Improving Exam Performance using BDNF

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ABSTRACT
In this paper, I will be discussing the potential use of Brain Derived Neurotrophic Factor (BDNF) to improve the exam results of young people. BDNF is a protein secreted by the human body, found in the hippocampus of the brain. Recent research has proven that an increase in BDNF produced causes the neuron survival rate to increase. It has also been proven that an increase in BDNF causes an increase in the ability to retain and consolidate information. With this cumulative knowledge, it can be concluded that by increasing the concentration of BDNF present in the hippocampus, it may be possible to improve the rate of retention while studying and thereby improve exam results.

INTRODUCTION
The brain is the most complex organ in the human body, and controls all of the body’s actions. Although, the majority of neurons in the mammalian brain are developed before birth, the adult brain also maintains the ability to carry out neurogenesis. The neurons are plastic and are thus able to undergo structural change such as sprouting new branches or synapses. A synapse is the point of connection between a neuron’s axon terminals and another neuron’s dendrites. Information is transmitted from one neuron to one another through synapses. Neurotransmitters released in the presynaptic terminal are attached to receptors in the post synaptic terminal for information transfer. Figure 1. Synaptic connection between two neurons is strengthened with increased information transfer from one to the other. The majority of signals are formed by two neurotransmitters – glutamate which is stimulatory (increases activity) and gamma aminobutyric acid which is inhibitory (clamps down activity).

Brain derived neurotrophic factor (BDNF) is a member of the neurotropin group of polypeptide growth factors that direct the growth and differentiation of the developing central nervous system. BDNF works actively on certain neurons in the hippocampus, cortex and basal forebrain. In these regions, the BDNF increases the survival rates of the neurons present, encourages the growth of new neurons as well as encouraging the rate of synapses. This is done by increasing the number of dendrites. Dendrites are the receptor sites in neurons for electrical signals passed from the neurotransmitter and this allows more synapses to occur. These processes are, in some cases, aided by the cooperative reactions of BDNF and glutamate. A study carried out by Martin J (2011) in the University of Lausanne in Switzerland found that dendrical growth in cortical neurons require the secondary messenger cAMP – stimulated by the BDNF and a protein activated by glutamate.
BDNF is one of the most active neurotrophins. It is created in the endoplasmic reticulum of the cell and is secreted out of dense-core vesicles. In the Johns Hopkins News and Report Making memories: how one protein does it (2012), they report research done by Mollie Meffert who has shown how BDNF controls regulatory microRNA levels. This controls the proteins synthesized within the cells. BDNF suppressed certain microRNAs and through this enhanced the production of proteins that can enhance learning and memory.

Brain derived neurotrophic factor (BDNF) in the hippocampus (figure 2) plays a crucial role in learning and memory. In their review of the role of BDNF, Yamada K (2003) show that BDNF is formed in the endoplasmic reticulum and secreted into the synapse where it rapidly depolarises neurons through activation of tyrosine kinase (TrK) receptors and increases phosphorylation of NMDA receptors in the hippocampus. This signalling process is important for memory. The role of BDNF on memory has been studied in animals. A lack of BDNF secondary to genetic mutation or due to treatment with anti BDNF antibodies in mice resulted in an impairment in water maze learning, spatial learning and memory. Zigova T (1998) showed that infusion of BDNF into the cerebral ventricles increased the number of newly generate neurons. While endogenous BDNF is associated with memory in rats, work by Alonso M (2005) showed that infusion of human recombinant BDNF into the cortex of rats increased their long term memory. In another study conducted by Gourley S (2008) BDNF was administered to the hippocampus of rats as they were placed in stressful situations. This was done with the knowledge that rats’ memories are affected by stress related hormones such as...
glucocorticoids. With the BDNF in place, the amnesia and motivation impairment was avoided and the rats learned to carry out the required task even in a stressful situation.

**Figure 2: Location of hippocampus in brain**

![Hippocampus in Brain](http://morphons.com/software/education/science/brain/game/specimens/images/hippocampus.gif)

It is well known that exercise has beneficial effects on health and reduces cardiovascular disease, diabetes and improves general well being. The link between exercise and BDNF is becoming more well known. I would like to explore the use of exercise to improve exam performance in young people.

**DISCUSSION**

Many young people nowadays have a very sedentary lifestyle with a lot of their time spent indoors, seated, playing video games, watching TV or online in chatrooms and forums of various sorts. The recommended level of exercise for children and younger people as per the NHS Choices information on Physical activity guidelines for children and young people, is to do at least 60 minutes of exercise every day. This should be a mixture of moderate-intensity and high intensity aerobic activity every day and there should also be muscle and bone strengthening activity three times a week. But not all young people do the amount of physical activity that is required. According to the Scottish Government report ‘Health of Scotland’s Population’, in their teenage years, only around 75% of boys and 48% of girls do this amount of physical activity. When it comes to exam time, students spend even more time sitting down to study for the all important grades they must achieve to allow them entry into their career of choice.

Exam time is a period of stress in young people. This period could be associated with a reduction in BDNF levels and may adversely affect learning. In animal models of acute stress, Lubben J (2006) has found that there is an increase in glucocorticoids and in chronic stress. This is accompanied by a reduction in neuronal cells, fewer synaptic connections especially in the hippocampus and a reduction in long term memory.
Exercise and BDNF

Many studies in mice and rats have shown that exercise can increase BDNF and improve memory and learning. Different types of exercise in humans can improve different aspect of memory. High impact running can improve vocabulary memory and cycling can improve map recognition tasks and Stroop word-colour task. Baker L (2010) found that in older people with an average age of 70 years, 6 months of aerobic exercise improved performance in memory tests. It is not known if the improvements in cognitive tests seen in older people will be as effective in younger people who start off with better baseline memory function.

Studies have consistently shown that exercise can increase levels of BDNF. Griffin E (2011) showed that an acute bout of exercise transiently increases BDNF levels and increases cognitive function in human beings. They also found that chronic exercise done over a longer time does not change levels of BDNF before exercise but increases the BDNF release following exercise and improves cognitive function. Increases in BDNF levels have been shown with both aerobic exercise and when exercise with running for shorter distance is done with a load. Aguair A (2011) found that relatively short bursts of exercise can also increase BDNF levels.

However, one must be cautious. Excessive exercise may not have beneficial effects on memory. In mice that were bred to run to high levels, neurogenesis in the hippocampus increased to high levels but Rhodes (2003) found that there was no increase in learning or memory. Therefore it is unlikely that memory is likely to increase tremendously in people who exercise a lot and hence athletes would be the most intelligent people. In fact Grego F (2005) showed that exercising till one is exhausted can negatively affect ones memory, reduce learning and lead to mistakes because of exhaustion caused by the exercise.

High Intensity Interval Training

High intensity interval training (HIIT) has been used since the 1970’s as a form of exercise training. It is an efficient means of exercise that can produce the same physical benefits as conventional long duration of exercise training even though it is done for a much shorter period of time. Shiraev T (2012) has described HIIT and its clinical benefits. HIIT involves repeatedly exercising at a high intensity for 30 seconds to a few minutes at a time. This is followed by 1–5 minutes of recovery during which no exercise or very low intensity exercise is done. This cycle of exercise and recovery is repeated 4–6 times per session, with three sessions per week. Only 2–3 minutes of exercise is done at maximum intensity with 15–25 minutes of rest or low intensity exercise per session, making it a time efficient method of exercise. Less demanding protocols can be used for sedentary, overweight people who are just starting off on exercise.

De Araujo A (2012) have tested HIIT in obese children and found that this is as effective as endurance training. HIIT is more likely to be accepted by young people due to the fact that the attention span in children and teenagers is shorter and children perceive longer duration of exercise as more fatiguing. Therefore HIIT may represent a viable strategy to improve memory and exam performance in young people. The Shape magazine article ‘8 benefits of HIIT’
suggests that HIIT exercise also has the advantage of reducing fat and increasing the metabolic rate meaning that on the whole young people would be healthier. This would lead to lowering the rates of obesity and heart disease which would reduce the money needing to be spent on that area of healthcare.

There may be a relationship between when the cognitive task is done in relationship to when the exercise is done. Endorphins and BDNF are released around 20 to 30 minutes after short intensity exercise. If BDNF is the key to increasing memory and learning, the best time to study for exams might be 20 minutes after exercise or it might be the best time to memorise factual things. Therefore research searching for the best timing of HIIT that can enhance learning and exam performance in young people needs to be done.

**Ethical issues**

While HIIT may become a recognised means of improving exam performance, not all students may have access to facilities for HIIT thus leading to inequality. HIIT may not be recommended for people with disabilities who cannot perform the activities and therefore may further disadvantage this group of students in finding jobs when they are older. Studies into the benefits of HIIT on enhancing learning and exam performance should focus on how to maximise access to HIIT in all groups of students.

The underpinning factor connecting exercise to improved memory and learning is the increase in BDNF. New research technologies looking at delivery of BDNF to the brain are developing. The use of recombinant human BDNF has commenced in rats. Griffin F (2005) injected recombinant BDNF into the brains of rats and found that this can enhance learning in rats. If this was used in humans, it may be a different route to take to increase the BDNF content in the brain.

Gene therapy is the process by which genetic material is delivered into the body for treatment purposes. A viral system based gene therapy has been used to deliver BDNF to specific sites in the brain. Zhang et al have used recombinant adeno-associated virus carrying the BDNF gene to infect cells in the rat brain to stimulate the production of BDNF. This increase in BDNF was associated with nerve cell growth. There is the potential to use nanotechnology to target recombinant BDNF to specific areas of the brain, especially the hippocampus, to enhance learning and memory.

However such research is unlikely to be undertaken for the sole purpose of improving exam performance in children due to concerns about the safety of administering an intracerebral injection or using a recombinant virus. Children and teenagers would not understand to weigh the risks of participating in such an experiment. An intracerebral injection gone wrong may cause the blood-brain barrier to be damaged, leading to a pathway being created for infections to reach the brain. This could result in brain damage, making giving intracerebral injections a dangerous procedure.

It is more likely that such research on trying to deliver BDNF to the brain will progress only in people having serious illnesses. The first experiments will be to look into improving memory performance in Alzheimers disease given that this is a progressive illness with far reaching consequences because it affect day to day activities and how a person lives. Any research needs to weigh the risk benefits of therapy to the participant. So such futuristic research in younger
people can only be justified if it is undertaken for severe depression/suicidal behaviour in students who are taking exams. Gene therapy using Adeno-associated virus may be the experiments that can be used in human beings soon.

CONCLUSION
Despite the fact that exercise improves mood and increases levels of endorphins, exercise is not addicting. Endorphins bind to the same receptors that morphine binds to but the endorphin release from exercise occurs almost 30 minutes following the exercise. McGovern M (2005) suggested that the level of fortitude and determination required to endure the pain of exercise is not seen in younger people used to immediate gratification from video-games or time saving devices. The motivation for exercise therefore needs to be maintained in order to derive the benefits on memory and exam performance. As described, HIIT is likely to appeal to young people because of its high intensity, short duration and perception of less fatigue. HIIT therefore may be the way to reduce exam stress and improve memory and exam performance in young people.
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