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Movement and Cognition From the Perspective of New Technologies

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ABSTRACT

This paper discusses the relationship between movement and mental and cognitive function, as well as the potential for it to be utilized by new technologies. The first section of the paper presents the cerebral mechanisms responsible for associating physical with mental activity, and discusses examples of this influence on cognitive and emotional processes, as well as learning. The second section focuses on physical activity as an element of human interaction with a computer, including, but not limited to, so-called "exergames". The subject of physical activity and cognitive functions is presented in the final section of the paper from the perspective of immersive virtual reality technology – a tool which appears to be highly compelling. Virtual reality seems uniquely suited to research on the relationship between movement and cognitive function.

Keywords: Exemplary paper, Human systems integration, Systems engineering, Systems modeling language

INTRODUCTION

In the last 50 years, there has been a significant development of computers, which almost always involve a sitting position. This position, from the point of view of human evolution, is very unnatural and can contribute to the formation of a number of diseases, so-called civilization diseases. For the last 150 thousand years of evolution, man has led a hunter-gatherer lifestyle. Research on cultures that have preserved this way of life until today (such as the Kung) indicates that due to difficulties in finding food, a lot of time and energy is used for searching for food. It is estimated that the daily distance covered by members of these tribes is between 10 and 20 km (for men and women respectively (Cordain *et al.*, 1998). At the same time, there are indications that the need for physical activity is written in our genes (Booth *et al.*, 2002). It is likely that the link between physical activity and cognitive ability stems from the fact that the main reason humans engaged in physical activity during their evolution was to obtain food, which simultaneously required the engagement of mental processes. According to some researchers, thinking is an internalized form of movement (Llinas, 2002). This in turn leads to the fact that physical inactivity not only negatively affects many aspects of a person's physical health - many available data indicate that physical inactivity has a negative impact on mental functioning (Kramer and Erickson, 2007; Ratey and Loehr, 2011).

Given the current way of life in Western societies, it is hard to imagine that people would suddenly make such a significant change in their habits to walk ten or twenty kilometers a day. Fortunately, research indicates that even a much lower level of activity can lead to positive effects on mental functioning. It turns out that as little as 30 minutes of exercise causes a noticeable improvement in memory or coordination (McDonnell *et al.*, 2013). Half an hour of activity is also known to improve cognitive functioning in people with depression. Also, short but intense types of explosive activity, such as sprints, improve memory (Winter *et al.*, 2007).

In recent years, with the growing popularity of technologies such as virtual reality and smartphones, the way of using computers is changing from stationary to mobile. This change is important because it opens up the possibility that computers may go from being a factor promoting stationary and sedentary lifestyles, and thus having a negative impact on health, to being an element in the fight against the spreading epidemic of immobility. This potential area of interest is also very attractive from a commercial perspective, hence large corporations in the electronic entertainment industry such as Nintendo or Sony have been trying to introduce various solutions aimed at activating users' movement. Nintendo created the Wii console, and the Playstation console was equipped with Move controllers or EyeToy camera. Also, for more modern solutions in the field of virtual reality are created for various forms of activity such as Icarus or VirZoom. It is therefore worth asking the question to what extent computer systems can be effective in stimulating physical activity and thus improve mental functioning. First, however, it is useful to gather some basic information about the effects of movement on brain function.

MOVEMENT AND COGNITIVE FUNCTION

As early as the 19th century, Galton conducted research on arousal and how its levels affect performance on various tasks. This research lays the foundation for current research on the effects of physical activity on cognitive functioning. As part of this work, a structure was discovered in the mid-1920s that provided a potential neurophysiological basis for the relationship between mental processes and physical activity. This structure was the reticual activation system (Lindsley *et al.*, 1950). The RAS is a network of neurons located in the brainstem that sends its connections to the cortex, among other things. The RAS is responsible for regulating states of wakefulness and sleep, as well as providing arousal levels during wakefulness. RAS activity decreases with age, which is thought to account for the differences observed in a number of experiments on reaction times - the reactions of older people around the age of 60 are at least 20-50 percent slower than those of younger people (Birren and Fisher, 1995; Salthouse, 2000). Since RAS activity is related to what an individual's momentary activity level is, one might suspect that the sitting position is the least conducive to mental tasks. According to the Yerkes-Dodson law (Yerkes, Dodson and Others, 1908) An inverted-U relationship would be expected here, i.e., that both too little and too much stimulation of the RAS would have a negative effect on mental task performance. This potential possibility is also supported by studies on people with pacemakers - externally increasing the frequency of heart contractions led to better performance on mental tasks (Lagergren, 1974).

Even a short period of exercise can affect the performance of the human mind. There is ample evidence that just one exercise session can have a positive effect on cognitive functioning, improving, for example, working memory (Lambourne and Tomporowski, 2010). These effects persisted even up to an hour after the exercise. Similar results were also observable for example for cognitive flexibility (Heath and Shukla, 2020).

All these results make it clear that if the goal of societies is to nurture the mental development of young people and also to ensure that the elderly can function effectively, then it is important to look for ways to increase physical activity. Can technology help with this?

PHYSICAL ACTIVITY IN VIDEO GAMES

Physical activity games (exergames also called) active video games (AVGs), have the potential to be an effective method of promoting physical activity. These types of games have been shown to have the same benefits at a physiological level as physical exercise (Gao *et al.*, 2015) and also cause a change in attitudes, such as increasing motivation to engage in activity. Energy expenditure in AVG games and traditional training is also similar (Luke, 2005). However, the problem identified by the researchers is the jumping nature of the physical effort - periods of activity (game) are often interspersed with breaks resulting from the reloading of game elements (Smith, 2005). The AVG phenomenon has been very successfully exploited commercially by console manufacturers by creating so-called sports games. It also turns out that applications such as Pokemon GO can affect users' activity levels (Howe *et al.*, 2016) despite the fact that users used this application primarily for fun and social reasons (Broom *et al.*, 2019).

VIRTUAL REALITY AND PHYSICAL ACTIVITY

A promising area for developing methods to promote physical activity and thus effective cognitive functioning is virtual reality. This technology could help to increase motivation while reducing the natural tendency of users to avoid the effort associated with exergames. A game played in virtual reality could include elements that force the user to move their entire body. The potential of this technology has been tested even before the launch of widely available immersive headsets like the Oculus Quest or HTC Vive. One such solution was the Astrojumper game created by Finkelstein and colleagues (Finkelstein *et al.*, 2011). It is an arcade game set in space, in which the player must jump, squat and bend to avoid planets rushing towards him. The game itself takes place in a room on the walls of which a stereoscopic image is projected, and the user's movement is tracked thanks to sensors mounted on the body. User evaluations indicated that they found the game motivating and encouraged them to exercise. One factor that is exemplified in the effectiveness of exergames as a tool to promote physical activity is that the technology naturally distracts the user from the physical activity itself. In the case of exergames using ergometers, for example, this factor proved to be effective. The effort combined with the game also evoked more positive emotions in the users (Glen *et al.*, 2017). Virtual reality can be expected to be even more effective in this regard. Reports of initial reactions to being in an immersive VR environment clearly indicate that the experience is perceived by users in terms of experiencing, or being transported to, another world, rather than in terms of pure perception (Bohdanowicz *et al.*, 2020). Virtual environments are effective in evoking emotions in users (ie. (Pan *et al.*, 2018)). This significantly affects attractiveness, and Sinclair's dual-flow game attractiveness model suggests that attractiveness will affect exercise effectiveness, measured as training intensity (Sinclair, Hingston and Masek, 2007).

PSYCHOLOGICAL EFFECTS OF EXERCISE IN VIRTUAL ACTIVITY

Much is known about the impact of physical activity on cognitive functioning. Much is also known about how to use virtual reality to motivate people to exercise, and how effective such training is compared to real world activity. What is missing so far is a strong connection between these two strands from the research side. There are reports in the literature that are usually limited to very specific domains - these are studies on the functioning of older adults with cognitive deficits, on rehabilitation, or focusing on reducing symptoms of depression or depressive states. However, even in these areas, reports are few. A 2020 systematic review of the literature on the effects of training in VR (psychological, physiological, and rehabilitation effectiveness) found only 4 such papers (Qian, McDonough and Gao, 2020). Additionally, a great many different types of training can be implemented in VR, after all, not necessarily based on taking advantage of the movement capabilities offered by the technology. An example would be the aforementioned depression and medication studies. In these areas, VR exposure therapy (VRET) is the typical method, while studies on the effects of movement or physical activity are isolated.

Plante and colleagues (Plante *et al.*, 2003) examined potential psychological benefits of VR training. They compared responses to four types of activity - traditional walking, treadmill walking, treadmill walking in VR, and virtual walking in VR (in a seated position). It turned out that treadmill walking combined with VR most strongly increased subjects' energy levels, reducing tension and fatigue. In a fairly similar study on cycling and mood (William D. Russell and Mark Newton, 2008) researchers did not show an effect of VR on mood, they did show efficacy in this area of exercise alone compared to being sedentary. The effect of VR was also observed for cognitive function (Sañudo *et al.*, 2020), such as cognitive flexibility and selective attention, which (measured with Wisconsin Card Sorting Test (Heaton, 1993) and Strop Test (Scarpina and Tagini, 2017)). The Wisconsin Card Sorting Test involves sorting cards based on constantly changing rules and is used to test cognitive flexibility. The Stroop test measures the ability to inhibit cognitive interference, i.e., the ability to respond to certain features of a stimulus while ignoring others. In its most popular implementation it consists in reacting to words of different colors appearing on the screen (e.g., the word 'red' written in blue). The task is to react to the color of the word, ignoring its meaning. The results suggest that VR technology used to enrich physical activity can positively affect cognitive flexibility and selective attention. A study conducted on college students using immersive VR paired with a stationary bike (VRZoom) indicates that experiencing virtual reality during a workout positively affects their ratings on self-perception of their abilities and subjectively perceived enjoyment (Zeng, Pope and Gao, 2017).

However, when analyzing the results of the studies presented above, it should be kept in mind that they were not always performed in systems that provided full immersion. Also, the type of movement studied was very limited and specific (exercise bike/runway) and did not include interaction with the surrounding environment. These studies did not completely exploit the potential to engage people in terms of movement that virtual reality offers.

CONCLUSION

In conclusion, it seems that computer technologies such as virtual reality can be useful in promoting a higher quality of life, not only by increasing physical activity levels.

Such improvements may also occur because, as indicated above, increased physical activity is associated with improved cognitive functioning. It especially important from the perspective of increasing epidemic of obesity and neurodegenerative diseases.

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