

Cognitive enhancement Techniques

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Abstract

Cognition refers to all the processes that organism uses to organize information. This includes cognitive abilities like memory, attention, language, visual and spatial processing, logic and reasoning, interpersonal and intrapersonal reasoning. It has been scientifically proved that cognitive abilities can be improved upon by certain interventions. This article briefly explains various techniques of enhancing these cognitive abilities. Two ways of classification of these techniques are also discussed.

Keywords

Cognition, cognitive abilities, cognitive enhancing techniques, cognitive assessment

1. Cognition

The word cognition comes from the Latin word *cognosco* (con means 'with' + gnōscō which means 'know'), hence cognition means 'get to know' [1]. Therefore, we can say that a system is cognitive if it knows something. Humans and animals are good example of cognitive system as humans know how to build houses, communicate, etc and Animals know how to survive. Another example for cognitive system is Autonomous robots they know how to perform certain tasks independently.

In science, cognition refers to mental processes. These processes include attention, memory, solving problems, making decisions, calculations, producing and understanding language reasoning.etc Cognition is studied in various disciplines such as linguistics, psychology, science , philosophy and computer science [2]. Thus, Cognition may be defined as the process that organism uses to organize information. This includes selection (attention), acquiring information (perception) retaining information (memory), representation (understanding), and using it to guide behavior (reasoning and coordination of motor outputs) [3].

2. Cognitive abilities

Brain based skills are cognitive abilities. These are used to carry out simplest to the most complex task. In other words, abilities that are concerned with some of cognitive task are known as cognitive abilities. Any task is cognitive task if major determination of its successful performance is dependent on processing of mental information [4].

Some of the cognitive abilities are listed as:

2.1 Memory

Memory is that cognitive ability which stores and recalls information. Memory is of two types: short term (or working memory) and long term memory. Storage capacity of short term memory is limited; usually it holds about seven items for not more than 20 to 30 seconds. Short term memory is the ability to store information in immediate awareness while performing a simultaneous mental operation. As an illustration, we take example of a student who has weak short term memory. As a result, while copying a text, he will see text again and again; while solving a mathematical problem, he will read the data repeatedly; while following multiple instructions, he will refer to instructions more often.

Storage capacity of long term memory is unlimited and remains for indefinite time. Information in short term memory is transferred into long term memory if it is used repeatedly. Symptoms for weak long term memory are like forgetting phone numbers, names etc.

2.2 Attention

Attention is the ability to continuously focus on a particular action, thought or object. It is classified into three prime types

- Sustained attention: it is the ability to maintain focus on a particular task over sustained period of time. Symptom for weak sustained attention skills is that student will drift from one activity to another without completing it.
- Selective attention: it is the ability to remain focussed on a task while ignoring any irrelevant information or distraction. Student with weak selective attention have problem in studying or carrying a conversation while there is any type of distraction in surrounding area.
- Divided attention: it is the ability to focus on more than one thing. Problems faced by person having weak divided attention are difficulty in making good notes and following multiple instructions.

2.3 Language

Language is the cognitive ability to translate sound or sight into verbal output and vice versa. It provides us with listening skills, reading skills, comprehension and formulation. Comprehension means converting language to thought, while formulation means converting thought to language.

2.4 Visual and spatial processing

Visual processing is the cognitive ability to perceive and analyse the incoming visual stimuli. This also includes visualizing, which is the ability to create pictures and scenarios in mind. Persons with lack of visual processing abilities may have problems in reading maps, solving word problems (referred to mathematical exercise in which necessary information for solving a problem is written in text rather than in mathematical notations), following instructions etc. Spatial processing is the ability to distinguish differences among similar objects or forms.

2.5 Logic and reasoning

Logic and reasoning are cognitive abilities that make concepts, help in solving problems using unfamiliar procedures or information. Problem solving ability can further be extended to draw conclusion and come up with solution using deductive reasoning (the process of reasoning one or more general statements to reach a logically general conclusion) by analyzing the relationship between given conditions. Underdeveloped logical and reasoning skills cause trouble in solving word problems in maths and other abstract learning (involves understanding concepts) challenges.

2.6 Interpersonal skills

Interpersonal skills are the skills that are used every day while interacting and communicating with other people in group or individually. In workplace strong interpersonal skills are required. Employees with strong interpersonal skills will work well in team and be able to communicate effectively with costumers, colleagues and clients. Interpersonal skills are beneficial not only in workplace but also in social and personal life.

2.7 Intrapersonal skills

Skills found within a person's mind are known as intrapersonal skills. These skills are the foundation of successful career. For example, emotional intelligence (to understand, manage and know your own emotions), self confidence, knowing your own strengths and limits, ability to control emotions likes anger and frustration, knowing what drives and inspires you etc.

Apart from the above listed classes of cognitive abilities, several other abilities are also provided by researchers and include language, reasoning, memory and learning, visual perception, auditory reception, idea production, cognitive speed, knowledge and achievement [4].

3 Cognitive Enhancement

Cognitive enhancement may be defined as amplification or extension of core capacities of the mental processes through improvement or augmentation of information processing systems. Some sort of intervention is used to bring about these improvements. Cognitive enhancement, thus, aims to improve the cognitive functioning of brain like improved learning, more focus, better memory, faster reaction time, better perception, improved reasoning capacity etc.

Cognitive enhancement comprises of three steps. It begins with assessment of cognitive abilities, detail of which is given in section 3.2, followed by intervention aimed at improving the cognitive abilities. Intervention may be given for several days and can be in the form of drugs, meditation, odor, color, videogames, or any other kinds of stimuli. Finally the validation of improvement takes place by again assessing the cognitive abilities after intervention. The second assessment is compared with the first assessment to know the extent of cognitive enhancement. The entire procedure is conceptually shown in figure 1

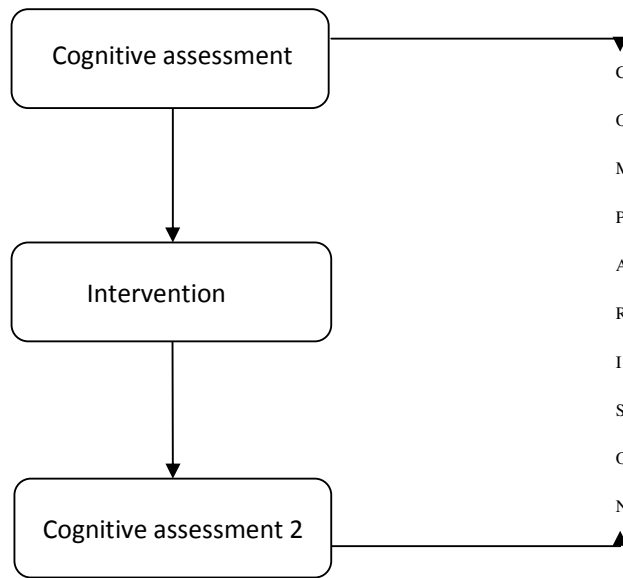


Figure 1: Cognitive Enhancement Procedure

3.1 Difference between Enhancement and Therapy

In case, the intervention is used to correct a specific pathological condition or defect of cognitive subsystem, then it is referred as a therapy. On the other hand, if an intervention is used to improve a subsystem in some way other than repairing something that is broken or remedying a specific dysfunction, then it comes in the category of enhancement [3].

Let us understand the difference between enhancement and therapy by taking short term memory as the cognitive availability. A common misbelieve is that improvement from abnormal to normal is therapy, while improvement from normal to super normal is enhancement. This misbelieve is dispelled by taking the following example. A person “A” has inborn short term memory of retaining 60 words out of 100 shown to him. On the other hand a person “B” suffering from some identifiable pathology such as early-stage Alzheimer’s disease may be able to recollect 75 words out of 100 shown in spite of disease. His memory score before the disease was 85. Now an intervention is given to improve the score of “A” from 60 to 70. This shall be classified as enhancement. On the other hand, intervention given to “B” to bring memory score from 75 to 85 shall be classified as therapy. It may be noted that pre-intervention score of “B” is more than the post intervention score of “A”. Hence irrespective of post intervention performance or pre intervention score, intervention used to correct the harm done by any pathological condition is called a therapy, while bringing about the improvement in cognitive abilities in absence of any disease is called enhancement.

3.2 Cognitive assessment

Cognitive assessment is an examination that is conducted to determine level of cognitive functioning of brain [5]. Cognitive assessment is broadly divided into two groups: 1) Task oriented assessment 2) Physiological assessment

1) Task oriented assessment

In this type of assessment, subject will be asked to complete a series of task like matching numbers, word series etc. that require cognitive skills. There are certain standard batteries that are used for cognitive assessment like Psychological Experimental Building Language (PEBL), Prevention and Early Intervention Program for [5].

2) Physiological assessment

Cognitive assessment can also be done by using Physiological methods like Electroencephalography (EEG), Electrocardiography (ECG), Galvanic skin response (GSR), Heart rate variability (HRV) etc. [5]. EEG is conventionally used to detect pathological conditions like epilepsy [6-10], but nowadays it is also being used to detect and quantify emotions [11-15]. EEG is a record of neural activity, and it acquired in a non-invasive manner by placing electrodes over the scalp of the subject [16]. The signal of EEG is conditioned by de-noising and features are extracted from frequency bands of different ranges like theta, beta, alpha, beta, and gamma [7, 8, and 11]. For emotional detection or for diagnosing any pathological condition like epilepsy, the features extracted from EEG frequency bands are given to a related classifier, that may be rule based, nearest neighbour classifiers, or more advance technique like SVM [17]. It is found that activity of different lobes of brain increases as per the task performed. As in case of attention task power of theta, beta 2 band decreases and alpha2 increases and with age power of frontal theta increases [18-19]. In case of working memory power of alpha increases in posterial and bilateral central areas [20].

4 Classification of cognitive enhancement techniques

There are different ways by which we can classify techniques of cognitive enhancement. One way of classifying cognitive enhancement techniques are whether they are conventional or unconventional [3]. Another way of classifying cognitive enhancement techniques is whether they are external/internal to the user and whether they are hardware/software based [21]. A diagnostic representation of cognitive enhancement classification is given in figure 2.

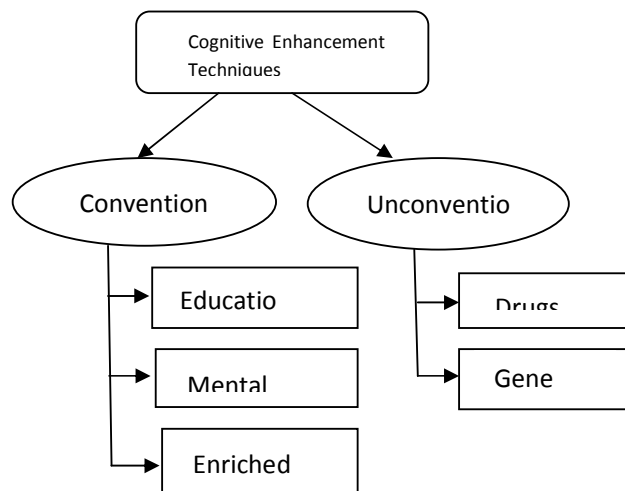


Figure 2: Classification of Cognitive Enhancement Techniques

4.1 Conventional

Education, mental training as well as use of external information processing devices come under “conventional” means of enhancing cognition [3].

1) Education

Whatever we learn in our school is “mental software” for managing various cognitive domains: mathematics, reading, writing and understanding language, problem solving in particular subject etc. This type of mental software will reduce one’s mental load by clever encoding, organization, or processing [21]. From Wikipedia education is defined as a form of learning in which through teaching, research or training group of people transfer skill, habits and knowledge from one generation to next. Education can be any experience that has effects on the way one thinks, feels or acts. Education is commonly separated into five stages starting from preschool, then primary school, followed by secondary school, then college, then university or apprenticeship [22]. Accordingly education by default enhances cognitive abilities. However for a particular task special efforts may be made to improve the speed or efficiency of performance. Abacus, which is a simple mechanical calculation device used to store numbers during mental calculations, increases the speed of calculations and these forms are example of cognitive enhancement. In this device, the beads are slid up or down on various rods to simplify the mathematical processes like subtraction, addition, division, multiplication, etc. Interestingly, with practice, the person is able to do the calculations without any physical abacus, by mentally picturing the beads. Many children trained on this technique are able to do calculations faster than those done with the help of electronic calculator. Learning this method thus can be classified as a cognitive enhancement technique. A basic abacus is shown in figure 3.

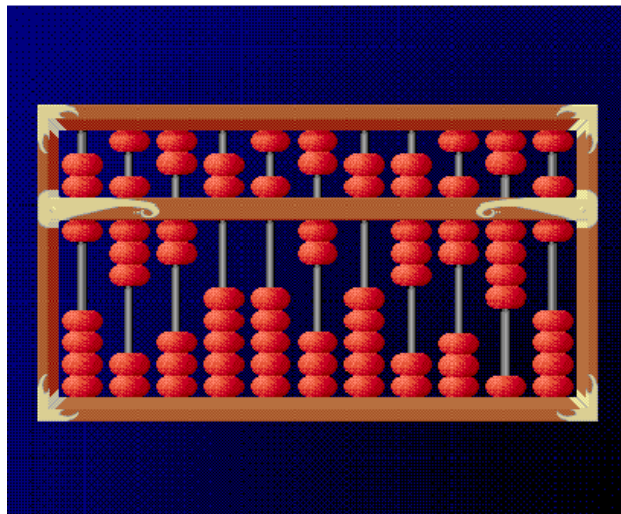


Figure 3: Basic Abacus

Another sub class of cognitive enhancement through education includes use of short cut techniques in mathematics. For example, taking square of any two digit number conventionally requires multiplication of the number with itself. In one of the shortcut method, we first make unit digit zero. After all, it is easy to multiply when unit digit is zero. Here we multiply (the number + unit value) with (the number-unit value) and then add square of unit value. Let us see how it works by taking square of 53: $(53+3)*(53-3) + (3*3) = (56*50) + 9 = (560*5) + 9 = 2800 + 9 = 2809$. Similarly for square of 64: $(64+4)*(64-4) + (4*4) = (68*60) + 16 = (680*6) + 16 = 4080 + 16 = 4096$. These strategies and short cut techniques improve the cognitive ability of number crunching. Interestingly these are popularly categorized as Vedic mathematics, though they don’t find any mention in Indian Vedas.

All these types of methods have a narrow range of applicability but can be used for improving performance within a particular domain.

2) Enriched Environment

Enriched environment is another conventional technique by which we can enhance one's cognitive abilities. Enriched environment is the stimulus for brain by its social and physical surroundings [23].

There are various ways to provide enriched environment. Learning something new like – chess, poker, a new computer game, learning some musical instrument, learning new language etc is one simple way to provide enriched environment. Another way of enriching environment is travelling. Travelling will cut a person's daily routine and provide a new environment to him as well as to his neurons.

Various studies have demonstrated a positive effect on brain for those animals which are offered enriched environment. By comparing a single rat in normal cage with group of rats in a cage with toys, ladders, running wheels, it was found that growing up in enriched environment affects enzyme cholinesterase activity and hence helps neurons to return to their resting state after activation, thereby retrieving stress [24].

Stimulation-seeking children, who might be seeking out and creating enriched environment for themselves, score higher on Intelligence Quotient (IQ) test and do better at school than less stimulation seeking children [25]. It is recommended that cognitive ability of children might improve if they are provided an enriched environment that makes learning and exploring much more appealing for them. Enriched environment also makes brain more resilient to stress and neurotoxins [26]. Some of such interventions have both cognitive enhancement as well as therapeutic effects. For instance, an optimized intrauterine environment will not only help avoid specific pathology and deficits but is also likely to promote the growth of the developing nervous system in ways that enhance its core capacities [3].

No wonder, the expecting mothers in India are traditionally given extra importance on both physical as well as psychological level. Abhimanyu, a great archer and philosopher, is believed to learn the intricacies of archery and philosophy, even as a foetus in his mother's womb. Dr. T Mythily-chief music therapist, Apollo hospital, Chennai, reports that music therapy ensures natural and smooth delivery, and also increases the chance of high cognitive abilities, grasping concepts and mathematical abilities, spatial and depth perception and significantly high APGR scores (calculated on five simple criteria Appearance, Pulse, Grimace, Activity, Respiration) of children. She believes that prefrontal lobe, which facilitates efficient and easy learning, and application of intelligent thinking, develops rapidly in foetus in the womb of mother by providing music stimulation. These babies are always ahead of their counterparts in all aspects of life whether acquiring skills and knowledge, this tendency seems to continue well into their lives.

3) Mental training

There are various forms of mental training by which cognitive enhancement can be done.

Even general mental activity, "working the brain muscle" can improve performance [27] as well as long-term mental health [28], while relaxations techniques help regulate the activation of brain [29]. It has been suggested that the Flynn-effect [30], produces a general increase in raw intelligence test scores by 2.5 IQ (intelligence quotient) points per ten years in most western countries [3]. Flynn-effect is the sustained and long-sustained increase in general cognitive abilities across the population with passage of time. It can be explained on account of increased cognitive demands of abstract and visual thinking in modern society and schooling, although there are certain factors such as improved nutrition and health status that may also play a major part [31].

Another form of mental training consists of learning strategies to memorize information (i.e. memory techniques). "The method of loci" is one such strategy. In this method subject will visualize the layout of shops on a street, any building or any geographical entity and in her imagination she will walk from room to room,

depositing imaginary object that evokes natural association to the subject even though she is memorizing. During retrieval, subject will recall all the memorized information from her imaginary steps while walking to objects she placed [3]. As this method relies on memorizing and recollecting the content, it is used in tackling brain's spatial navigation system to remember objects or propositional contents. In basic term, it is a method of memory enhancement which uses visualization to organize and recall information.

There are various other methods for memory enhancements such as use of rhyming, recalling colorful or emotional scenes, recalling number series or letters. This kind of Memory techniques are used in everyday needs such as remembering passwords, door codes, shopping list, and by students who need to memorize name, dates and terms while preparing for exams [32-33].

Some other forms of mental training such as yoga, martial arts, meditation, video gaming are also used for cognitive enhancement [3].

Meditation is one of the techniques for improvement in cognitive abilities. From ancient period meditation is practiced by humanity across the globe in some form or other. It is helpful to reduce anxiety, improve psychological health, reduce stress, improve memory, attention etc. Mindfulness meditation helps in reducing anxiety and pan [34]. Mindfulness meditation improves short term memory, attention and decreases reaction time [35]. Another technique used for enhancing cognitive abilities is yoga , with alternate nostril breathing pranayama (one of the oldest yoga) mental stress reduces, physical strength and health improves [36].

Video gaming is yet another mental training technique to improve cognitive abilities. Gaming is good mental exercise. Persons playing fast paced games have better vision perception, attention and cognition. Video games are used in various fields like education, physical exercise and cognitive training [37]. Playing first person shooter game improves working memory [38].

4.2 Unconventional

Unconventional techniques of Cognitive enhancement include drugs, gene therapy, or neural implants; nearly all of them are considered as experimental at present time [21].

1) Drugs

The general perception of drugs used for enhancing cognitive abilities is that these are illegal and unhealthy. Contrary to this some drugs are legal and when taken in proper amount are very useful for cognitive enhancement.

Cognitive abilities like memory, attention, and concentration can be improved by drugs such as nootropics. Nootropics work by improving the brain's oxygen supply, by stimulating nerve growth, or by altering the availability of the brain's supply of neurochemicals (neurotransmitters, enzymes, and hormones). Nootropics formulations have been used in ayurvedic system since ages. Some examples for enhancing memory are almonds, ginger, tulsi, ambla, Indian tulip tree etc [39]. These being conventional may not be considered under this category. These will provide a long term effect. However, some of the unconventional drugs which are used to improve memory are Ritalin and Adderall which provide short term effects. These are commonly used by college students to improve grades and provide an edge over their classmates [40]. These methods of cognitive enhancement are legally not approved as they form a type of cheating, just in the same manner as doping for sports persons is banned. Some drugs which are used for treating Alzheimer's disease and other cognitive deficits also improve cognition in healthy individuals. US Food and Drug Administration has already approved a number of these drugs, including donepezil (Aricept®), rivastigmine tartrate (Exelon®), galantamine HBr (Reminyl®), and memantine (Namenda®). In addition, the new psychostimulant modafinil (provigil®) improves alertness, a key factor in cognitive performance [41]. It is also being tested for use by military and has shown improvement in simulator performance by helicopter pilots [42].

Two most popular drugs which are for long being used for improving cognition are nicotine and caffeine [3]. In case of caffeine tiredness reduces [43-45], while with nicotine a complex interaction with memory and attention occurs [46-48]. Caffeine is being used traditionally as a stimulant for providing alertness. It is often consumed in extremely high dosages. For example starbucks is a very popular coffee due to the fact that in a very small serving say 16- ounce contains 550 milligrams of caffeine, a 5 times the amount in a regular cup of coffee.

Supplement like choline when given to rats prenatal (during pregnancy) and perinatal (few days before and after birth) stage have reported to improve memory [49-50]. Choline is naturally available in foods like eggs, sunflower, broccoli, peanuts etc.

2) Gene therapy

Gene therapy or gene modification is a technique which inserts genes directly into cell. It is used to cure or prevent disease instead of using drugs or surgery. This is useful in enhancing cognitive abilities as well. In rats and mice it has been demonstrated that gene modification enhances memory. NR2A subunit of NMDA (N-Methyl-D-aspartic acid) is linked with low plasticity of brain (or neuroplasticity is the ability of brain to change based on new experience). While normal animal is maturing, synthesis of NR2B is replaced by NR2A; hence memory is low in adult animals. Genetically modified mice to produce more of the NR2B subunits. The NR2B “Doogie” mice showed improved memory performance, in terms of both acquisition and retention [51].

5 Another way to classify Cognition Enhancement Techniques

There are another ways of classifying cognitive enhancement techniques into internal and external. Both internal and external techniques are further classified into software and hardware techniques. This type of classification is represented in figure 1.8

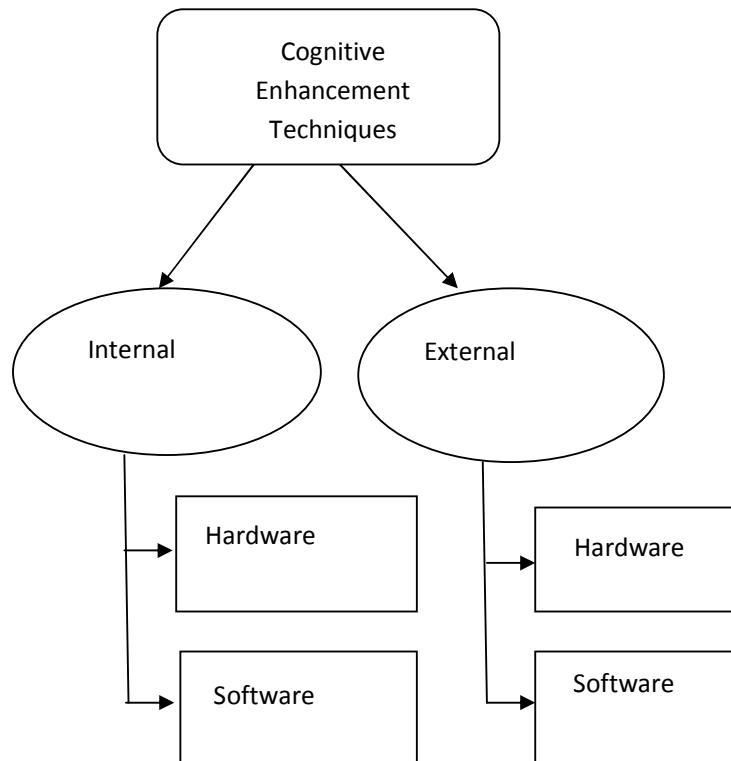


Figure 4 : Classification of Cognitive Enhancement Techniques

5.1 Internal hardware

It is similar to unconventional means of enhancement. It deals with biological modifications such as genetic modifications (through hybridization or screening), surgery, tissue engineering, pharmaceutical or nutritional interventions and neural implants [21].

5.2 Internal software

The first cognitive enhancement strategy developed was internal software that helps us organize thoughts and memories. Internal software enhances cognition by learning improved cognitive strategies or making use of neuroplasticity [21]. The ability of brain to change with learning i.e. lifelong ability of brain to reorganize neural pathways based on one's new experience is known as neuroplasticity or the plasticity of brain.

Internal software deals with all types of mental training and education that basically comes under conventional means of cognitive enhancement.

5.3 External hardware

From long history external hardware has been used for improving cognitive abilities. Clay token was used as first external hardware for cognitive amplification. They were found across near east dating from 8000 BC up to the time of writing in 3000BC [52]. Originally they were just used for counting aids and recording of possession. As time changed their shapes also changed and we started using clay tablets for writing purpose. It laid the groundwork for the permanent storage and transmission of information. Later we developed paper and ink. This is the most used and most powerful cognitive amplifier as it is most suitable means of storing information.

However computers are needed because paper is passive and is not used for processing.

Wearable computers and Personal Digital Assistants (PDAs) are already intimate devices worn on the body, but there have been proposals for even lighter interfaces. Digital control of external devices through brain activity has been studied with some success for the last 40 years, although it remains a very low bandwidth form of signaling [53].

5.4 External software

Until recent practice all cognitive software's were internal. Today software Computers is not only used for storing information and performing calculations, they can also supplement our skills. For example symbolic math programs are able to amplify our mathematical skills by providing perfect storage and remember of formulas, the skill to do calculations with no risk of making slips and graphical visualization of the result. Similarly, decision support tools attempt to help making rational decision in uncertain situations (Walter 1997). When information is so large that human brain cannot handle it, like searching for relevant data in huge pile may take enormous time, by using data mining and information visualizing we can solve this problem. A very common example of such a searching is Google. Other tools such as symbolic math program, expert systems, and search agents amplify specific skills and capacities [3].

Conclusion

Cognitive abilities deal with performance of brain. Familiar examples of cognitive abilities include memory, attention, language, interpersonal skills, intrapersonal skills etc.

In the present age of information technology, where knowledge, data and its processing rules the world, a matching cognitive ability in human being is essential for its survival. The cut throat competition in every stage, right from being a student to professional life requires the best of cognitive abilities. This research article written after extensive literature survey briefly touches upon the various aspects of enhancing these cognitive abilities. The different types of classification of these techniques and their brief introduction may create interest among the researchers to take up this widely rewarding field of cognitive enhancement techniques.

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