Pharmacological and non-pharmacological pathways to enhance cognitive capabilities

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Introduction

Cognition is the process by which the sensory input is transformed, reduced, elaborated, stored, recovered, and used. It can be divided into several functions, which have been qualified as low and high considering its complexity and distribution within animals and their sensorial and cognitive capabilities.

Cognitive functions that derive from a more ancient phylogenetic origin: **habituation and sensitization**, **inhibition of spontaneous behaviours**, produce a **behavioural response when presented to a neutral stimulus**, **reinforced procedural conditioning**. Advance in the phylogenetic line and the brain becomes more developed it holds the ability to use information in a very specific manner: **Cognitive mapping** and **Spatial mapping**.

Neuroplasticity

The human brain is the most remarkable structure that we are aware of, it is capable of incredibly **rapid processing speed**, which enables us to understand complex information in our environment within a tenth of a second. Our brain is a **massive structure** and it has been estimated that it contains 1x1014 neurons in it which are interconnected by an even more massive number of connections, creating an incredibly **network of unbelievable complexity**.

The brain is **flexible and adaptable**. This new idea brought the concept of neural plasticity which defines its ability to modify its function and structure in response to new experiences throughout life. An experiment run on London's taxi drivers proved how their response and posteriors hippocampus changed over several months, after and during their training, in order to obtain the license, with a shockingly increase **(Figure 2).** The same happened in those persons that were asked to learn juggling; they were summited to brain scans in order to observe the modification that occurred in several visual areas **(Figure 3)**.

Pharmacological improvement

Cognition has always been associated to **acetylcholine** (ACh) as a neurotransmitter, yet it is also considered the effect of **dopamine** and **serotonin.** These elements modify the response over information, and how, in conclusion, individuals respond to the information that their environment releases. Also, a hyper or hypo activity of these systems can cause several pathologies.

Cognitive neuropharmacology is the discipline that studies the action mechanisms and therapeutic use of determined drugs that have certain effect onto cognition. These drugs are divided into several different categories:

1. Anxiolytic and hypnotic drugs: reduce several disorders related to anxiety such as panic, phobias, post-traumatic stress. Examples: benzodiazepines, buspirone, propranolol, zolpidem, barbiturates and several other miscellaneous substances.
2. Antipsychotic drugs: used to treat schizophrenia and other similar pathologies related to mental illness. Examples: chlorpromazine, haloperidol, fluphenazine, flupenthixol, clopenthixol and the second clozapine, risperidone, sertindole, quetiapine, amisulpride, aripiprazoleand zotepine.
3. Antidepressant drugs the inhibitors of the monoamine uptake (fluoxetine or fluvoxamin, maprotilina and reboxetine, imipramine and amitriptyline), also the monoamine oxidase inhibitors (MAOIs) (phelezine and moclobemide) and the miscellaneous receptor blocking compounds (mianserin and trazodone).
4. Antiepileptic drugs: used to control seizures or treat and prevent convulsions caused by other brain diseases such as trauma, infections and brain tumors. Examples: phenytoin, carbamazepine and phenobarbital, various benzodiazepines, such as diazepam, clonazepam. Newer drugs include vigabatrin, gabapentin, lamotrigine, felbamate and tiagabine.

Nootropics have been also referred as memory enhancers or cognitive enhancers. They can be from drugs to supplements that allow an improvement in mental functions such as cognition, memory, intelligence, motivation, attention and concentration. These elements, it is thought, they work altering the availability of the brain's supply of neurochemicals, such as neurotransmitters, hormones and enzymes, and improving the supplies of oxygen into the brain.

Non-Pharmacological improvement

This area takes on an approach that allows the increase of an individual's capabilities, without the use of pharmacological enhancers, exploiting the brain's natural neural plasticity. These studies have focused in several points of our brain that may decrease over time and become limitations to our capacities: attention, working memory and speed.

Attention is something that cannot be focused over a huge environment, it has to be directed and focused over a specific objective in order to obtain results. **Working memory** is the ability to hold information in mind, for short periods of time and use it to guide our behaviour. **Processing speed** depends in the processing of information at high speeds but, they never work by themselves.. This, causes the generation of a lag in information processing that slows down the velocity in which information goes through the brain .
The brains reaction and response becomes affected highly but the ever slightest interference; even the regular environment in which we are exposed to starts to cause these interferences. All these negative influences over the brain result in a reduced working memory and long term memory.

Games of strategic kind, with rules and tricks to perform an action allows the development of new pathways to solve more challenging difficulties that might be presented later. Action videogames can improve resistance to distraction and capacity of attention, allowing for an improvement in the brain's limitations and a reduction in the amount of interferences that are generated **(Figure 4)**. An important point demonstrated by several studies is that not all games allow the same level of improvement being those that set players in a first-person shooter scenario would have the higher effects.

An amazing example of these ideas is the game that was developed by the Gazzaley Laboratory associated with Robert Wood Johnson Foundation called **Neuroracer**. It comprises the whole idea of multitasking and also, it becomes more challenging as time passes and the player moves on in the game. Also , this game, o make it a fair evaluation of the improvement, shifted its characteristics depending of those of the user.

Neurodegeneration

Progressive **loss of structure and function** of fragments of the network of neurons that composes the brain, the loss of biological integrity at the cellular level is what is called neurodegeneration. It is **insidious** after a certain period of normal function from the brain; it is relentless over years, sometimes even decades.

Includes affections such as **Parkinson's disease**, with a well-known loss of dopaminergic nigrostriatal neurons, **Huntington's disease** characterized by a loss of spiny, medium-sized striatal neurons or **Alzheimer's dementia (Figure 1)** due to diffuse cerebral atrophy. Also diseases like **primary dystonia** or essential tremor.

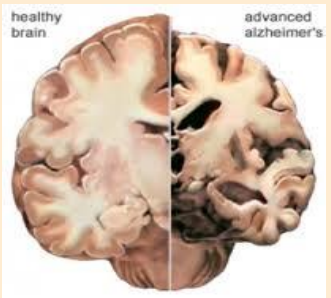

Figure 1. Degeneration of brain tissue due to Alzheimer's dementia as a result of diffuse cerebral atrophy (Rang et al.).

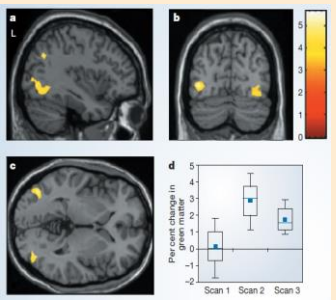

Figure 2. Variation in brain matter's percentage in hippocampus through out an experiment in London's taxi drivers (J. A. Anguera et al.).

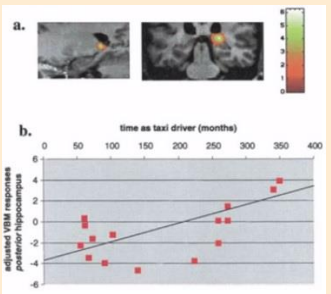

Figure 3. Positive correlation in the increase of brain matter in several visual areas while learning to juggle (J. A. Anguera et al.).

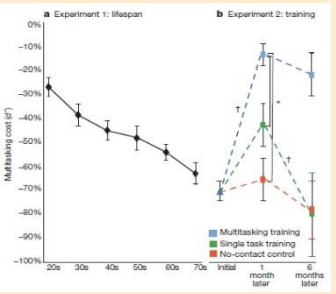

Figure 4. Development of multitasking cost (working memory and attention) over life time and during training methodologies (J. A. Anguera et al.).

Conclusion

Our brain is a changing structure that can be modified and redirected to improve its performance both by a pharmacological and non-pharmacological pathway. **Pharmacological** approaches try the recovery of a physiological state that has been altered due to a pathology or, to enhance capabilities through the modification of the brain's physiological environment, whereas the **non-pharmacological** approaches, among them the gaming experiences, work basing themselves on the modification of the brain's network through the creation of external stimulus.

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