Fig. 3 A). It is well-known that frontal cortical areas represent general polymodal gestalts and mental attributes that many consider to be uniquely human, such as symbolic thought, language, and creativity (Noack, 2012). Since the frontal areas increase in size in the phylogeny (in a primitive prosimian primate the ratio of frontal cortex to total cortex is only 8.5%, in the macaque monkey it is 11.5%, and in the chimpanzee, it rises to 17%)

⁴ In general terms, order parameter means the parameter that determines (or enslaves) the behavior of individual parts of a system at the subordinate level (Haken, 1977, 2004; Freeman and Vitiello, 2009).

⁵ By ‘implicitly’ we mean here that the dominant task, which the subject needs to perform, was not of an attentional kind.

(Changeux, 2004; see also Goldberg, 2001; Fuster, 2002) and reach their maximum in modern humans (the ratio of frontal cortex to total cortex is the largest among the mammals – more than 30%, almost a full third of the total amount of neocortex) (Changeux, 2004), it is of no surprise that humans master voluntary attention as no other animal (including primates) can do. Essentially, humans alone possess the ability to internally direct their attention to combine symbols in an essentially unlimited and temporally extended fashion which can be independent of external training or presence of actual stimuli-objects in the external environment (Yufik, 2002; Noack, 2012). Though some ‘animal-cognition’-oriented researchers have repeatedly tried to demonstrate such internal skill to voluntary attention in non-human mammals (Preuss, 2006), all such attempts have failed to do so (Terrace et al., 1979; Povinelli and Bering, 2002; Rivas, 2005; Preuss, 2006; Gazzaniga, 2008; Penn et al., 2008).

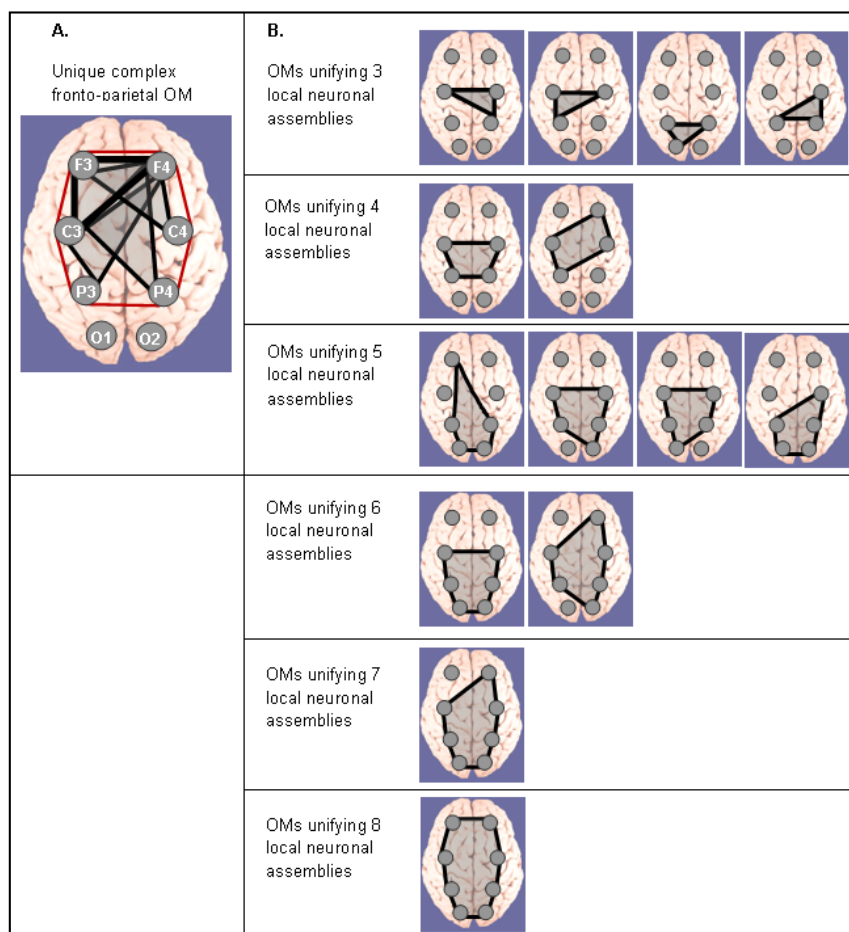


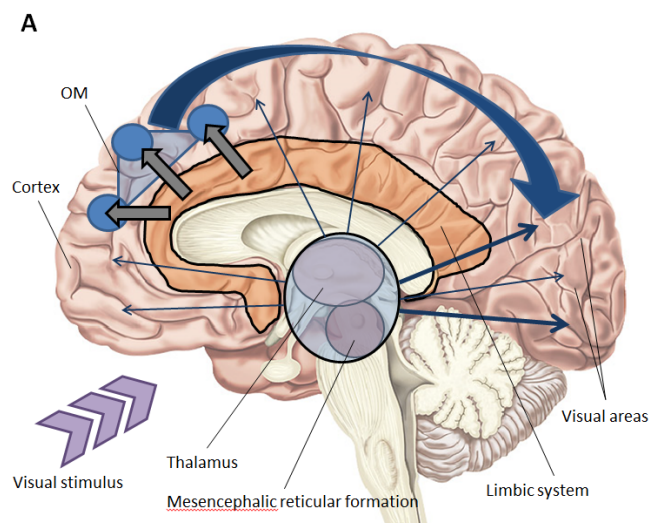
Figure 3. Unique (A) and specific (B) OMs during cognitive tasks (indexed by synchrony of operations executed by different neuronal assemblies). The most frequent/representative OMs, that occurred (i) in the largest number of repetitions (in %) across all trials and (ii) more than in 80% of EEGs, are mapped onto schematic brain maps as connecting lines between the EEG channels involved. Grey shapes are used for easier visual representation and are indicative of simple OMs. Red line marks a complex OM. OM – operational module. The figure is adopted from Fingelkurts, 1998.

4. INTEGRATION OF TWO MODES OF ATTENTION (INVOLUNTARY AND VOLUNTARY)

We start this section with the description of involuntary bottom-up attention processes, since they are biologically successful and continue to be the primary functional mechanism of attention utilized in every mammalian species (including humans) alive today. The self-emergence of bottom-up attention has several stages. In the first stage, a particular simple sensory stimulus automatically triggers the activation of those neurons that are sensitive (due to phylogenetic and ontogenetic predispositions) to that concrete stimulus. At second stage, the collective behavior of these neurons leads to the formation of a transient neuronal assembly emitting the local 3D-field. This 3D-field self-presents sensory information. Which set of neurons will respond at any given temporal moment depends on the arousal and reinforcement brain systems (Borisjuk and Kazanovich, 2004). This bottom-up attention allows selecting locations in space, instants in time, or modality-specific inputs.

Complexity of the stimulus is represented by the coupling of several 3D-fields (responsible for the separate simple features) within the unified operational module (OM) that self-presents an already polymodal gestalt – the meaning and significance of that complex stimulus to that particular organism (Fingelkurts et al., 2010). In other words, within the OM's activity the components of an attentional episode are bound together, constructing the specific conjunction of processing events fulfilling the current behavioral requirements. Thus, the emergence of an OM indicates the appearance of attentional focus (top-down attention), that serves to (i) preferentially prime the neuronal assemblies that are included in the given OM (using the arousal and reinforcement systems of the brain) and (ii) instruct or trigger an associated motor behavior (see large, blue arrow that starts from the frontal lobe and goes to the parietal-occipital ones at the Fig. 4 A,B). This top-down attention allows the selection, modulation, maintenance and order of internally generated information (e.g., task rules, responses, short-term or long-term memories). It is at this stage that animals and humans diverge.

In animals, at this final stage, the overt motor behavior triggered by the OM changes the proximate sensory environment of the animal as well as the activity of reinforcement system in the brain; these changes together present new sensory stimuli to the animal. This new sensory stimulation then starts the next cycle in the loop, and so on (Fig. 4 A). Thus, in animals the bottom-up attention dominates.



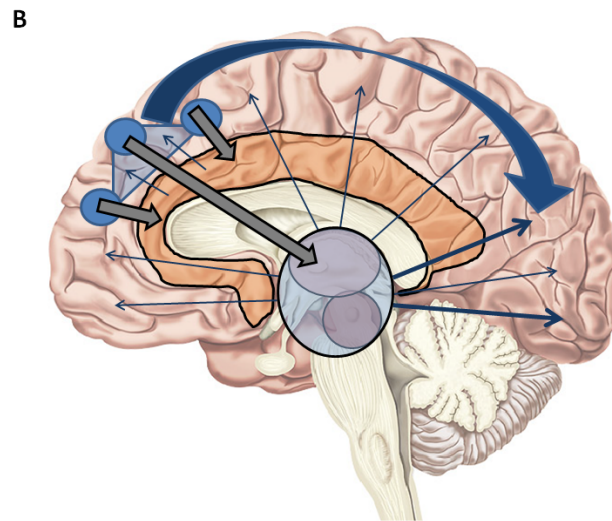


Figure 4. Simplified schematic representation of bottom-up (A) and top-down (B) attention processes in the brain. As an example, processes related to a visual stimulus (or image) are shown. OM – operational module. Arrows indicate activated influences/reinforcement/priming. Different thickness of arrows represents different strength of influences. Large, blue arrow that starts from the frontal lobe and goes to the parietal-occipital ones indicates the appearance of attentional focus, that serves to either instruct or trigger an associated motor behavior or preferentially prime the neuronal assemblies that are included in the given OM (using the arousal and reinforcement systems of the brain). Further explanations are provided in the text.

In humans, due to an anatomical and functional organization of the brain (see the previous section), OMs dominate the neurodynamics of the brain leading to a symbolic thought, language, creativity, self-awareness, and even consciousness (Fingelkurts et al., 2013). This unique property allows the human brain to voluntarily concentrate its attention on specific stimulus or task without the actual presence of stimuli-objects in the external environment in order to manipulate them and also to construct uniquely novel behaviors without external training (Fig. 4 B). Thus, in humans the top-down attention dominates and serves as a *dynamic bridge* between arousal and the content of consciousness. At the same time, some stimuli acquired high importance (intrinsic value) during the course of evolution, so that even in humans, when present, they immediately switch the attentional dominance to an automatic (bottom-up) mechanism that, even when the stimulus event is unrelated to the current goal-directed activity, usually interrupts the current voluntary (top-down) attention (Fig. 4 A). For example, a sudden onset of motion, such as a moving car, turn of the head or hand movement, automatically capture attention of the person in a stimulus-driven manner (Levin and Varakin, 2004; Buschman and Miller, 2010).

5. CONCLUSION

Even though the subject of attention has a long history in the philosophical studies and neurobiological research, it still poses a serious problem when one considers the whole multitude of phenomena associated with it and attempts to understand its neurophysiological mechanisms. In this chapter we tried to conceptualize attention within the theory of Operational Architectonics of brain and mind functioning (Fingelkurts and Fingelkurts, 2001; Fingelkurts et al., 2010, 2013). Our analysis has shown that involuntary

(bottom-up) attention arises as a result of self-organized formation of neuronal assemblies whose operations are divided by rapid transients that signify the breakpoints of attention. The duration of these operations is determined by external stimuli and modulated by arousal as well as affective reinforcement. Voluntary (top-down) attention emerges due to a binding of multiple operations responsible for sensory percepts or motor programs in a context-dependent way as a function of a saliency, priori knowledge and expectancies. During this process, the ever changing and multiform stream of our cognition and conscious experiences is somehow ‘frozen’ and ‘classified’, thus representing focused attention. The skill to voluntarily attract attention to a specific image, object or thought is guided by a specific fronto-parietal operational module that serves as an order parameter and determines which particular operational module of cortical dynamics should be reinforced at any given moment of time in order to present a particular image, object or thought in the focus of attention.

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