**Testing and Cognitive Enhancement**

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**Abstract**

*We are entering a new era. New and improved means of enhancing cognitive abilities are being developed at an ever faster rate. Cognitive enhancement (CE), both short- and long-term, can now be achieved by means of drugs and brain stimulation, in people of all ages. In the near future we may also witness CE through genetic engineering and man-machine coupling.*

*Following a description of various ways to achieve CE and their effects on cognitive abilities, I address the question of what exactly is measured or assessed under conditions of CE, and how such measurement can be aligned with the goals of assessment. Other questions considered are to what extent and in what direction, if at all, we should modify testing standards and professional ethics, and what the relation is between testing under CE conditions and test accommodation in the case of disabled examinees.*

*Relevant to the discussion of these issues is the fact that behavior-modifying drugs, such as pain killers, anxiety reduction drugs, and others, are routinely used by examinees, either with or without the testers’ knowledge. The discussion is further guided by reference to methods of physical enhancement (PE) that are routinely employed (e.g. audio and visual aids), and by the discussion of more extreme PE means, such as drugs or bionic devices that are employed (or banned) in competitive sports.*

**Introduction**

Rapid developments in biology, pharmacology, cognitive-neuroscience and computer science, in the latter half of the twentieth century, have made it possible to enhance our cognitive skills by means beyond the traditional methods of training and education. Cognition is one of several aspects of human skills or features that can be, and are, enhanced by technology. Others include aesthetics (how we move and look) and the motor or athletic aspect (how fast or how strong we are), and more.

The means for cognitive enhancement are varied and diverse, and there are new developments in the relevant fields of science and technology on an almost daily basis. Psychoactive drugs can change a student’s behavior overnight; marketers of cognitive training programs promise to raise our scores on psychometric tests; computer specialists are working on systems that harness the power of computers to aid our brains through sophisticated interfaces; and there is talk about enhancing our cognitive skills by means of genetic engineering.

With regard to the measurement of human cognitive skills, we assume that there are relatively constant levels of cognitive functioning that can be reliably evaluated and measured. But in an era of technologically-enhanced cognitive skills, what exactly are we measuring? It is definitely not the intact skill. Instead, we measure the behavior of a combined technological and biological medium. This raises numerous questions in the domains of psychometrics, ethics and social policy.

This paper presents the questions and dilemmas and attempts to analyze possible and probable answers and solutions while focusing on the psychometric issues. As a preface to this discussion, I would like to discuss in some detail the various ways in which technology can enhance, or has the potential to enhance, cognitive skills.

**Methods for Cognitive Enhancement (CE)**

The various methods for CE can be grouped into five broad categories, as follows:

 1. Food (sugar, caffeine) and psycho-active drugs such as Methylphenidate or Amphetamines, one use of which is to enhance attentiveness or awareness.

2. Brain stimulation techniques, at various levels of invasiveness, which are said to improve specific skills such as speed of learning (retention) or mental calculation.

3. Behavioral shaping – by means of neuro-feedback and cognitive fitness programs.

4. Genetic Engineering – which has already been documented as a possible CE in lower animals.

5. Bio-cybernetics – a field rich in ideas that often sound like science fiction.

The five categories are ordered according to the extent to which they have been researched, applied and proven effective. Although research, application and proof of effectiveness are three separate dimensions, they are correlated to a large degree. In the sections below these five categories are described in more detail and evidence regarding their effectiveness is reported and evaluated.

***Food and Psychoactive Drugs***

Balanced diet is a necessary condition for normal cognitive performance. There is ample evidence of the detrimental effect of malnutrition on cognitive functioning (Sigman, Neumann, Jansen, & Bwibo, 1989). There is, however, also evidence that consumption of some type of foods can improve cognitive performance in the short and long terms. For example, Flavonoids – a class of organic compounds that are found in variety of foods (citrus, parsley, white and green tea, red wine, blueberry and dark chocolate) – can improve human memory and neuro-cognitive performance in the short term and can also protect against the debilitating effects of aging on learning and memory (for a review of the evidence and a discussion of the possible mechanisms involved see (Spencer, 2008)).

Methylphenidate, better known by brand names such as Ritalin and Concerta, is the most commonly prescribed psychoactive drug for children. It is prescribed mainly for the treatment of attention-deficit hyperactivity disorder (ADHD). It is effective in increasing and maintaining alertness, and in improving the aspect of attention referred to as the ‘executive functions’ (Steele, Weiss, Swanson, Wang, Prinzo, & Binder, 2006). The short-term benefits of methylphenidate are well established, although long-term effects are unknown. According to research conducted at the U.S. Department of Energy's Brookhaven National Laboratory, methylphenidate works in the treatment of ADHD by increasing levels of dopamine in the brain (Volkow, et al., 2001 (21))

***Brain stimulation techniques***

For over 100 years it has been known that brain function can be modulated by electrical stimulation. Of the following broad classes of brain stimulation techniques, the first three are non-invasive, but the fourth involves surgical intervention. The four classes of brain stimulation techniques are:

1. Transcranial direct current stimulation (tDCS), in which a low current is delivered directly to the cranium above the brain area of interest using small electrodes. There is some evidence that administration of tDCS prior to a verbal working-memory task improves performance in young adults (Fregni, et al., 2005) (Ohn, et al., 2008) (zaehle, Sandmann, Thorne, Jancke, & Herrmann, 2011) and in some older adults (Berryhill & Jones, 2012).
2. Cranial Electrotherapy stimulation (CES, also known as Electrosleep Therapy, Cranial-electro Stimulation, or Transcranial Electrotherapy) is a treatment that applies small, pulsed electric current across the cranium. It has a long history and was probably used in ancient Rome (Stillings, 1975) for medical purposes. In the context of cognitive enhancement, CES may indirectly improve performance due to its proven effectiveness in reducing anxiety (De Felice, 1997) (Klawansky, Yeung, Berkey, Shah, Phan, & Chalmers, 1995)***.***
3. Transcranial magnetic stimulation (TMS) employs electromagnetic induction to induce weak electric currents, using a rapidly changing magnetic field. A successful application of this technique was first reported by (Barker, Jalinous, & Freeston, 1985). The use of magnetic induction instead of direct electrical stimulation reduces the reported discomfort of the patients and provides a relatively easy procedure for research of localized functions. The main therapeutic use of TMS is in treatment of depressed patients or those with Parkinson’s disease. Its use for cognitive enhancement was demonstrated by (Gagnon, Schneider, Grondin, & Blanchet, 2011). They showed that TMS during encoding or retrieval of both verbal and non-verbal material facilitated recall.
4. Deep brain stimulation (DBS) involves implantation of a “brain pacemaker” which sends electric impulses to specific parts of the brain. Direct electrical stimulation of the human brain was first demonstrated, to the dismay of the American Medical Association, which condemned the experiments, by Robert Bartholow in 1874 (Perlmutter & Mink, 2006). Later, DBS was shown to be effective in treating essential tremor, symptoms of Parkinson’s disease (Kleiner-Fisman, et al., 2006), dystonia, chronic pain (Young & Brechner, 1986), depression and OCD (Lakhan & Callaway, 2010). The results concerning cognitive performance following DBS surgery are mixed. There are some short-term debilitating effects which are usually attributed to the surgery itself (halpern, Rick, Danish, Grossman, & Baltuch, 2009), but in the longer term the results are mixed; both improvements and deterioration have been reported, even for the very same cognitive tasks (Israel, et al., 2011). It has recently been reported (Laxton, et al., 2010) that DBS may slow, stop or even reverse the cognitive decline in Alzheimer’s disease, probably due to increased connectivity between neurons (Smith, et al., 2012). Lastly, Hu et al. (Hu, Eskandar, & Williams, 2009) have suggested that DBS may be used in the future “for enhancing or improving otherwise nonpathological aspects of cognitive function”.

***Neuro-feedback and cognitive fitness programs***

Neuro-feedback is a method for controlling brain activity by observing the electrical activity (EEG) of the brain. The goal of the program is to let the trainee gain control over the frequency of his or her EEG. There are some indications that neuro-feedback can alleviate symptoms of ADHD, but the results are not conclusive (Loo & Barkley, 2005) and, at most, the technique is successful in about 75% of cases (Diaz, Sloot, Mansvelder, & Linkenkaer-Hansen, 2012). The main advantage of this technique, when compared to drugs or trans-cranial stimulation, is its long term effect. There are also reports on the effectiveness of neuro-feedback on cognitive tasks such as mental rotation (Zoefel, Huster, & Hermann, 2011) or working memory (Escolano, Aguilar, & Minguez, 2011) in healthy adults.

Beneficial effects of relaxation training, without any biofeedback, have been demonstrated (Nava, Landau, Brody, Linder, & Schachinger, 2004). Their study showed a positive effect on long term visual memory, following a 12-minute relaxation training session that preceded a learning session.

Memory training has been around since ancient times. The ‘method of loci’, (which recently received renewed fame in “Moonwalking with Einstein” (Foer, 2011)), was known to the ancient Greeks and Romans and was practiced by them. But recently we have been offered more and more training courses – mainly computer based – that are aimed at “exercising the brain muscle”. There are reports on the efficacy of these programs, but in a recent serious review of the evidence (Shipstead, Hicks, & Engle, 2012) regarding the “Cogmed” training programs, the authors conclude that *“The only unequivocal statement that can be made is that Cogmed will improve performance on tasks that resemble Cogmed training. However, for people seeking increased intelligence….current research suggests that this training program does not provide the desired result”.* A recent meta-analysis(Melby-Lervac & Hulme, 2012)concludes similarly that memory training programs appear to produce short-term, specific training effects that do not generalize. So evidence is mixed regarding the long-term efficacy of memory training and its generalizability.

***Genetic Engineering***

The young technologies of genetic engineering and gene therapy are going to change our potential to control and enhance behavior in the next few decades. Although as yet there is no proof of the ability to use gene therapy in order to enhance cognition, there are numerous studies that show how muscle volume and body weight can be controlled in mice and rats by means of gene therapy (see for example Chapter 1 in (Naam, 2005)). The potential of gene therapy is promising, but the application to human beings is fraught with risks and ethical dilemmas, and is still far from fruition.

***Bio-cybernetics***

Another young and promising technology is that of bionics, or bio-cybernetics – the linking of electro-mechanical or electronic devices to the human body and brain. Sophisticated prosthetic sensory and motor devices such as cochlear implants and muscle-activated artificial limbs are already in wide use. But this is just the beginning of a technological adventure that will, someday, culminate in the linking of biological systems to the digital world. First steps were taken by (Warwick, et al., 2004) who demonstrated that remote devices can be controlled via the Internet by using electrodes implanted in the brain, and that communication between two brains via the Internet can be achieved by similar means.

The implications of these chimeras of man and computer – so called Cyborgs – are of course far reaching. Linking the human brain to vast amounts of readily searchable information and to electronic problem solvers can greatly amplify human intelligence.

**Cognitive Enhancement, Testing, and Test Accommodations**

In the near future the arena of testing will most likely undergo a radical change. In addition to the technological advances and enhancements in testing methods (Bennett, 1999), (Bennett R. , 2001), the examinees themselves are going to be equipped with modified, enhanced and augmented abilities.

Actually, examinees have been employing sensory enhancement aids for many years – hearing aids and eye glasses. These do not seem to present a problem for test administrators, with one caveat: As long as we test cognitive performance and not sensory abilities per se, then the sensory aids do not, or so we believe, interfere or modify the measured construct. In some cases – as with surgically corrected vision, or cochlear implants – if the examinee does not provide any information about the alteration, we are not even aware of the sensory disadvantage prior to the intervention. In the future we may face the same situation with respect to cognitive abilities. We may not be able to detect whether the examinee is equipped with a trans-cranial magnetic or electrical stimulation device, or with implanted electrodes for deep brain stimulation or for wireless brain-to-brain communication.

The issue of testing under conditions of cognitive enhancement is not very different from the issue of offering test accommodations due to learning disabilities. In the case of accommodations, the tester is faced with the same problem: to what extent do the modified conditions change the construct being measured, and to what extent are the tests fair to those who are tested under standard conditions (Ben-Simon, Beyth-Marom, Inbar-Weiss, & Cohen, 2008)? With a view to maintaining fairness, we try to modify the testing conditions in such a way that examinees with accommodations are not “over compensated” relative to examinees tested under standard conditions. For example, in order to equate the condition of ‘extended testing time’ for examinees with learning disabilities, we, at NITE, developed a special version of the test in which the score distribution under conditions of extended time for examinees not requiring accommodations was equated with the score distribution of the same examinees under standard conditions (Cohen, Ben-Simon, Moshinsky, & Eitan, 2008) .

We should however, keep in mind that the ‘enhanced brain’ of the future may be permanently enhanced. From electrode implantation on, the enhanced brain will function on the same, augmented, level. So, in fact, we are dealing with a permanent change of cognition that will also affect the criterion performance and not only the performance during the test. Therefore, in the case of permanent enhancement, test validity is not in danger of corruption.

**Sports and Psychometrics**

It is interesting to note that in sports, national and international regulating bodies have been facing similar problems and issues for many years. Technological advances, such as in clothing, bicycle engineering and special equipment, have been approved and have definitely pushed athletic achievements to higher levels. In contrast, the use of drugs is prohibited and the athletes and trainers are closely monitored for illicit use. There is however one interesting case of physical augmentation – that of the so called ‘blade runner’—the sprinter Oscar Pistorius. In his case, due to below-the-knee double amputation, he runs with carbon-fiber artificial limbs. Following a long process of arbitration, in which he was initially refused, he was allowed to compete in the Olympic Games. The court's finding was that, overall, there was no evidence that Pistorius had any net advantage over able-bodied athletes.

**Summary**

We are at the beginning of a century that will host the fastest technological changes in human history (Kurzweil, 2005). Testing technology is not an exception in this respect. We are in the process of changing the technology of testing due to general technological progress and at the same time face the need to change our attitude to the object of assessment. As with all technological changes, we will have to adapt by modifying our view of what is considered human and what we consider human abilities. We will also have to revise our professional ethics and operational standards. It is an exciting beginning.

**References**

Barker, A. T., Jalinous, R., & Freeston, I. L. (1985). Non-invasive magnetic stimulation of Human Motor Cortex. *The Lancet* *, 325* (8437), 1106-1107.

Bennett, R. E. (1999). Using new technology to improve assessment. *Educational Measurement: Issues and Practice* *, 18* (3), 5-12.

Bennett, R. (2001). How the Internet Will Help Large-Scale Assessment Reinvent Itself. *Education Policy Analysis Archives* *, 9* (5).

Ben-Simon, A., Beyth-Marom, R., Inbar-Weiss, N., & Cohen, Y. (2008). Regulating the Diagnosis of Learning Disability and the Provision of Test Accommodations in Institutions of Higher Education. *IAEA Annual Conference.* Cambridge.

Berryhill, M. E., & Jones, K. T. (2012). tDCS selectively improves working memory in older adults with more education. *Neuroscience Letters* .

Cohen, Y., Ben-Simon, A., Moshinsky, A., & Eitan, M. (2008). *Computer Based Testing in the Service of Test Accommodations.* Jerusalem: NITE.

De Felice, E. A. (1997). Cranial electrotherapy stimulation (CES) in the treatment of anxiety and other stress related disorders: A review of controlled clinical trials. *Stress Medicine* *, 13* (1), 31-42.

Diaz, B. A., Sloot, L. H., Mansvelder, H. D., & Linkenkaer-Hansen, K. (2012). EEG-Biofeedback as a Tool to Modulate arousal: treands and perspectives for treatment of ADHD and insomnia. In P. Bright, *Neuroimaging -- cognitive and clinical Neuroscience* (pp. 431-450). InTech.

Escolano, c., Aguilar, M., & Minguez, J. (2011). EEG-based upper alpha neurofeedback training improves working memory performance. *Engineering in Medicine and Biology Society,EMBC, 2011 Annual International Conference of the IEEE* (pp. 2327-2330). Boston: IEEE.

Foer, J. (2011). *Moonwalking with Einstein: the art and science of remembering everything.* Penguin Press.

Francis, S. T., Head, K., Morris, P. G., & Macdonald, I. A. (2006). The effect of flavanol-rich cocoa on the fMRI response to a cognitive task in healthy young people. *The effect of flavanol-rich cocoa on the fMRI response to a cognitive task Journal of Cardiovascular Pharmacology* , 47(Supplement 2), S215-S220.

Fregni, F., Boggio, P. S., Nitsche, M., Bermpohl, F., Anatal, A., Feredoes, E., et al. (2005). Anodal transcranial direct current stimulation of prefrontal cortex enhances working memory. *Experimental Brain Research* *, 166* (1), 23-30.

Gagnon, G., Schneider, C., Grondin, S., & Blanchet, S. (2011). Enhancement of episodic memory in young and healthy adults: A paired-pulse TMS study on encoding and retrieval performance. *Neuroscience Letters* *, 488* (2), 138-142.

Halpern, C. H., Rick, J. H., Danish, S. F., Grossman, M., & Baltuch, G. H. (2009). Cognition following bilateral deep brain stimulation surgery of the subthalamic nucleus for Parkinson's disease. *International Journal of Geriatric Psychiatry* *, 24* (5), 443-51.

Hu, R., Eskandar, E., & Williams, Z. (2009). Role of deep brain stimulation in modulating memory formation and recall. *Neurosurgery, Focus* *, 27* (1:E3).

Israel, Z., Winestone, J., Zaidel, A., Rosin, B., Soreq, L., Eitan, R., et al. (2011). The future of deep brain stimulation. In I. Segev, & H. Markram, *Augmenting Cognition* (pp. 194-205). Lausanne: EPEL Press.

Klawansky, S., Yeung, A., Berkey, C., Shah, N., Phan, H., & Chalmers, T. (1995). Meta-analysis of randomized controlled trials of cranial electrostimulation: efficacy in treating selected psychological and physiological conditions. *Journal of Nervous & Mental Disease* *, 183* (7), 478-484.

Kleiner-Fisman, G., Herzog, J., Fisman, D. N., Tamma, F., Lyons, K. E., Pahwa, R., et al. (2006). Subthalamic nucleus deep brain stimulation: summary and meta-analysis of outcomes. *Movement Disorders* (supplement 14), s290-304.

Kurzweil, R. (2005). *The Singularity is Near.* New-York: Viking.

Lakhan, S. E., & Callaway, H. (2010). Deep brain stimulation for obsessive-compulsive disorder and treatment-resistant depression: systematic review. *BMC Research Notes* *, 3* (60).

Laxton, A. W., Tang-Wai, D. F., McAndrews, M. P., Zumsteq, D., Wennberg, R., Keren, R., et al. (2010). A phase I trial of deep brain stimulation of memory circuits in Alzheimer's disease. *Annals of Neurologyl* *, 68* (4), 521-34.

Loo, S. K., & Barkley, R. A. (2005). Clinical Utility of EEG in Attention Deficit Hyperactivity Disorder. *Applied Neuropsychology* *, 12* (2), 64-76.

Melby-Lervac, M., & Hulme, C. (2012). Is Working Memory Training Effective? A Meta-Analytic Review. *Developmental Psychology* .

Naam, R. (2005). *More than Human: embracing the promise of biological enhancement.* Broadway Books.

Nava, D., Landau, E., Brody, S., Linder, L., & Schachinger, H. (2004). Mental relaxation improves long-term incidental visual memory. *Neurobiology of Learning and Memory* *, 81* (3), 167-171.

Ohn, S. H., Park, C. I., Yoo, W. K., Ko, M. H., Choi, K. P., Kim, G. M., et al. (2008). Time-dependent effect of transcranial direct current stimulation on the enhancement of working memory. *Neuroreport* *, 19* (1), 43-47.

Perlmutter, J. S., & Mink, J. W. (2006). Deep Brain Stimulation. *Annual Review of Neuroscience* *, 29*, 229-257.

Shipstead, Z., Hicks, K. L., & Engle, R. W. (2012). Cogmed workingmemorytraining: Does the evidence support the claims? *Journal of Applied Research in Memory and Cognition* .

Sigman, M., Neumann, C., Jansen, A. A., & Bwibo, N. (1989). Cognitive abilities of Kenyan Children in Relation to Nutrition, Family Charactersitics abd Education. *Child Development* *, 60*, 1463-1474.

Smith, G. S., Laxton, A. w., Tang-Wai, D. F., McAndrews, M. P., Diaconescu, A. O., Workman, C. I., et al. (2012). Increased Cerebral Metabolism After 1 Year of Deep Brain Stimulation in Alzheimer Disease. *Archives of Neurology* .

Spencer, J. P. (2008). Food for thought: the role of dietary falvonoids in enhancing human memory, learning and neuro-cognitive performance. *Proceedings of the Nutrition Society* *, 67*, 238-252.

Steele, M., Weiss, M., Swanson, J., Wang, J., Prinzo, R. S., & Binder, C. E. (2006). A randomized, controlled effectiveness trial of OROS-methylphenidate compared to usual care with immediate-release methylphenidate in attention deficit-hyperactivity disorder. *Canadian Journal of Clinical Pharmacology* *, 13* (1), 50-62.

Stillings, D. (1975). A srvey of the history of electrical stimulation for pain to 1900. *Medical Instrumentation* *, 9* (6), 255-259.

Volkow, N., Wang, G. J., Fowler, J. S., Logan, J., Gerasimov, M., Maynard, L., et al. (2001 (21)). Therapeutic Doses of Oral Methylphenidate Significantly Increase Extracellular Dopamine in the Human Brain. *The Journal of Neuroscience* , RC 121.

Warwick, K., Gasson, M., Hutt, B., Goodhew, I., Kyberd, P., Schulzrinne, H., et al. (2004). Thought Communication and Control: A First Step using Radiotelegraphy. *IEE Proceedings on Communications,* *, 151* (3), 185-9.

Young, R. F., & Brechner, T. (1986). Electrical stimulation of the brain for relief of intractable pain due to cancer. *Cancer* *, 57*, 1266-1272.

Zaehle, T., Sandmann, P., Thorne, J. D., Jancke, L., & Herrmann, C. S. (2011). Transcranial direct current stimulation of the prefrontal cortex modulates working memory performance: combined behavioral and electrophysiological evidence. *BMC Neuroscience* *, 12*, 2-11.

Zoefel, B., Huster, R. J., & Hermann, C. S. (2011). Neurofeedback training of the upper alpha frequency band in EEG improves cognitiveperformance. *NeuroImage* *, 54* (2), 1427-31.