5-2005

Effects of caffeine on reading performance on the Visagraph2

Kelly K. Larsen
Pacific University

Jeffrey L. Mellor
Pacific University

Effects of caffeine on reading performance on the Visagraph2

Abstract

Caffeine is a drug that "wakes people up" and stimulates the central nervous system. It is frequently found in many beverages and other consumed products. It also comes as an over-the-counter supplement. Since it is so common and gets used to help people stay awake during reading tasks, we wanted to see what effect it has on comprehension, attention and eye movements when reading. To do this we screened 27 optometry students for health problems and tested them twice on the Visagraph2, an instrument that objectively monitors eye movements and tests comprehension of material read. Tests were conducted when subjects had no caffeine in their system and when caffeine was at its highest concentration in their blood. Some started on caffeine and others did not in an attempt to limit a learning affect. In an analysis of our data, we found better performance when not on caffeine that was statistically significant in the number of fixations, regressions and percent of directional attack. Span of recognition, comprehension, rate with comprehension and grade level efficiency were also better when not on caffeine, but they were not statistically significant. Reading rate without comprehension was slower and the average duration of fixation was longer when not on caffeine. However, since comprehension was better and their were fewer fixations when not on caffeine it can be concluded that caffeine made reading more erratic and less efficient. In short, not using caffeine makes reading more efficient and improves comprehension. Using caffeine makes reading quicker, but less efficient and decreases comprehension. This means that caffeine keeps the mind and body "awake," but may not make you a better reader.

Degree Type

Thesis

Degree Name

Master of Science in Vision Science

Committee Chair

Leland W. Carr III

Subject Categories

Optometry

Kelly K. Larsen, O.D.

Jeffery L. Mellor, O.D.

A thesis submitted to the faculty of

Pacific University

College of Optometry

&

College of Education

For the degree of

Master of Arts in Education/Visual Function & Learning

May 2005

Advisors:

Leland W. Carr III, O.D.

Scott C. Cooper, O.D., M. Ed.

Anita McClain, M. Ed., Ed. D.

Effects of Caffeine on Reading Performance on the Visagraph2

Authors:

____

Kelly K. Larsen, O.D.

____

Jeffery L. Mellor, O.D.

Advisors:

____

Leland W. Carr III, O.D., Dean of the College of Optometry,
Clinical Professor of Optometry

____

Scott C. Cooper, O.D., M. Ed., Associate Professor of Optometry

____

Anita McClain, M. Ed., Ed. D., Professor of Education

Biographies

Kelly Larsen earned a Bachelor of Science degree in Human Biology at Eastern Washington University in 2000 and her Doctor of Optometry degree in 2005. She will continue her study of optometry as a resident of the Spokane VAMC.

Jeff Mellor is from Utah and comes from a family of seven. He received a B.S. in Medical Laboratory Science and a minor in chemistry from the University of Utah in May of 2000. He also received a Doctor of Optometry degree (O.D) in May of 2005 from Pacific University and is pursuing a Master of Arts in Education/Visual Function in Learning (M. Ed./V.F.L.) also from Pacific University. He will be doing a residency at the Salt Lake VAMC from July of 2005 to June of 2006 and plans on practicing optometry in the Salt Lake City, Utah region after that. He has been strongly supported by his wife through his education and has two children.

I. Abstract

Caffeine is a drug that "wakes people up" and stimulates the central nervous system. It is frequently found in many beverages and other consumed products. It also comes as an over-the-counter supplement. Since it is so common and gets used to help people stay awake during reading tasks, we wanted to see what effect it has on comprehension, attention and eye movements when reading.

To do this we screened 27 optometry students for health problems and tested them twice on the Visagraph2, an instrument that objectively monitors eye movements and tests comprehension of material read. Tests were conducted when subjects had no caffeine in their system and when caffeine was at its highest concentration in their blood. Some started on caffeine and others did not in an attempt to limit a learning affect.

In an analysis of our data, we found better performance when not on caffeine that was statistically significant in the number of fixations, regressions and percent of directional attack. Span of recognition, comprehension, rate with comprehension and grade level efficiency were also better when not on caffeine, but they were not statistically significant.

Reading rate without comprehension was slower and the average duration of fixation was longer when not on caffeine. However, since comprehension was better and their were fewer fixations when not on caffeine it can be concluded that caffeine made reading more erratic and less efficient.

In short, not using caffeine makes reading more efficient and improves comprehension. Using caffeine makes reading quicker, but less efficient and decreases comprehension. This means that caffeine keeps the mind and body "awake," but may not make you a better reader.

II. Discussion

A. Definitions

- Adjusted reading rate
- Comprehension
- Directional Attack
- Duration of Fixation (DOF)
- Fixations
- Pursuits
- Rate with comprehension
- Regressions
- Saccades
- Span of Recognition (SOR)

B. Introduction

Caffeine is the most commonly used drug in Western society.[1] Students frequently ingest caffeinated beverages and over-the-counter caffeine pills in an effort to remain alert and focused during study sessions. Because caffeine is used so frequently it is important to know what effect caffeine has on the reading task.

Previous investigations into the benefits of caffeine on study performance have been conflicting. While most researchers agree that caffeine has beneficial effects in low alertness states by counteracting reductions in the turnover of central noradrenaline, there has been some suggestion that caffeine usage is related to inferior performance on tasks requiring extensive cognitive effort.[1-4]

Several studies have attempted to determine the benefits and detriments of caffeine ingestion on visual accommodation and convergence, reading rate, eye-hand coordination and information processing.[2-7] However, the effects of caffeine on eye movements during the reading task have not been studied extensively.

Since there is limited information on the effects of caffeine on the eye movements used in reading, it is the aim of this study to determine if eye movements and other related variables during reading are hindered, enhanced or unchanged during a state of caffeine-induced arousal. Another aim is to provoke further investigation into the effects that caffeine has on the task of learning. With improved understanding of these matters, the use of caffeine to stay awake during a reading or learning task can be done more wisely.

C. Caffeine Pharmacology

1) Caffeine Levels of Commonly Consumed Products

- Coca-Cola (8 oz.) = 23 mg
- Diet Coke (8 oz.) = 31 mg
- Coffee, dripped brew (8 oz.) = 65-120 mg (85 mg typical)
- Brewed tea (U.S., 8 oz.) = 20-90 mg (40 mg typical)
- Cocoa (8 oz.) = 3-32 mg (6 mg typical)
- Milk chocolate (1 oz.) = 1-15 mg (6 mg typical)
- Dark chocolate (1 oz.) = 5-35 mg (20 mg typical)
- Pepsi Twist (8 fl. oz) = 25 mg
- Diet Pepsi Twist (8 fl. oz) = 24 mg
- Pepsi ONE (8 fl. oz) = 37 mg
- Pepsi Blue (8 fl. oz) = 25 mg
- Diet Pepsi (8 fl. oz) = 24 mg
- Pepsi (8 fl. oz) = 25 mg
- Mr. Green (8 fl. oz) = 37mg
- Diet Mountain Dew (8 fl. oz) = 37 mg

- Mountain Dew (8 fl. oz) = 37 mg
- Dr. Pepper (8 oz.) = 26.4 mg
- No Doz = 100 mg

2) Caffeine Pharmacodynamics

Caffeine affects all systems of the body via a complex mechanism of action. It is believed that caffeine takes its effect primarily via adenosine antagonism. Adenosine acts presynaptically to inhibit the release of acetylcholine, norepinephrine, dopamine, gamma amino butyric acid (GABA), and serotonin. Through a process of competitive inhibition of adenosine receptors, caffeine allows for the release of norepinephrine, dopamine, and serotonin in the brain, thereby increasing the systemic concentration of catecholamines. Catecholamines have a stimulatory effect on the nervous and cardiovascular systems; they are also associated with an increase in metabolic rate, body temperature and smooth muscle tone.[1]

3) Caffeine Pharmacokinetics

The body via oral, rectal or subcutaneous administration absorbs caffeine quickly. When in the body it gets converted into 1-methyluric acid and 1-methylxanthine by the liver. It typically has a half-life of 3.5 hours and reaches a blood level peak after two hours of oral administration. When taken with food its absorption is not changed significantly.[8]

D. **Eye Movements & Reading**

Several different eye movements take place during the reading task. These eye movements include saccades, fixations, regressions and return sweeps. Saccadic eye movements are very high speed, ballistic eye movements that take place between fixations. During these movements central vision is suppressed to avoid the perception of retinal blur. The blurred image is actively suppressed or masked so that only clear images are seen immediately before and after the saccade. Better/faster readers are able to make fewer and larger saccadic eye movements during reading. Fixations are the stops or pauses between saccades. It is during these pauses that the information being read is processed. The number and duration of fixations vary according to reading ability and difficulty of reading material with better/faster readers making fewer and briefer fixations. Regressions are backwards eye movements that are necessary when one must reread a piece of information that was not understood during the initial fixation. Better/faster readers make fewer regressions. When at the end of a line a reader moves his eyes to the start of the next line on the other side of the page and it is called a return sweep. Efficient readers have accurate return sweeps (they don't lose their place easily). Figure one shows the eye movements involved in reading. Figure two shows the eye movements of an efficient reader and figure three shows the eye movements of an inefficient reader.

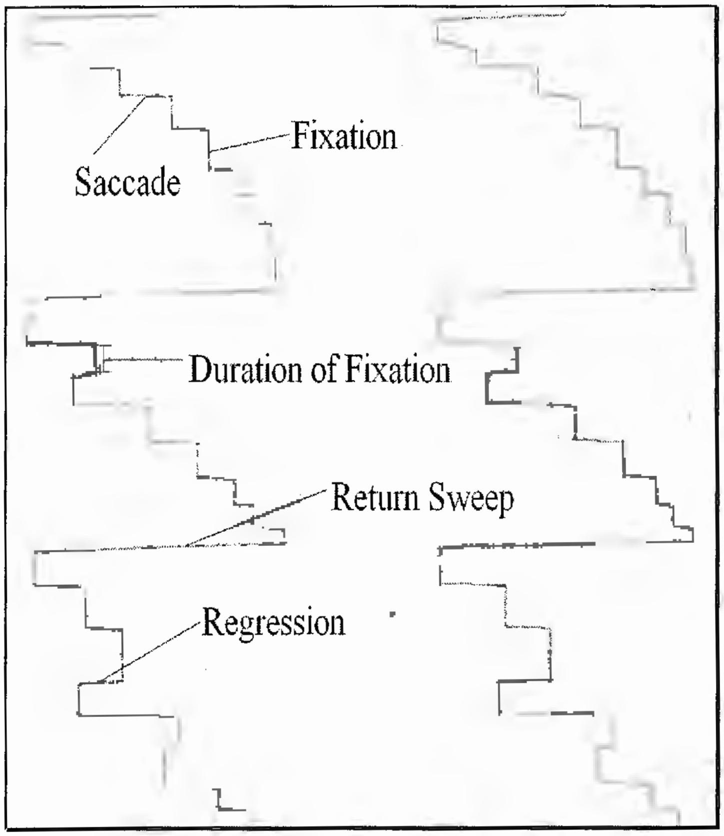

Figure #1

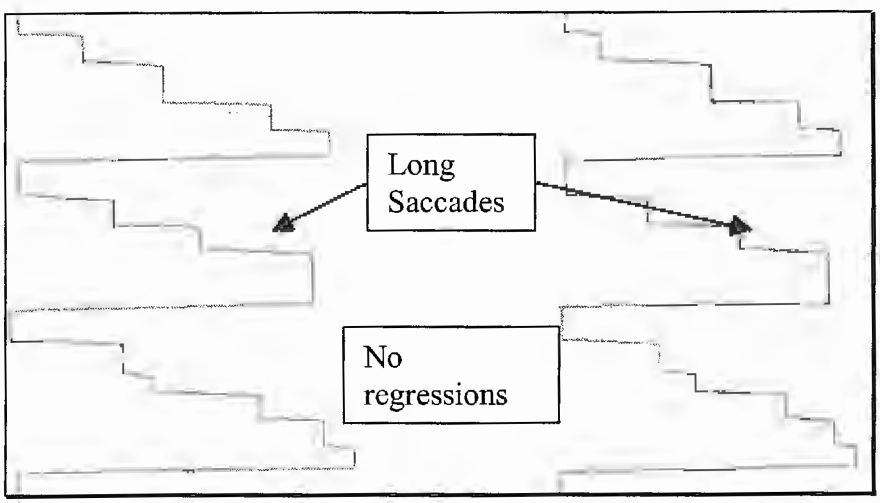

Figure #2-Efficient Reader

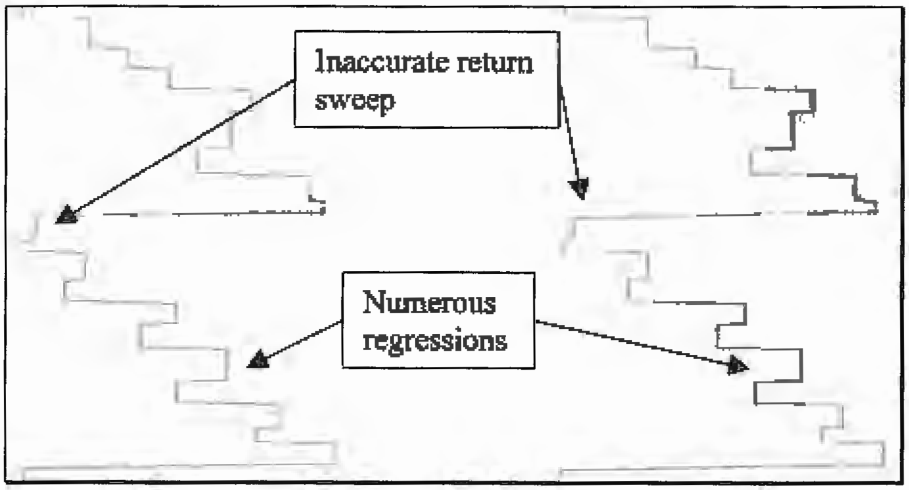

Figure #3-Inefficient Reader

Pursuits are smooth eye movements and used to follow slow moving targets. However, they have little to do with the task of reading so they will not be discussed further.

E. **Other related Factors**

Other important variables involved in the reading task include span of recognition, directional attack, reading rate, and comprehension. Span of recognition is the spatial extent of visual information (the number of letters or words) that can be processed during a single fixation. More proficient readers have larger spans of recognition; that is, they are able to process a greater amount of information during each fixation. Directional attack is the percentage of reverse-to-forward eye movements. Better readers have a lower percentage of directional attack. Reading rate is the number of words read/minute. Efficient readers read quickly, but also have good comprehension. Comprehension is the understanding an individual gets from the material being read.

A factor that is often overlooked when analyzing reading is attention. Attention is the control system of oculomotor eye movements when reading. In those that have a poor ability to maintain attention, like children with attention deficit hyperactivity disorder (ADHD), reading skills are usually slightly below average to poor. The effect that caffeine has on attention may influence eye movements when reading.

II. Testing

A. Health Assessment

Prior to participating in the study all 27 subjects were required to complete a health questionnaire in order to screen for pre-existing medical disorders that might have been exacerbated by the administration of caffeine, including, allergies to caffeine, hypertension, liver disease or kidney disease. Individuals who reported having any of these conditions were excluded from the study.

Prior to testing, a measurement was taken of each participant's blood pressure and heart rate. Acceptable criterion for blood pressure was set as follows: systolic pressure between 100 mmHg and 140 mmHg and diastolic pressure between 60 mmHg and 100 mmHg. The acceptable criterion for heart rate was determined to be between 60 and 100 beats per minute.

B. Visagraph2

The Visagraph2 is a standardized, objective, and automated system that assesses the specifics of reading eye movements. The reading eye movement skills that are assessed by the Visagraph2 system include:

- Fixations/100 words
- Regressions/100 words
- Average span of recognition
- Average duration of fixation
- Rate with comprehension
- Adjusted rate
- Grade level efficiency
- Directional attack
- Comprehension
- Cross correlation

C. Experimental Design

Participating subjects' reading eye movements were tested on the Visagraph2 Reading Eye Movement Recording System on two separate occasions, one with caffeine (from a caffeine pill) in their system and one without caffeine in their system. Prior to testing they were asked to refrain from the consumption of caffeinated beverages or foods and also caffeine supplements for 24 hours before testing or before taking our 200-milligram supplement of over-the-counter caffeine to eliminate any caffeine from their system. This helped to standardize our measurements. When caffeine supplements were taken for our testing, it was two hours prior to testing to assess caffeine's maximal effect (subjects were asked to not ingest any caffeine in that two hour time frame also to avoid "measurement contamination").

Subjects were divided into two groups. The first group consisted of 16 subjects who took the caffeine supplement before the first testing session and none before the second testing session. The second group of 11 subjects had no caffeine supplement before the first testing session and then took one before the second testing session. By mixing up subjects that started with and without caffeine, we were looking to limit any learning effect that may have occurred because of multiple testing sessions.

During each testing session on the Visagraph2 subjects did two trials. The first trial was a "practice run" and the second trial was the one we used for our measurements. This "practice run" warmed our subjects up and got them familiar with the testing procedure.

III. Results

A. Analysis

Overall reading performance and eye movement efficiency was better when caffeine was not ingested. When not on caffeine, performance was better by a statistically significant amount at the 0.05 level in fixations/100 words (7.30 fewer fixations/100 words), regressions/100 words (3.4 fewer regressions/100 words), and directional attack (0.02% lower).

When not on caffeine there was also a slightly larger span of recognition (0.4 words larger), greater grade level efficiency (0.84 greater), better comprehension (0.02%) and faster reading rate when corrected for comprehension (3.63 words/minute). However, those results only showed a trend and were not statistically significant.

Reading rate without correction for comprehension was slower and the average duration of fixation was shorter when not on caffeine. Although these results do not indicate improved performance, when taken into context and corrected for they show better efficiency when not on caffeine. It also indicates that time spent receiving, organizing and analyzing information was reduced when on caffeine. Table #1 has a summary of our results.

	Fix./100 Words	Reg./100 Words	Ave. SOR	Ave. DOF	Rate w/ Comp	Rate Adj.	Grade Level Eff.	Dir. Attack	Comp.	Cross Corr.
Ave. on caffeine	102.67	16.19	1.09	0.24	273.70	300.11	10.56	13.85%	80.00%	0.97
Ave. no caffeine	95.37	12.74	1.13	0.25	277.33	295.00	11.40	12.19%	81.85%	0.96
Diff.	[redacted]	[redacted]	[redacted]	0.01	[redacted]	-5.11	[redacted]	[redacted]	0.02	-0.01
T-test	0.0491	0.00988	0.25	0.1	0.7222	0.6465	0.0977	0.0393	0.5105	0.481

[redacted]

Statistically significant

Table #1

IV. Conclusion

The results of this study suggest that both the efficiency of reading eye movements and the degree of comprehension during the reading task are both negatively affected by the consumption of caffeine. From our data we concluded that avoiding caffeine when studying might be beneficial. However, when studying late for an exam early the next day it may be better to take some caffeine to remain alert and learn something than fall asleep and learn nothing.

Experience from this project has demonstrated four ways that could enhance further testing in this area. First, better measurements would have been attained if a few trials were run on the Visagraph2 after the first one and then averaged together. The average of those trials would have limited some random error. Second, instead of using a standard dose of 200 mg per subject, a particular amount should be given per unit of body weight (i.e. mg of caffeine/kg of body weight). This would assure a more standardized level of caffeine in the system of each participant. Third, there should be an equal balance of participants that start with caffeine when tested and those that do not start with caffeine when tested. It would further eliminate a learning effect from measured data. Fourth, a larger number of participants would also add more validity. These factors would be important in further study in this area.

References:

1. Smith A, Brice C, Nash J, Rich N, & Nutt D. Caffeine and central noradrenaline: effects on mood, cognitive performance, eye movements and cardiovascular function. Journal of Psychopharmacology, 2003; 17(3): 283-292.

2. Anderson K, Revelle W. Impulsivity, caffeine, and proofreading: a test of the Easterbrook hypothesis. Journal of Experimental Psychology: Human Perception and Performance, 1982; 8(4): 614-624.

3. MacPherson J, Sternhagen S, Miller T, Devitt M, & Petros T. Effect of caffeine, impulsivity, and gender on the components of text processing and recall. Experimental and Clinical Psychopharmacology, 1996; 4(4): 438-446.

4. van Boxtel J, Schmitt J, Bosma H, & Jolles J. The effects of habitual caffeine use on cognitive change: a longitudinal perspective. Pharmacology, Biochemistry and Behavior, 2003; 75: 921-927.

5. Putz-Anderson V, Setzer J, & Croxton J. Effects of alcohol, caffeine and methyl chloride on man. Psychological Reports, 1981; 48: 715-725.

6. Kirshner A, Schmid R. The effects of caffeine on near point plus acceptance. Journal of the American Optometric Association, 1984; 55: 97-101.

7. Zhai H, Goss D, & Hammond R. The effect of caffeine on the accommodative response/accommodative stimulus function and on the response AC/A ratio. Current Eye Research, 1993; 12(6): 489-499.

8. www.maripoisoncenter.com/ctr/9411caffeine.html