Imagination: its definition, purposes and neurobiology

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IMAGINATION: ITS DEFINITION, PURPOSES AND NEUROBIOLOGY

Summary. *Imagination, distinct from imagery, memory, and cognition, is a poorly understood but fascinating cognitive ability of human beings. Herein, imagination is defined as 'the cognitive process which enables the individual to manipulate intrinsically generated phenomenal information in order to create a representation perceived by the mind's senses.' This definition is expanded within the context of the neurobiology of the brain and the possible purposes the imagination fulfills in daily living, human development, and normal behavior. [REV NEUROL 2007; 45: 353-8]*

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'If it was not for imagination, I would have been trapped in a dark and hopeless prison'.
Alejandro del Sol: The tunnel

INTRODUCTION

References to imagination can be found everywhere, in conversations, books, journals, and various media in many, if not all, cultures; yet, despite being such a fundamental component of the human psyche, surprisingly little attention has been devoted to it in the scientific literature. The reason for this omission is unclear, but it may reflect the difficulty in defining imagination as a specific cognitive function, distinct from other aspects of cognition. Herein, we discuss the definition, purposes and neurobiology of imagination, as well as delineate some of the challenges encountered in research on this fascinating topic.

BASIC CONCEPTS

Definition

The Webster dictionary defines imagination as 'the act or power of forming a mental image of something not present to the senses or never before wholly perceived in reality.' This is an incomplete definition. In an attempt to incorporate the neurobiology of imagination, we will define imagination as 'the cognitive process which enables the individual to manipulate intrinsically generated phenomenal information in order to create a representation «perceived» by the «mind's senses».' This definition contains several terms that merit further discussion.

Phenomenal information is that which can be described as having been seen, heard, tasted, smelled, or felt by means of the sensory systems. Intrinsically generated means that the information is generated within the self in the absence of stimuli from the outside environment. This is in sharp contrast to extrinsic information which originates from outside the self and 'enters' the brain through the sensory systems. For example, when I look at an apple the source of the image is located outside of my self. If I close my eyes and 'imagine' the apple, the source of this image is from within myself. Perception refers to the process by which the brain extracts specific phenomenal features of an object and interprets them to arrive to a global representation unique to that particular object.

Somewhat more challenging is to define is the mind's senses. The 'mind's eye' is a frequently utilized (but rarely defined) term in the literature which refers to a cognitive mechanism which 'sees' an object that had been previously visualized but is no longer present in the environment. Since, as we will discuss, imagination incorporates information previously acquired through all of the sensory systems, we prefer the term 'mind's senses' to conceptualize an inner mechanism that not only 'sees' but also 'hears,' 'feels,' 'smells,' and 'tastes' intrinsically generated phenomenal stimuli.

While information about an object acquired through any of the five sensorial modalities can be conceivably imagined, the visual, auditory and tactile modalities appear the most likely source of our imagined representation. The fact that visual information is the most likely to be imagined comes as no great surprise, since we, like other primates are 'visual' animals with over half of the cortex dedicated to the processing of visual information. Although taste and smell appear to be less commonly incorporated in the imagination process, recent studies have explored both olfactory [1,2] and gustatory imagery [3,4]. Although an imagined representation can clearly invoke an emotional response, we would argue that non-phenomenal representation, such as emotional states, could not be imagined independently of the object that generates the emotional response. Thus I cannot imagine 'love' or 'fear' independently of the object which triggers those emotions.

In order to better understand the neurobiology of imagination, we find it useful to divide imagination into a perceptual and motor component. The former refers to the perception of an imagined object (a unicorn, for example), while the second concerns performing an action (leading the unicorn around by means of a leash). As we will discuss in subsequent sections, functional neuroimaging studies indicate that imagined representations have both a 'perceptual' and 'motor' component.

Relationship between imagination and declarative memory

It is important to explore the relationship between declarative memory and imagination. The process of imagination draws from and incorporates data stored in memory; however, imagining differs from remembering in that remembering is (presumably) a relatively faithful recall of an image or event from the

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past. In contrast, through the process of imagination, an individual is able to recruit and combine selective 'portions of data' stored in memory to create new images or events that have not previously been experienced. Therefore the information is not simply contained within memory stores, such as when one imagines an animal or an interaction with an extraterrestrial being. Of course, it could easily be argued by a person familiar with science fiction tales that imagined animals or events have a great deal in common with those in the realm of reality.

A recent study suggests that brain lesions affecting memory may impair the capacity to imagine. Hassabis et al recently explored the relationship between memory and imagination [5]. In their fascinating study, five patients with amnesia secondary to hippocampal damage as well as ten control subjects (matched for age, education and intelligence quotient) were given short verbal cues and then asked to vividly imagine the situation from the cue and describe it in as much detail as possible. Participants were also asked not to recount an actual memory but instead create a new plot. Amnesic patients did much worse than controls in this task The authors concluded that the deficits in the patient group were due to the lack of spatial coherence in imagined experiences. As opposed to controls, the patients' imagined constructions were fragmented and lacking in richness.

Relationship between imagination and working memory

It is clear that imagination requires working memory. Working memory is the ability to hold and manipulate information in the attentional store over short periods of time. In order to manipulate information during the imagination process, information must be kept 'on line,' or within the realm of consciousness. It remains to be studied whether impairment in working memory affects the ability to imagine.

Relationship between imagination and thought

We propose that imagination can be differentiated from thought. Thought is a declarative process, an 'internal dialogue' that mostly, if not exclusively, makes use of language. In contrast, imagination is principally a non-'language-bound' process that utilizes images instead of lexical information. That is, we imagine images, without need for words. It must be stressed that words can be included within the imagined representation.

Relationship between imagination and volition

An important aspect of imagination is that it is to a large degree, but not exclusively, a volitional process. The person wills the occurrence of an imagined representation and wills much of its content. However, experience also teaches us that imagined representations frequently appear without the will of the imaginer. Extreme cases of this phenomenon are represented by pathological states such as traumatic stress disorder [6] and certain forms of compulsive disorders…

POSSIBLE PURPOSES OF IMAGINATION

We propose that imagination serves a number of executive and other non executive functions including roles in cognitive development, skill acquisition and improvement, behavior rehearsal, theory of mind functions, creativity, anxiety reduction, and 'escape' from immediate reality. Each of these are discussed, in turn.

Cognitive development

Imagination may have an important role in cognitive development. This has been stressed by a number of social scientists, most notably in the 20th century work of Piaget. Popular credence leads us to believe that children spend a greater amount of time imagining than do adults, which supports its importance in development. However, we are not aware of studies that have attempted to 'quantify' the amount of time devoted to imagination among age groups.

Skill acquisition and improvement

There is data in the literature indicating that the imagined performance and practice of a specific motor skill can improve the performance of that skill in 'real life'. This has been proposed in athletes [7,8], surgeons [9], and musicians. Some studies, however, have not shown this same beneficial effect of imagery [10]. It is presumed that the improvement in skill performance is secondary to a reorganization of the brain network which is responsible for that particular skill. Thus, it is suggested that imagination can impact brain plasticity, which may attest to the enormous power contained within imagination. Recently, motor imagery training has also been suggested as a possible modality to improve motor recovery after stroke [11], although more work is needed on this topic.

Behavior rehearsal

Behavior rehearsal within the mind's stage is perhaps one of the most important and unique of human qualities. Imagination provides a unique setting for behavioral rehearsal prior to the actual performance of that behavior. It provides a relatively safe environment where behaviors prior to (or instead of) action yield no consequences to the imaginer. Multiple alternative solutions to problems, considering multiple potential outcomes, can be safely tested and practiced on the mind's stage. In this regard, imagination is an important component of the series of cognitive abilities included by the term 'executive functions'.

Anxiety reduction

Imagination provides a stage to safely 'perform' behavior sequences that may aid in ameliorating anxiety. For example, revenge for a wrongdoing is possible and easy within the realm of imagination, with seemingly no untoward consequences. Many psychotherapeutic modalities utilize the process of imagination to treat anxiety, phobias, and other disorders.

Escape from immediate reality and need fulfillment

Through means of imagination a person can transiently depart, at least in the mind, from his or her immediate reality and transport themselves into a more favorable one. Those who are hungry can imagine food, those that are tired can imagine rest, those alone can imagine friends, and those that are bored can imagine excitement. Virtually any need or want can be fulfilled, albeit temporarily, in the realm of imagination.

Creativity

George Bernard Shaw stated**;** 'Imagination is the beginning of creation. You imagine what you desire, you will what you imagine, and at last you create what you will'. While the cognitive processes involved in creativity have not been well elucidated, many creative individuals, such as artists, relate that they imagine a creation prior to committing it to the 'physical' world. And indeed,within the stage of our imagination we are free to create, with fewer boundaries than those present in the 'real world'.

Theory of mind

One of the most fascinating abilities of human beings is to determine how another person will think, feel and behave in a particular situation or circumstance. This magnificent ability to temporarily assume another person's self has been studied under what has become to be known as the theory of mind. When required to determine how a second person will think, feel and behave in a particular situation, the first person develops a 'theory' about the second person mind which will allow them to theorize about and predict the other person's response. In order to do so, the first person must attribute to the second an 'independent mental state,' distinct from their own. The theory of mind is one of the most important and magnificent abilities possessed by human beings, and one of the most important functions for everyday social interactions and function. It is not only important for qualities such as empathy, but also for other less noble traits such as deceit. Thus, a soldier must employ theory of mind functions in predicting how the enemy will respond in a particular battle strategy . We submit that imagination plays a key role in theory of mind functions, since it provides the stage where we can foresee how others feel or how they will behave in a particular situation.

THE NEUROBIOLOGY OF IMAGINATION

In recent years and with increased sophistication in neurophysiological measurement and functional imaging techniques, the neurobiology of various complex cognitive processes has become better understood. Unfortunately, there is little published information on the neurobiology of imagination itself although much more has been written on the related cognitive processes of perception, sensorial imagery and motor imagery. The neurobiology of imagination must therefore be inferred from our increased understanding of these related cognitive processes.

In order to attempt to understand the brain mechanisms for intrinsically generated perception, we must briefly review the neurobiology of both extrinsically generated perception as well as of the brain mechanisms for motor processing. This will allow us to develop a greater understanding about the neurobiology of both the perceptual and motor aspects of imagination.

Perception and motor processing in the brain

Sensory processing in the cerebral cortex involves serial operations within hierarchically organized structures that progress in complexity from primary sensory areas involved in sensation (elementary features of an object) to unimodal areas involved in perception (representation of an object as an unique entity), and then to transmodal areas involved in recognition. These areas project to the prefrontal and premotor areas of the frontal lobes in order to initiate motor behavior as well as paralimbic and limbic areas that are involved emotional processing and memory.

Hierarchical processing encompasses both forward 'bottom-up' and backward 'top-down' connections. 'Bottom-up' connections are involved in propagation of sensory information and backward 'top-down' connections modulate the responses of hierarchically lower sensory levels to the higher processed sensory stimuli.

Ventral and dorsal streams of sensory information processing

The different features of an object are represented in parallel in topographically separated but functionally related areas of the cortex. Visual, auditory, and somatosensory stimuli that reach the corresponding primary and then the unimodal association cortex are further processed in two parallel systems or 'streams' of information processing. A 'ventral' stream primarily involves the temporal lobe and processes information about features of the object required for object recognition ('what' is the object). A 'dorsal stream' involves the parietal lobe and is required for processing of spatial information, such as the location and motion of an object necessary for attention and motor behavior towards it ('where' is the object).

These two streams of information eventually reach the prefrontal cortex which has a primary executive function. It processes information from the dorsal stream to initiate, maintain, and monitor motor behavior via its projections to premotor areas of the frontal lobe. The prefrontal cortex actively interacts with the temporal lobe areas of the ventral stream to focus attention on particular features of the stimulus.

The parallel processing of sensory information has been best characterized in the visual system. The primary visual cortex (Brodmann area 17, V1, or striate cortex) receives inputs from the retina via the lateral geniculate nucleus. The retinal ganglion cells are specialized into subtypes which process form, color, and movement. Each subtype of ganglion cells projects to different portions of the lateral geniculate nucleus which, in turn, conveys information to different layers of the primary visual cortex. Each layer in V1 projects to different neuronal compartments in the unimodal visual association areas of the extrastriate cortex (Brodmann areas 18 and 19) that give rise to ventral and dorsal streams of visual processing. In humans, the ventral visual stream for object recognition involves hierarchically organized areas in the inferior occipitotemporal cortex.

Each object category activates different regions of the inferior temporal cortex. In humans, the fusiform gyrus in the inferior temporo-occipital cortex contains neurons that respond selectively to specific combinations of features is involved in the rapid identification of faces, objects, and words. Functional magnetic resonance imaging (fMRI) studies show that the ventral occipitotemporal cortex, involved in the ventral stream of visual processing, contains category-specific regions that respond preferentially to faces, houses animals, tools or other objects.

Neurons that show specific responses to an object exhibit perceptual constancy; they maintain their response independently of changes in luminescence, color, format, size, and angle of view. Information about different features of an object may be stored in different regions of the cortex, within the same neural systems, that are active during perception. Although areas within the ventral temporal cortex show relative selectivity for faces versus objects, the same neurons can respond to objects of different classes, depending on their visual similarity.

The ability of modality-specific visual information about faces and objects to activate the relevant associations that lead to recognition requires the mediation of the anterior middle temporal and the temporopolar cortices. These cortices are critical for object recognition. This constitutes the basis for semantic memory.

Object recognition is critical for naming, and the emotional reaction one has toward an object. Object recognition depends on connections from the lateral temporal and anterior temporal cortices, particularly in the left hemisphere. Especially instrumental are Wernicke's area (involved in word comprehension), the perirhinal cortex of the medial temporal lobe (involved in object recognition with its connections to the hippocampal formation via the entorhinal cortex), and the amygdala (involved in the emotional reaction towards the object).

The dorsal visual stream involves areas located in the temporoparietal-occipital junction and portions of the supramarginal and angular gyrus that correspond to the middle temporal area and middle superior temporal area (MT/MST) identified in experiments in non-human primates. The dorsal stream eventually reaches the posterior parietal cortex, in particular the intraparietal sulcus, which contains neurons that simultaneously respond to visual and other sensory information. A 'map' of representation of the body and external world is generated and transferred to the premotor cortical areas to initiate specific programs. In this way, a person may direct attention toward an object, reach for it, and then grasp it.

There is a context-dependent modulation of processing of sensory information, so that the brain selects only those inputs that are meaningful for control of action according to goals and motivation. This processing involves mechanisms of selective attention. The prefrontal cortex and the posterior parietal lobe have a major role in selective attention, via feedback projections that introduce a top-down bias on neural processing in sensory areas.

Sensorimotor transformations and motor planning, programming, and execution

The cerebral cortex controls motor behavior through a hierarchy of commands. The highest level is involved in driving and selecting motor plans. Motor programs are a set of commands that precede the beginning of the motor act and are then fed forward to the neurons of the primary motor cortex. Motor plans are generated in the prefrontal cortex (for voluntary initiation of movement according to the subject's motivation and their adequacy to the external contingencies) and in the parietal association cortex (in response to attended stimuli from the external world) and are driven by emotional inputs via the anterior cingulate cortex.

Sensory feedback adjusts the programmed movements by bringing the program commands up to date and correcting errors during motor execution. Learning of movements and programming optimize motor skills and depend on experience. The continued use of the same programs for the performance of the task increases the accuracy of task execution and is required for maintenance of motor skill.

The cortical motor areas include the primary motor cortex (area M1), the dorsal and ventral lateral premotor cortex (PMC) the supplementary motor area (SMA), the pre-supplementary motor (preSMA) area, and the cingulate motor area. The primary motor cortex is critically involved in control of learned, programmed skilled tasks that depend on 'fractionated' hand and finger movements. The lateral PMC receives inputs from functionally siring groups of multisensory neurons of the intraparietal sulcus. Parallel connections between functionally distinct posterior parietal and PMC neurons are critical for sensorimotor transformations required for goal-directed towards an object of the external environment.

The ventral PMC cortex contains neurons that code goal-related acts, such as grasping. Some of these neurons form part of a frontoparietal network refereed to as the 'motor mirror neurons system. The mirror system is includes the ventral PMC, the posterior parietal cortex, and areas and MT/MST in the temporal lobe and is particularly suitable for matching the action that is observed with the action that is executed. Mirror neurons may also be involved in understanding the goal of an action that is observed. Transcranial magnetic stimulation (TMS) studies also indicate that not only the observation of actual motion but also that photographs of implied motion of the hand (for example pincer grips) increases excitability of the cortical motor neurons controlling the hand muscles; this activation is selective for the muscles that would be involved in the execution of the action, being it observed or implied.

The SMA is primarily involved in selection and preparation of movement, generation of motor sequences and bimanual coordination. The pre-SMA has been implicated in learning of sequential movements and in the decision to start a movement according to contingencies or motivation under the influence of inputs from the prefrontal cortex.

Cortical motor areas become activated long before the actual execution of the movement execution. This activity is recorded as different movement-related cortical potentials, which are to assess motor reaction times, preparatory activity preceding self-paced movements, and potentials triggered by a warning stimulus. Motor cortical maps continuously change in a use-dependent manner, in response to injury, motor skill acquisition, and practice. Simple motor tasks activate predominantly the contralateral M1 whereas performance of newly acquired complex tasks also activates the SMA and lateral PMC bilaterally. As the movement is learned and executed more efficiently, there is a progressive decrease in the area of motor cortex activated.

Functional studies on mental imagery

After this brief discussion about extrinsic perception and motor processing, we are ready to return to the topic of the neurobiology of imagination. The first 'problem' in understanding the physiology of imagination is the most obvious; the object of perception in extrinsic perception arises from a clearly identified stimulus which is located outside of the self. There is thereafter a clearly delineated stream of information from the sensory organs to the thalamus, primary, and association sensorial cortex, and from there to other areas as described above. This is not the case in the perception of an imagined object. The perception is itself 'generated' from within the self, devoid of the actual presence of the object. The obvious question that arises is the following; how does the brain generate the 'inner' stimulus perceived by the mind's senses?

This question is far from being satisfactorily answered, but much of the information that sheds some lights on this issue stems from studies involving visual (or other sensorial) imagery. Imagery refers to the creation of a 'mental image or representation' of an object in the absence of the actual object. It is thus an internally generated perception. Because many of these studies rely on the imagery of stimuli that have been previously extrinsically perceived, imagery invokes to a great degree visual memory (since the image is not 'de novo'). Thus, it is not synonymous with imagination, but it provides an approximation that allows us to understand the process of internally generated perceptions.

Human research on sensorial perception and imagery has recently focused on functional imaging and, to a lesser degree, single cell recording in patients who are undergoing neurosurgery

[12]. Other techniques have included the use of transcranial brain imaging and computerized EEG recording. The paradigm frequently utilized in functional imaging studies involves the comparison of brain activation during perceptual versus imagery tasks. Thus, these studies have undertaken a functional 'neuroanatomical approach' to identify three areas related to vision and imagery: i) Those that selectively become active with extrinsic perception; ii) Those that selectively become active with both intrinsic and extrinsic perception; and iii) Those that become uniquely activated with intrinsic perception. In general, these studies show that the regions associated with mental imagery show significant correspondence with those involved in the perception, in the same modality.

Imagery can be divided into two major categories: visual and motor.

Visual imagery

The nature of mental imagery is a source of debate and active research. A major point of controversy is whether there is involvement of primary sensory or motor cortical areas in the corresponding sensory domains during the formation of mental images. For example, some theories pose that mental imagery depends on activity of primary sensory areas involved in the early phases of perceiving an object (that is, a bottom-up process) whereas others indicate that mental imagery depends on symbolic representations akin to language and involves an attentional mechanism dependent on the prefrontal cortex.(that is, a top-down process).

Many studies using transient brain inactivation with TMS indicate that mental imagery is possible without the involvement of the corresponding primary sensory or motor areas. A recent fMRI study showed that visual imagery may evokes a retinotopic activation of the primary visual (striate) and adjacent visual association (extrastriate) cortex that is similar to that evoke by perception of the same stimulus extrinsically [13]. This map of activation was different from the activation maps evoked by general attention tasks. This result supports the concept that visual imagery may actively engages areas involved in early processing of visual information, at least in some tasks. However, activation of primary visual areas may not occur in all subjects, perhaps indicating individual variation in the ability or strategy to imagine.

Whereas the controversy as to whether primary sensory or visual areas are consistently engaged in mental imagery is yet to be resolved, there is consistent evidence that association areas of the cerebral cortex, including the parietal and particularly the prefrontal cortex, consistently participate in imagery across modalities, including visual, auditory, tactile, and motor modalities. As mentioned above, fMRI studies show that the ventral occipitotemporal cortex (that is, the ventral stream of visual processing) contains category-specific regions that respond preferentially to faces, houses animals, tools or other objects. A recent study that utilized dynamic a causal modelling paradigm, to make inferences about the influence on the activation of one cortical network on that of another showed a different pattern of coactivation of category specific areas of the occipitotemporal cortex with early visual cortical areas or prefrontal and parietal cortex according to the task [14]. Category-specific occipitotemporal activation during visual perception was associated with increased functional connectivity with early visual; cortical areas (bottom-up mechanism). In contrast, content-related occipitotemporal activation during visual imagery was associated with increased functional connectivity from the prefrontal cortex (top-down mechanism). There was also activation of the superior parietal cortex during mental imagery.

It has been proposed that both the prefrontal and the posterior parietal cortices form a 'imagery network.' General attentional mechanisms necessary for this network arise in the parietal cortex and a content-sensitive mechanism likely originates in the prefrontal cortex. Specifically, the superior parietal cortex, including the precuneus, is activated during tasks of spatial and non-spatial attention as well as in a variety of mental imagery tasks. This area likely mediates the attentional process required for mental imagery irrespective of the content. The precuneus may have a general role in the retrieval of imagery from episodic memory. In contrast, the prefrontal cortex mediates the retrieval of specific sensory representations that are already established from visual representations in the ventral occipitotemporal cortex. This suggests category-selective responses during imagery tasks

Neuroimaging studies indicate that the areas of the 'dorsal stream' of visual processing, the MT/MST and the posterior parietal areas are activated during visual experience of motion, including actual movements, illusory motion, and visual images that imply motion. Not only observation, but also imagery of human body movements activate areas typically involved in motor planning and execution. As stated above, these areas, together with the posterior parietal and ventral PMC are part of the motor mirror system. These mirror neurons respond to either self-generated or observed actions and continue to be active even when the rest of the action is not observed. They also respond to symbolic cues signaling the upcoming movements and have a role in predicting and anticipating actions of other individuals.

Motor imagery

Motor imagery ('mental practice') is the 'internal simulation' of movements involving one's own body in the absence of overt execution. Motor imagery can modify motor performance, indicating that the neural network involved in actual movement execution is also active during mental motor imagery. There are several similarities between motor imagery and executed movements. For example, the time taken to mentally perform an action closely mirrors the time that takes to execute the actual movement, and increased speed reduces accuracy of the imagined movement, as it occurs with actual movements. There are several hypotheses on the mechanism underlying cortical motor activation during motor imagery. The brain may form a 'template' of movements without actually activating the appropriate motor plan, with overlapping networks for motor preparation and execution. Alternatively, mental rehearsal of a particular motor skill may also activate descending corticospinal pathways that are involved in the execution of the actual movement. Cortical activation during mental practice may also reflect plastic changes in cortical excitability induced by the absence of kinesthetic feedback when the limb is not actually moved, or cortico-cortical inhibition required to prevent activation of the peripheral motor apparatus.

Functional neuroimaging studies indicate that mental practice in normal subjects activates a variety of areas involved in all stages of motor programming. The areas found to be most consistently activated include the dorsal primary motor cortex

(PMC) bilaterally, the ventral primary motor cortex, pre-supplementary motor (SMA) cortex, contralateral intraparietal sulcus, and ipsilateral cerebellum. Importantly, these studies have shows inconsistent or absence of activation of the primary motor cortex (M1). This may represent secondary motor areas involved in motor learning, preparation, programming and memorizing (preSMA, SMA, dorsal PMC and/or inferior parietal lobule) exerting not only an excitatory but also an inhibitory modulatory role on M1 during motor imagery. TMS of M1 cortex may reduce motor imagery accuracy. Therefore, the importance of M1 for motor imagery is still undetermined.

CONCLUSIONS

This paper has attempted to summarize the current best knowledge on the brain's capacity and use of imagination. The first challenge in this concept is developing a definition that clearly describes 'imagination' as a cognitive concept. The second challenge is to understand why imagination may exist and what purposes it serves in human behavior. Finally, elucidating the complex and intricate neuroscience of imagination, extrapolating from research on the related but distinct concept of mental imagery, and hypothesizing based on the crude data available, reveal that much is still to be learned.

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IMAGINACIÓN: DEFINICIÓN, UTILIDAD Y NEUROBIOLOGÍA

Resumen. *La imaginación, a diferencia de la generación de imágenes y la memoria, es una fascinante capacidad cognitiva del ser humano que no está bien estudiada. Definimos la imaginación como 'el proceso cognitivo que permite al individuo manipular información generada intrínsecamente con el fin de crear una representación que se percibe a través de los sentidos de la mente'. Esta definición se amplía dentro del contexto de la neurobiología del cerebro y el posible propósito que la imaginación satisface en la vida diaria, en el desarrollo humano y en el comportamiento normal. [REV NEUROL 2007; 45: 353-8]*

Palabras clave. *Cognición. Imaginación. Memoria. Neurobiología.*