



Effect of Caffeine on the Fixation Component of Eye Movement in the Reading Process

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ABSTRACT

Background: Caffeine is a kind of methylxanthine whose consumption can promote the cognitive and executive functions of the human brain.

Objectives: In this study, we seek to investigate the effect of drinking coffee on the period of the eye movement fixation component.

Materials and Methods: The research was of the quasi-experimental type. 60 subjects were randomly divided into two groups of thirty. The subjects in one group drank coffee before the experiment was conducted. The other group, which is the control group, did not. Both groups would then read a text, and the eye movement tracking device would record the fixation periods of the subjects' eyes while reading.

Results: The results of the independent t-test comparing the mean fixation time in the two groups demonstrated that the difference was significant at the 0.001 level, where the group that drank coffee before studying had significantly less fixation time than the control group. Additionally, Cohen's d index of 4.29 determined that the difference lies in the maximum effect size range.

Conclusion: It can be concluded that drinking a cup of coffee before studying can lead to decrease in eye movement fixation period and increase in information encoding and processing speed.

Keywords: Caffeine; Fixation; Ocular; Reading; Eye Movements

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Introduction

Caffeine is a kind of methylxanthine used in many foodstuffs including drinks and chocolate, some pharmaceutical formulations, and sports supplements, and is the most frequently used psychoactive substance worldwide [1]. It also stimulates the central nervous system, heart

muscles, and the respiratory system, and postpones fatigue [2]. The caffeine taken orally can be absorbed through the digestive system very quickly at a rate of 99 percent, and it finally reaches its maximum density in the blood plasma up to an hour after taken, where it reveals its effects by blocking the

adenosine receptors in the brain [3]. Caffeine can cause different effects in different dosages, but taking 60 milligrams of it, usually available in a cup of coffee, can lead to improvement in consciousness and mood [4]. Caffeine consumption can also promote the cognitive and executive functions of the human brain [5]. An increase in selective attention and information processing speed has also been reported after drinking beverages containing caffeine [7,14]. The effectiveness of caffeine on cognitive functions was also observed using MRI [8,15]. It was also demonstrated in another study with the same tools that caffeine can lead to improvement in executive functions [9]. Caffeine can also increase sustained attention [6,13]. One of the cognitive skills of the human brain is the reading skill, which includes language, attention, memory, and perception. Reading is a dynamic, decoding process through which readers can learn about the message of the text. The major part of the information we seek every day is obtained through reading [10]. Reading includes the ability to extract visual information from the paper and comprehend its meaning [11]. Investigation of reading has a long history in psychological research. However, as technology is expanding and modern tools are always innovated, research in this field is also evolving, and the obtained results are more precise. Furthermore, the new tools make it possible today to track and study the class of components and variables that could not have been examined and investigated before. One of these tools is the eye tracking device, used for examining the different components of eye movements. Fixation is one of the eye movement components, the period of which is evaluated in psychological research as an index for assessment of encoding and

information processing. Thus, the lower the fixation period of a word is, the faster it is encoded and processed [12]. Fixations are like a series of photographs. What is involved in a fixation is that the eyes are fixed on the presented stimulator in a fraction of a second. The stimulator can be part of an image or a word in text. It is during the fixation process that information is received from the stimulator concerned.

Given that caffeine consumption leads to changes in the cognitive functions of the brain, and that many people obtain it every day through different drinks to promote their attention, concentration, and consciousness, we seek in the present research to investigate the effect of drinking caffeine-containing drinks on the eye movement fixation component during the reading process. This will lead to a more precise acknowledgement of its effectiveness by studying it with modern tools and from a different angle. It is hypothesized that drinking coffee before studying leads to a decrease in the eye movement fixation component period.

Materials and Methods

The research was of the quasi-experimental design type. The subjects were initially selected by the convenience sampling method, then they were placed in groups, and the quality of intervention in each group was determined randomly. Methods of descriptive statistics, including frequency, mean, and standard deviation, as well as methods of inferential statistics, such as independent t-test, were used for data analysis. The research was conducted by first having the subjects read a familiar text on Gestalt psychology. For assessment of the eye movement fixation component, 10 technical words were first selected from the text

concerned, and the fixation values in the words were evaluated and statistically analyzed.

Statistical population and statistical sample

The statistical population of this study included all male and female Bachelors level students of the Faculty of Psychology and Education of Shahid Beheshti University who were studying in academic year 2015–2016. In this study, convenience sampling was used. First, one hundred people were selected and then due to their being available during the study, the final number of statistical sample was narrowed down to 60 individuals. The rest were excluded from the study. Then, the subjects were divided into two groups. To eliminate the gender-induced effect on result interpretation, each group was formed with equal numbers of male and female subjects.

Instruments

To measure eye fixation as the dependent variable during studying of the text, the SMI-RED-120Hz model eye tracking system was used. The system setup included a 22 inch screen for presenting the text which is the stimulus, a receiver device of infrared waves for registration of eye movements with a sampling speed of 120 Hz per second, iView X software for eye movement data analysis and interpretation, experiment center software for designing the experiment and the way of presenting stimuli, and BeGaze software for the final analysis of registered data, which calculates and reports the values of measurement error for the place of eye fixations (deviation from the X axis and deviation from the Y axis); therefore, experimental attempts with high errors are recognizable and can be discarded from the experiment. Furthermore, another index known as tracking ratio is also computable;

this is the time percentage of the subject's eyes tracked by the device.

Methodology

Subjects attended individually in the psychology laboratory of Shahid Beheshti University. To conduct the experiment, one group drank a cup of espresso coffee which contained approximately 60 mg of caffeine and the control group did not drink coffee. After a period of 15 to 30 minutes and receiving the necessary explanations and instructions about the experiment, the subjects were asked to sit on a chair in front of the eye tracking system with a distance of 60 centimeters from the device. After performing the calibration stage, the subjects formally participated in the experiment. At the beginning of the experiment, the validation stage of the eye tracking system was performed to recognize the measurement error value of eye movements. Then, subjects observed the stimuli on the screen and read them. The text font was B Nazanin with size 14. The fixation of eyes on the 10 technical words previously mentioned in the method section of this article was recorded by the device.

Result

After calculating the time of eye fixation for each group, an average time fixation value per subject was calculated. This is technically an average of 10 fixation times corresponding to 10 reading trials per subject. At the end, the mean and standard deviation of average values for each group were calculated which are summarized in table 1.

Table 1. Mean and standard deviation of fixation duration of each group, in milli second

Standard deviation	Mean	Number	Groups
10.57 (ms)	227.55 (ms)	30	With coffee consumption
12.34	276.87	30	Without coffee consumption

To select the suitable parametric or non-parametric statistical test, initially the data normality was assessed by the Shapiro-Wilk test. According to the result of the normality test, data are normal and for this purpose, parametric independent t-test was used for statistical analysis.

The results of the independent t-test in Table 2 show that there is a significant time fixation difference in the 0.001 level between two groups. Hence, the underlying research hypothesis was confirmed and it could be concluded that coffee consumption before studying results in decreasing fixation times of eye movements during studying. Also, the calculated effect size is greater than 0.8, which is placed in the period of the most Cohen effect size.

Table 2. The t-test results of fixation duration for two groups of study

Effect size of Cohen's d index	4.29
Difference of the standard error of two groups	2.96
Difference of means of two groups	49.32 (ms)
Significance level	0.001
Degree of freedom	58
t value	16.623

Discussion

On the basis of the results of underlying research, it can be concluded that drinking coffee before studying can be effective in decreasing the time of eye fixations. As it was mentioned in the introduction, fixation is considered as an index for evaluating information processing speed and its encoding. So, it seems that the difference observed in the time of fixations of two groups may be due to the difference in the quality of encoding and information processing speed of each group. In other words, the group who consumed coffee had less fixation times than the other group. Therefore, it can be concluded that their cognitive function was at a better level and

also the processing speed and information encoding were more effective in this group. The results of this research are consistent with the results of Beachwood *et al.* study indicating that coffee consumption can result in the improvement of consciousness status [4]. Also, these results are consistent with the results of some other studies [5,9,15], that showed caffeine can improve the brain's executive functions. In addition, these results are in line with the result of Lanini *et al.* study, which shows that caffeine causes an increase in information processing speed [7]. So consuming a cup of coffee before studying is recommended. On the basis of the results of the underlying research, it can be concluded that fixations, at least in the first time of reading a text, can be a good criterion for evaluating encoding speed and information processing. This is because in the next round of reading repetition, there is this possibility that fixations will become less as a result of repetition and habituation. This does not necessarily lead to improvement in information processing and encoding. Since the underlying results are consistent with the results of abovementioned studies, it seems viable to further investigate the effect of different stimuli with various caffeine doses on quality and speed of the information processing. As mentioned in the introduction, MRI can be used in psychological studies to investigate the effect of caffeine. This research confirms that an eye movement tracking device may also be a suitable instrument for achieving meaningful results in this type of studies. In present work, caffeine consumption was evaluated but there are more psychoactive compounds that can be evaluated with the same method. There is also a possibility that an upsurge in consumption of psychoactive compounds such as caffeine

(which is beneficial at 60 mg dose based on the outcome of this research) can exhibit an inverse effect by increasing the subjects' levels of anxiety and intoxication. Hence, it is proposed that the present experiment to be repeated at different doses. By using this method, the most products which claimed to be effective for mental and cognitive functions can be evaluated. In addition, it is proposed that the sustainability duration of the effect of these psychoactive compounds to be studied as well.

Conclusion

The findings of this research suggest that, fixation duration decreases with respect to caffeine consumption. Therefore it can be concluded that drinking a cup of coffee before studying can lead to an increase in information encoding and processing speed in subjects who are not medically restricted to drink coffee.

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Conflict of interest

The authors have no conflict of interest.

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