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An experimental study of the effect of caffeine upon athletic performance

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AN EXPERIMENTAL STUDY OF THE EFFECT OF CAFFEINE UPON ATHLETIC PERFORMANCE

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by

Roger Baer III

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CHAPTER I

INTRODUCTION

The improvement of physical performance has long been a problem of great importance to athletes, coaches, and physical educators. Many different methods and techniques of coaching, conditioning, and motivation have been utilized in an effort to push the participant to his top or ultimate performance.

There is much conjecture as to whether this optimum or top level of performance can be raised by artificial stimulation after peak condition has been reached and the skills involved in the performance have been mastered. According to Boje[1], stimulants are widely used today by athletes in all types of competition. He groups the substances used into four classes: (a) Food preparations, including the sugars, vitamins, phospates, and salts; (b) Oxygen; (c) Artificial sunshine; and (d) Pharmaceutical substances, including the 'dopes' which influence the nervous system, heart, and circulation.

One of the pharmaceutical substances listed by Boje[2]

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[1] O. Doping Boje, "A Study of the Means to Raise the Level of Performance in Sports," League of Nations Bulletin of the Health Organ, 8(3):440, 1939.

is caffeine.[3] Although this drug is commonly used in beverages of many kinds, there is no general agreement concerning its use in connection with physical effort. Some coaches forbid it to be used in any form while the athlete is in the process of training; others encourage the drinking of coffee or tea before an athletic contest, believing that the stimulating effects will 'pep-up' the participant and postpone the feeling of fatigue. No definite evidence has been produced to support either contention, and no concrete proof has been offered that caffeine has any influence, beneficial or detrimental, on athletic performance. It would seem, under these circumstances, that experimental investigation should be made in regard to this question.

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[3] S. O. Potter, Therapeutics Materia Medica and Pharmacy, p. 187. According to Potter, Caffeine (Theine, Trimethylxanthine) $C_8H_{10}NO_4 \cdot H_2O$, a feeble base obtained from the dry seeds of 'Coffea arabica,' occurs in colorless, silky crystals, soluble in water and alcohol. The plant 'Theobroma cacoa' contains Theobromine, a principle closely allied to caffeine. Another, 'Erythroxylon Coca,' contains the alkaloid cocaine, which is allied to caffeine in action, but is more powerful.

CHAPTER II

REVIEW OF THE LITERATURE

Many studies have been made showing the effect caffeine has upon work out-put, fatigue, and reaction time. Relatively few have been found which directly concern the use of caffeine to stimulate athletic performance. Until more research is presented along this line, it shall be necessary to study work performances which closely resemble and parallel athletic participation.

Brief physical efforts. Research to date has failed to discover any influence caffeine might have upon brief physical efforts. Herxheimer, as reported by Boje[1], administered caffeine to 46 subjects before a 100 metre race. His results indicated that no improvement was apparent due to the use of the drug. Haldi and Wynn[2] tested a group in a 100 yard swim, using both caffeine and a control to observe if performance was modified. Their results showed that caffeine had no influence on initial

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[1] Ibid., p. 459

[2] J. Haldi and W. Wynn, "Action of Drugs on Efficiency of Swimmers," Research Quarterly, 17:96, May,

speed and increment of speed during the test.

Work production and recovery from fatigue. More protracted forms of work are favorably affected by the drug. Rivers and Webber[3] made an early study of the effect of caffeine on fatigue induced by the continued lifting of small weights. They concluded that caffeine produces a large increase in the capacity for muscular work. Another observation made by Rivers and Webber and substantiated by Hyde and Root[4], was that quantitatively and qualitatively, caffeine has a varying effect on different subjects. Much of the research dating from this time considered the amount of caffeine administered in relation to kilograms of body weight. The factors of tolerance and habituation to caffeine were also considered in many other later studies.

There is almost unanimity of opinion that strength and work out-put are accelerated and recuperative processes are speeded by the use of caffeine. However, there

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[3] W. H. Rivers and H. H. Webber, "The Action of Caffeine on Capacity for Muscular Work," Journal of Physiology, 36 (1):33, 1907.

[4] I. Hyde, C. Root, and H. Curl, "Comparative Effects of Breakfast, of No Breakfast, and of Caffeine on Work of Athlete and Non-athlete," American Journal of Physiology, 43(3):371, 1917.

seems to be a point of diminishing return in relation to the size of the dose used. Hyde and Root[5] found that endurance and power do not keep pace with increased dosage. Subjects used in their experiments greatly increas ed their capacity for muscular work with an optimum dose. When this dose was increased, muscular power declined. The same experiment also indicated that different sized doses exerted specific effects on each individual and the result could not be predicted. This conclusion indicates that it would be a difficult problem for a coach to prescribe the amount of caffeine needed to obtain the maximum result.

Comparative effects on trained and untrained subjects. Studies made by Foltz and associates[6,7] showed that there is a difference in the effect of caffeine on work production and recovery in trained and untrained subjects, it was disclosed that training overshadowed the

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[5] Ibid., p. 390.

[6] E. Foltz, H. C. Ivy, and C. J. Barborka, "Influence of Benzedrine, Pervitin and Caffeine on Work Output and Recovery When Rapidly Exhausting Work is Done by Trained Subjects," Journal of Laboratory and Clinical Medicine, 28(5):603, 1943.

[7] E. Foltz, M. J. Schiffrin, and A. C. Ivy, "Influence of Benzedrine and Caffeine on Performance of Rapidly Exhausting Work by Untrained Subjects," Journal of Laboratory and Clinical Medicine, 28(5):601, 1943.

influence of the drug, which in itself merely produced subjective feelings of euphoria, but no material results. A point to be considered in these studies is that the stool-stepping test with a heavy pack could be a rapidly exhausting work-task when done by untrained individuals. There might be some connection between this possibility and the inability to stimulate short, exhausting performances as noted by Haldi and Wynn[8]. The fact that trained subjects received benefits from caffeine may make this theory sound like a contradiction, but trained subjects might react to the stool-stepping test as endurance work, and the untrained might become so rapidly exhausted that the test would approximate performance in a short, vigorous athletic test.

Handgrip strength. The strength of the handgrip would also seem to be an important factor in certain activities such as gymnastics, combatives, and weight lifting. Tests of handgrip strength and maintained handgrip[9] indicated that scores are better on days in which

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[8] J. Haldi and W. Wynn, "Action of Drugs on Efficiency of Swimmers," Research Quarterly, 17:96, May, 1946.

[9] G. R. Thornton, R. Holck, and E. L. Smith, "Effect of Benzedrine and Caffeine on Performance of Certain Psychomotor Tasks," Journal of Abnormal Psycho-

caffeine is taken. Schulte[10] reported that caffeine produced a large rise in the work curve for the strength grip, and a drop was recorded when decaffeinated coffee was used. The only dissenting opinion on handgrip strength was given by Guilliland[11] who found no difference in strength grip with or without caffeine in his test group.

Motor tests. Motor tests used in caffeine experiments include the Target test, Tapping test, Steadiness test, and Coordination test:

A. Target test: Horst[12] found that the target test improved under the influence of caffeine, and performance became impaired after withdrawal. Participants were rated on their ability to hit a target with a softball. This would seem to be one test very closely approximating athletic performance.

B. Tapping test: Two opinions are given in studies of

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[10] R. W. Schulte, "Der Einfluss des Kaffies auf Koper and Gust," Psychology Abstract, 45:381-384, 1919.

[11] A. R. Gilliland and D. Nelson, "The Effects of Coffee on Certain Mental and Psychological Functions," Journal of General Psychology, 21:333, 1939.

[12] K. Horst, R. Buxton, and W. Robinson, "The Effect of the Habitual Use of Coffee or Decaffeinated Coffee on Blood Pressure and Certain Motor Reactions of Normal Young Men," Journal of Pharmacy, 52(3):322, 1934.

the tapping test: Gilliland[13] stated that coffee decreased the rate of tapping 10 per cent to 15 per cent, while Hollingsworth[14] claimed that the rate increased after a slight initial retardation. He found that stimulation varied with the size of the dose taken, beginning in about 45 minutes and lasting as long as four and one-half hours when the dose was as large as six grains. Thornton[15] supported Hollingsworth's conclusions and asserted that results of the tapping test were better under caffeine.

C. Steadiness test: Gilliland[16], Thornton[17], and Hollingsworth[18] agree that steadiness suffers when caffeine is used. In one of Hollingsworth's

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[13] A. R. Gilliland and D. Nelson, op. cit., p. 348.

[14] H. L. Hollingsworth, "Influence of Caffeine on Tapping Test," Archives of Psychology, 22:43, 1912.

[15] G. R. Thornton, R. Holch, and E. L. Smith, "Effect of Benzedrine and Caffeine on Performance of Certain Psychomotor Tasks," Journal of Abnormal Psychology, 34:113, 1939.

[16] A. R. Gilliland and D. Nelson, op. cit., p. 347.

[17] G. R. Thornton, R. Holch, and E. L. Smith, op. cit., p. 113.

[18] H. L. Hollingsworth, "Influence of Caffeine on Steadiness Test," Archives of Psychology, 22:48, 1912.

several motor tests[19], he suggests the relationship of measurable muscular tremors produced by caffeine, with the nervous excitement responsible for insomnia which is also produced by large doses of the drug. Foltz made the claim that caffeine increased hand tremor slightly, however the test made for this condition was not indicated.

D. Coordination test: The article by Hyde[20], although essentially a study of fatigue, contained a reference on the effect of caffeine on coordination. A footnote in the article stated that one of the two subjects attempted a punching bag demonstration after participating in an experiment in which he had assimilated several large doses of caffeine. Even though he had been extremely dexterous and clever before engaging in the caffeine test, he now completely failed to attain any of his earlier proficiency. Opinion of the authors and doctors attending the experiment was that the stimulating influence of caffeine caused mental impressions to follow so rapidly that

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19 Ibid., p. 47.

20 I. Hyde, C. Root, and H. Curl, "Comparative

Attention was disrupted, causing more effort to concentrate on a single object.

Reaction time. The study of the effect of caffeine on reaction time is closely related to the problem of the stimulation of athletic performance. Since a fast reaction time seems advantageous in most types of athletic participation, and if we can conclude that caffeine shortens the time of response, we may be able to assume that it will indirectly affect the outcome of performance. Some research has indicated that there is a positive correlation between athletic ability and a quick reaction time. Burley[21] shows a significant difference in mean reaction time between athletic and non-athletic groups. Westerlund and Tuttle[22] found that champion track competitors had the shortest reaction times of the track groups tested and discovered a high degree of relationship between success in the 75 yard dash and reaction time (r-.863).

A survey of research on the influence of caffeine on reaction time shows, in almost every instance, a

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[21] L. R. Burley, "A Study of the Reaction Time of Physically Trained Men," Research Quarterly, 15:232, October, 1944.

[22] J. H. Westerlund and W. W. Tuttle, "Relationship Between Running Events in Track and Reaction Time,"

quickening of response. Hawks[23] reported a prolonging of reaction time in his test group, but his study is vague in the account of the testing and the size of the dose used. Studies by Cheney[24,25], in which a psychometer tests eye-hand decision response, show that reaction time is shortened.

Cheney[26] and Horst[27] compared the effects of caffeine alkaloid and coffee of equal caffeine content in two separate studies. Horst believes the two have the same reductive action on reaction time, while Cheney claims that pure caffeine is more effective, except during the first half hour.

Hollingsworth[28] tested reaction time in a carefully

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[23] P. Hawks, "A Study of Physiological and Psychological Reactions of Human Organism to Coffee Drinking," American Journal of Physiology, 90(2):380, 1929.

[24] R. H. Cheney, "Comparative Effect of Coffee Per Se and a Caffeine Beverage (Coffee) Upon Reaction Time in Normal Young Individuals," Journal for Pharmacy, 53(3):304-313, 1935.

[25] R. H. Cheney, "Reaction Time Behavior After Caffeine and Coffee Consumption," Journal of Experimental Psychology, 19:353-369, 1936.

[26] Ibid., p. 360.

[27] K. Horst and W. Jenkins, "The Effect of Caffeine, Coffee and Decaffeinated Coffee Upon Blood Pressure, Pulse Rate and Simple Reaction Time of Men of Various Ages," Journal of Pharmacy, 53(4):385, 1935.

controlled experiment in which sixteen subjects were observed. His test involved the element of discrimination in which both hands were used. He found that small amounts of caffeine created a preliminary 'briskness' which caused false reactions. Retardation of reaction time followed as a voluntary caution in an effort to reduce these false reactions. Larger amounts of caffeine (6 gr.) eliminated this preliminary retardation of reaction time.

CHAPTER III

THE PROBLEM

The specific problem of this study is to ascertain if the administration of caffeine alkaloid will in any way influence the starting times of a group of high school track men.

In a review of the literature concerned with the effect of caffeine upon reaction time, we find in almost every case a faster reaction time resulted when caffeine was given. In accordance with these findings, it might be expected that caffeine would also reduce the time required in making a start. However, conclusions from other research writers[1,2,3] are largely drawn from studies in which hand response is tested. The action of starting might differ from other reaction tests in such a manner as to produce other results. Also to be considered is the

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[1] R. H. Cheney, "Comparative Effect of Coffee Per Se and a Caffeine Beverage (Coffee) Upon Reaction Time in Normal Young Individuals," Journal of Pharmacy, 53(3):304, 1936.

[2] R. H. Cheney, "Reaction Time Behavior After Caffeine and Coffee Consumption," Journal of Experimental Psychology, 19:353, 1936.

[3] K. Horst and W. Jenkins, "The Effect of Caffeine, Coffee, and Decaffeinated Coffee Upon Blood Pressure, Pulse Rate, and Simple Reaction Time of Men of Various

voluntary caution which Hollingsworth[4] found in his experiments. If the subject is stimulated into making false reactions when influenced by caffeine, his starting time might be retarded by a self-imposed wariness to avoid breaking before the stimulus of the starting signal.

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[4] H. L. Hollingsworth, "Caffeine and Discrimination-

CHAPTER IV

THE PROCEDURE

Thirty-four members of a high school track team were tested in this experiment which covered a period of five weeks. Eleven of the boys had taken part in a previous test on starts, and the entire squad was given daily starting practice for two weeks before the actual test began. Each of the 34 subjects was tested ten times; five periods with and five periods without caffeine. The testing period consisted of twelve starts, meaning that all members of the group started 60 times with, and a like number without caffeine, making a total of 120 starts for each subject. The boys in the squad were tested every other day and caffeine was alternated with a control substance.

The apparatus. The apparatus which was employed to measure the starting time of the group, consisted of a clapboard, a Cenco chronoscope, and two wooden starting blocks, one of which contained electric contact points. This apparatus (Figure 1) was wired in series with a rectifying circuit to a counter.

A. The clapboard: The wooden clapboard (Figure 2) was so constructed that when the two surfaces were

FIGURE 1

DRAWING OF ELECTRIC CIRCUITS IN RESPONSE UNIT

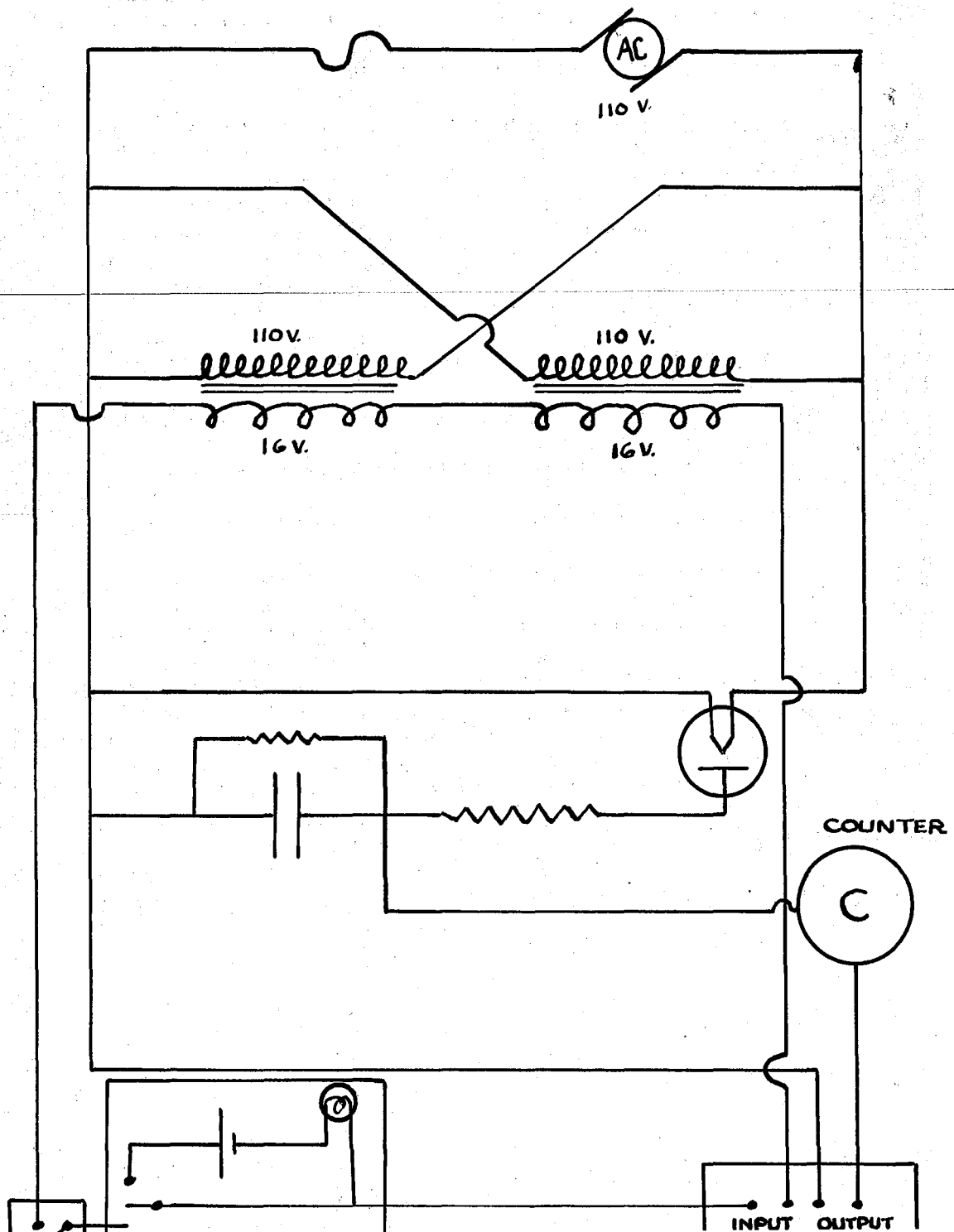
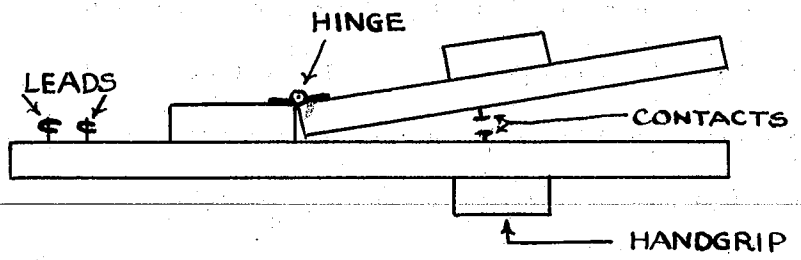


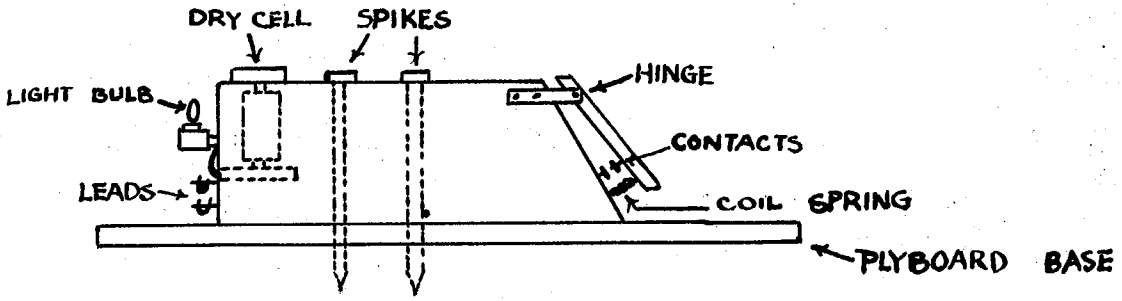
FIGURE 2

DIAGRAM OF CLAPBOARD AND STARTING BLOCK

USED IN RESPONSE UNIT



CLAPBOARD



STARTING BLOCK

electric contacts met and activated a chronoscope.

B. The chronoscope: The chronoscope was a 60 cycle, 110 volt timer, operating on A. C. Time read from the dial was indicated in 1/120 second when the oscillations were based on a 60 cycle impulse from the power source.

C. The starting block: The starting block (Figure 2) which supported the subject's rear foot was built with a hinged board in the front. This board was separated from the block by two steel coil springs. When the subject was in position for his start, the weight of his rear foot compressed the hinged board against the face of the block. This action contacted two electric points in the hinge and the face of the block. When these points met, a small bulb at the rear of the block became incandescent and indicated the apparatus was in readiness for the start. The front starting block contained no contact points and was not connected electrically with the rest of the apparatus.

D. The counter: A Counter was also included in the series in the event that some of the starts might involve more than one sweep of the dial. This did not prove to be the case, and the counter was not

was used, however, in the calibration of the testing apparatus with a mechanical stopwatch.

The action of the apparatus. The apparatus was thrown into action when the hinged clapboard gave the stimulus or starting signal to the subject, the contact starting the chronoscope. When the sprinter shoved off with his rear foot after hearing the signal, the coil springs in the starting block separated the hinged board from the face. The resultant breaking of the electric contacts stopped the chronoscope. The starting time, or the interval between the stimulus and the shoving off with the rear foot, was indicated on the dial of the chronoscope. False starts were not recorded as the chronoscope would not start when the sprinter was off the starting block at the time of the starting signal.

Definition of the start. A survey of available literature on related starting tests emphasizes the importance of defining starting time. According to Tuttle and Bresnahan[1], the sprinter makes four contacts with the track when in the 'get set' position. These contacts, the two hands and feet, are lifted from the track during the progression of the start, and any of the four breaks could

be used as the basis for defining the start. Nakamura[2] interpreted starting time as the interval between the stimulus and the moment the hands were lifted from the track. Tuttle and Bresnahan[3], however, concluded that the logical definition of the start would consist of the period between the starter's signal and the lifting of the rear foot. This was based on the assumption that a sprinter has commenced his start before all of the ground contacts are broken. Obviously, it is optional as to the point of body movement which might be considered as constituting a start. However, as most of the recent research on starting has used the same criterian as Tuttle and Bresnahan[4], in order to have a basis for comparison, the writer has accepted this definition and has collected data according to this standard.

The administration of caffeine. The administration of caffeine presented several problems: Public opinion had to be considered first in regard to the matter of giving a compound classified as a drug to a group of minors. The size of the dose to be given was also an important item;

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[2] H. Nakamura, "An Experimental Study of Reaction Time in Starting Races," Research Quarterly, 5:33, March, 1934.

[3] W. W. Tuttle and B. Bresnahan, op. cit., p. 110

it should be large enough to have a stimulating effect, yet not too large as to cause distress in the subject. The choice of a control substance or placebo which could not be distinguished from the actual drug and which would have a neutral effect in the body was necessary for the success of the test. Other factors which had to be controlled included the scheduling of the time of taking the drug so as to receive the maximum effect; alternation of the placebo and caffeine; and avoidance of caffeinated beverages which might develop a tolerance in the subject and modify the results.

In order to avoid adverse public opinion and the suspicion that we were endangering the health of the test subjects, permission was first secured from the parents of the squad members and from the school doctor (Table V). A pledge sheet was also signed by each member of the test group in an effort to control other conditions which might influence factors in the test. Especially important were the matter of eating before the starts and the abstinence from other sources of caffeine during the test (Table VI).

The drug was given in the form of caffeine alkaloid which appears as a fluffy, white powder, Cheney[5]

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[5] R. H. Cheney, "Comparative Effect of Coffee Per Se and a Caffeine Beverage (Coffee) Upon Reaction Time in

concluded that caffeine per se reduced the reaction time 8 per cent as compared to a 4 per cent reduction when coffee was used. Another advantage of using caffeine in the pure form was the possibility of standardizing the dose. This would have been extremely difficult if the beverage had been used. The caffeine alkaloid was put up in 3.5 grain capsules by the McKee Drug Company of Oakland, California. Pink gelatine capsules, No. 2 size, were used as containers for the drug, having the advantage of camouflaging the contents and quickly dissolving in the stomach.

Placebos were made by filling the same size capsule with sodium bicarbonate. It was impossible to tell the difference between the capsule containing caffeine and the control capsule even under close examination. It should be mentioned that the subjects were under the impression that all capsules contained caffeine, and there appeared to be little interest in them after the first dose was taken.

The caffeine and the placebo were taken at the same time each testing day. The half of the squad slated for the day's testing would report to the boys' gym at 2:20 p.m. In a room used especially for this purpose, they would receive their capsule for the day in an envelope

would take their capsule with a glass of water. They would then return their envelopes and report to their next class.

Warm-ups and order of starting. At 3:45 p.m. the test group reported to the track. After a warm-up period consisting of jogging laps, stretching exercises, and practice starts, they were called to the starting station. Their starting order, which was drawn in random order, was given to the group. It should be noted that the subjects were tested at the same time each day. This was done to avoid the hourly variation in reaction time noticed by Elbel[6], and also so that the testing time would fall within the period of maximum effect of caffeine which Cheney[7] found to start within 30 minutes of ingestion and reach its peak in two and one-half to three hours. The testing period for the half of the squad taking starts covered approximately one hour, which meant that it was within the interval when caffeine exerted its greatest influence.

The starter. The starting for the test was done by

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[6] E. R. Elbel, "A Study in Variation in Response Time," Research Quarterly, 10:49-50, March, 1939.

[7] R. H. Cheney, "Reaction Time Behavior After

the same individual throughout the experiment. He was stationed slightly behind the subject and about six feet away. From this position it was impossible for the sprinter to observe the movement of bringing the clapboard together. The apparatus was set up in the same location for every test, and the starter assumed the same position each time.

Instructions for starting. After opening the clapboard, the starter would call the subject to his mark. As soon as it became apparent that the sprinter was in position, as evidenced by the lighting of the bulb at the end of the starting block, the command 'get set' was given. In accordance with preliminary instructions, the subject would immediately raise his hips in a comfortable starting stance and wait for the sound of the clapboard. On hearing the signal, he started as quickly as possible and sprinted to a spot approximately 20 yards down the track. It was found necessary to instruct the subject to run this additional distance to avoid the possibility that he might merely lift his rear foot from the block and stop the chronoscope without actually leaving the blocks in a definite start.

The holding interval. To prevent the sprinter from

starter and reacting to a holding interval rather than the starting signal, a random order of holding foreperiods was used. The writer had previously tested several of the track squad using intervals of 1.0, 2.0, and 3.0 seconds. It was concluded from data collected in this experiment that there was no difference between intervals of 2.0 and 3.0 seconds, but that there was a significant difference between 1.0 seconds and the other two holding periods. Statistically the difference was indicated by a critical ratio of 4.6. This 't' value is significant at the 1 per cent level.[8]

As this difference might possibly have modified the outcome of the experiment, it was thought best to eliminate the 1.0 second interval and use holding periods of 1.5, 2.0, and 2.5 seconds.

The accuracy of the holding periods was guaranteed by the starter's use of a 10th. second timer with a sweep hand. This seemed more accurate than the method of having the starter count to himself before bringing the clapboard together in the starting signal.

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[8] J. P. Guilford, Fundamental Statistics in Psychology and Education, p. 130. According to Guilford, a very significant difference is one that occurs by chance less than once in one hundred times. The critical ratio is the relationship of the difference to

Calibration of the apparatus. The apparatus was calibrated with a telechron timer at the University of California Physical Education Research Laboratory before the experiments began. The calibration certified the accuracy of the testing unit. To see that this accuracy was not altered significantly during the course of the experiment, four more calibrations, each a week apart, were run by checking the apparatus with a stopwatch which had been overhauled by a watchmaker and pronounced in good running order. This stopwatch was used solely in the experiment. The difference between the chronoscope and the stopwatch remained constant during the course of the experiment and averaged less than .70 per cent which would have no appreciable effect on the statistical data.

It was also found necessary to determine the impulse frequency of the local power source since the accuracy of the chronoscope is determined by the oscillation variation, and the frequency had been cut to fifty-nine and one-half cycles during the previous power shortage. This calibration was done by comparing an electric office clock with a mechanical stopwatch before and after each test. At no time during the course of the experiment was the impulse frequency less than sixty cycles.

control experimental conditions, the apparatus was set up at exactly the same location for each test. All contacts and terminals were kept clean and checked after each testing day. A track manager was assigned the task of using a bicycle pump to blow out the electrical starting block after each individual start. This kept the dirt from lodging against the contact points and interfering with the operation of the unit.

CHAPTER V

DISCUSSION OF DATA

Data were collected from 34 members of an experimental test squad after they had gone through a period of training to control the factor of learning. The total number of starts for the entire group was 4,080, of which 2,040 were tested after the subject had taken a 3.5 grain capsule of caffeine alkaloid. The remainder of the starts were taken after the subject had taken a control capsule of sodium bicarbonate. A summary of the data is shown in Tables I, II, and III.

An examination of Table I reveals that 18 of the 34 individuals started faster with caffeine than without. Fourteen started faster when the placebo was administered, and there was no difference in the starting times of two subjects.

In comparing the mean caffeine times with the mean placebo times (Tables I and II), we find that caffeine gave an advantage of .5 as expressed in 1/120 second when the group average was considered. This figure is expressed as .005 when converted to seconds.

If this advantage of .005 second were a significant or true difference, it would still not be large enough to in-

TABLE I

A COMPARISON OF THE STARTING TIMES OF SPRINTERS BOTH WITH AND WITHOUT CAFFEINE

(Time is expressed in 1/120 sec.)

Sub. No.	Total Chronoscope Reading for 60 Starts		Mean Chronoscope Reading			
	Caffeine	Placebo	Caffeine	Placebo	Diff.	$Diff^2$
1	2377	2332	39.6	38.9	-0.7	.49
2	2153	2274	35.9	37.9	2.0	4.00
3	2032	2118	33.8	35.3	1.5	2.25
4	2363	2433	39.5	40.5	1.0	1.00
5	2063	2080	34.5	34.8	0.3	.09
6	2197	2094	36.6	34.9	-1.7	2.89
7	2808	2642	47.0	44.2	-2.8	7.84
8	2275	2445	37.9	40.9	3.0	9.00
9	2298	2213	38.3	36.9	-1.4	1.96
10	2293	2193	38.2	36.5	-1.7	2.89
11	2207	2291	36.9	38.1	1.2	1.44
12	2457	2428	41.0	40.5	-0.5	.25
13	2163	2152	36.1	35.9	-0.2	.04
14	2471	2432	41.2	40.6	-0.6	.36
15	2320	2343	38.7	39.2	0.5	.25
16	2467	2440	41.2	40.7	-0.5	.25
17	2289	2327	38.2	38.8	0.6	.36
18	2340	2312	39.1	38.6	-0.5	.25
19	2371	2443	39.6	40.8	1.2	1.44
20	2310	2310	38.5	38.5	0	0
21	2374	2325	39.5	38.8	-0.7	.49
22	2370	2460	39.5	41.0	1.5	2.25
23	2577	2574	42.9	42.9	0	0
24	2470	2542	41.2	42.5	1.3	1.69
25	2140	2280	35.7	38.0	2.3	5.29
26	2448	2403	40.8	40.2	-0.6	.36
27	2623	2698	43.8	44.9	1.1	1.21
28	1930	1869	32.2	31.1	-1.1	1.21
29	2235	2167	37.2	36.2	-1.0	1.00
30	2207	2319	36.9	38.6	1.7	2.89
31	2266	2393	37.8	39.9	2.1	4.41
32	2151	2477	35.9	41.3	5.4	29.16
33	2293	2486	38.3	41.5	3.2	10.24
34	2200	2243	36.7	37.5	0.8	.64
TOTAL	78,538	79,538	Mean 38.5		Mean 39.0	16.7	97.89

TABLE II

SUMMARY OF THE MEAN STARTING TIME OF THIRTY-FOUR TRACK MEN WITH AND WITHOUT CAFFEINE

(The time is in seconds)

Sub. No.	With Caffeine Mean (60 starts)	Without Mean (60 starts)	Difference Mean
1	.330	.324	-.006
2	.299	.315	.016
3	.279	.294	.015
4	.329	.337	.008
5	.287	.290	.003
6	.305	.291	-.014
7	.391	.368	-.023
8	.315	.341	.026
9	.319	.307	-.012
10	.318	.304	-.014
11	.307	.317	.010
12	.341	.337	-.004
13	.300	.299	-.001
14	.343	.338	-.005
15	.322	.326	.003
16	.343	.339	-.004
17	.318	.323	.005
18	.325	.321	-.004
19	.330	.340	.010
20	.321	.321	0
21	.329	.323	-.006
22	.329	.341	.012
23	.357	.357	0
24	.343	.354	.011
25	.296	.316	.020
26	.340	.335	-.005
27	.365	.375	.010
28	.268	.259	-.009
29	.310	.301	-.009
30	.307	.321	.014
31	.315	.332	.017
32	.299	.344	.045
33	.319	.345	.026
34	.305	.312	.007
MEAN	.320	.325	.005

estimate of one second covering ten yards in a sprint, we can assume that .005 of a second would only give an advantage of 1.8 inches in a start.

In comparing the starting times of sprinters with and without caffeine (Table I), we observe that certain individuals were more susceptible than others to the effect of caffeine in this particular experimental study. One individual (No. 32) has a mean advantage of 5.4 with caffeine-influenced starts. Changed to seconds, we see that he started .045 of a second faster with the caffeine dose. Using the same standard of one second to ten yards, we find that this would give an advantage of 1 foot 4.2 inches, which could definitely prove a determining factor in a race. On further examination of Table I, we find only one subject (No. 7) who would probably be inversely affected by caffeine in a manner which would penalize his start. Although 14 subjects started slower with caffeine, only one or two of these would presumably be at a disadvantage when given caffeine before the starts. On the other hand, of the 18 whose starting time was shortened by the administration of caffeine, at least 10 would receive an advantage in starting time which might possibly modify the result in a short dash. The value of these hypothetical advantages is debatable as this experiment

off his blocks only, and has not become involved with such variables as velocity and momentum once the sprinter has broken from the starting block. Conceivably, a sprinter could be off his blocks first, but lose this initial advantage to a starter who left later but with better body balance and drive in the first few steps.

The significance of the mean difference in starting times is found in Table III. Referring to this table, we find the ratio of the obtained difference (.49) to the standard error of the difference (.283). This ratio is the obtained 't' value and equals .49/.283 or 1.73. Looking at Guilford's D Table[9], we find the value of 't' required for the number of degrees of freedom that our data provides. In this case, N-1 is equal to 33 degrees of freedom. This number is not indicated in the table, but we see that 35 degrees is the closest to our figure. For this number, we find that the difference would have to be 2.03 times its standard error to be significant at the 5 per cent level of confidence, and 2.70 times its standard error to be considered very significant at the 1 per cent level. If the critical ratio had been at least 2.03, we could have said that there are less than 5 chances in 100 that it was due to random sampling.

If it had been 2.70, we could figure that there is one chance in 100 that the difference is not a true one. Our critical ratio of 1.73 is below the 5 per cent level of confidence and we cannot therefore consider the difference between caffeine starts and no caffeine starts a significant one. Thereupon, we would not expect to find the same difference in another test. A re-test would be necessary to see if the same individuals are sensitive to caffeine, but it seems certain that their wide divergence from the norm was due to chance in the first test.

In view of the findings of Hollingsworth[10] in which he reported false reactions due to the stimulation of caffeine, a check was kept on the number of breaks made by each individual during the experiment (Table IV). Results indicated that false starts occurred no more often after the taking of caffeine than the placebo. Certain individuals broke two or three times during a laboratory testing period, but no more often on caffeine days than no caffeine days. No definite pattern of false starts was observed, the matter seeming to depend upon the mental set of the individual rather than the dose taken. In all, the number of breaks was small, indicating that the sprinters were listening for the stimulus rather than trying to out-

guess the starter and determine his rhythm.

TABLE III

SUMMARY OF STATISTICS IN COMPARISON OF STARTING TIMES WITH AND WITHOUT CAFFEINE

Statistic	Caffeine	Placebo
N	34	34
M (Chr.R.)	38.5	39.0
Σd_m	16.7	
M_d	.49	
$M2_d$	.24	
Σd^2_m	97.89	
md^2	2.9	
σ_{d_m}	.283	
t	1.73 (.490/.283)	

TABLE IV

NUMBER OF BREAKS MADE BY SUBJECTS

ON CAFFEINE AND PLACEBO TEST DAYS

Subject Number	Caffeine Breaks	Placebo Breaks	Subject Number	Caffeine Breaks	Placebo Breaks
1	8	4	18	0	0
2	8	10	19	0	0
3	1	1	20	0	1
4	3	2	21	1	2
5	0	0	22	1	0
6	2	1	23	1	0
7	0	0	24	2	1
8	2	1	25	0	1
9	6	7	26	0	1
10	0	2	27	1	1
11	0	1	28	0	3
12	4	6	29	0	2
13	0	2	30	0	0
14	5	3	31	1	0
15	0	0	32	5	0
16	0	0	33	0	1
17	1	0	34	1	1
			TOTAL	53	54

CHAPTER VI

SUMMARY

Thirty-four high school track boys were tested in an experiment to determine if caffeine per se would modify starting time. The squad was tested with caffeine alkaloid and sodium bicarbonate placebos on alternate days. Ten testing periods, each consisting of twelve starts, were given all subjects. Caffeine was given in five of the laboratory periods, and a control capsule was used in the other five. The results of the starts, with and without caffeine, were tabulated and compared to see if a significant difference existed between the two. A check was also kept on all false starts to observe if any of the breaks were caffeine-induced.

CHAPTER VII

CONCLUSIONS

1. A comparison of the starting times of thirty-four individuals engaging in a total of 4,080 starts indicated a slightly faster starting reaction when 3.5 grains of caffeine alkaloid was administered one hour and forty minutes before the test. This advantage was not significant statistically and was probably due to random sampling.
2. The amount of caffeine given did not cause the preliminary briskness, manifest by false reactions, which was reported in other studies. Breaks were no more common on caffeine days than others.
3. The reaction of some subjects in this test suggests the possibility that a certain type of individual may be hyper-sensitive to caffeine. Further research would seem to be indicated.

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APPENDIX

TABLE V

LETTER OF PERMISSION FROM PARENTS OF TEST GROUP

Department of Physical Education
Santa Cruz High School
Santa Cruz, California
February 10, 1948

Dear Parent:

In the near future, I am planning to test a selected group of track boys as the basis for a Master's Thesis. The purpose of the test will be to see if track starts are influenced by the administration of caffeine. Permission for this test has been given by medical authority connected with Santa Cruz High School.

I have asked your son to participate in this experiment. If it meets with your approval, he will be tested on 10 different days, both with and without caffeine. The dose of caffeine used will approximate the amount in a strong cup of coffee and only one dose will be given on the day of a test.

If you have no objection to your son taking part in this test, will you please sign the attached form and return it to me? It will add greatly to the significance of this research if you will aid your son in abstaining from caffeinated beverages during the course of the experiment.

Sincerely,

Roger Baer
Track Coach
Santa Cruz High School

Dear Mr. Baer:

_____ has my permission to take part in your test on track starts. I will cooperate in seeing that he does not drink caffeinated beverages (coffee, tea, cocoa, cola) during the ten days covering the testing

TABLE VI

PLEDGE SHEET SIGNED BY PARTICIPANTS IN CAFFEINE TEST

I am acting as a volunteer in the test on track starts. In order to insure accuracy of results and control of conditions, I promise to abide by the following regulations for the duration of the test.

1. I will drink no caffeinated beverages (coffee, tea, cocoa, cola) while the tests are being given.

2. I will not eat during the interval between my regular noon meal and the time the test is given.

3. I will report to the lecture room promptly at 2:20 p.m. on each day I am scheduled to be tested.

4. If I am unable to appear for my test, I will notify Mr. Baer by phone or messenger before 10:00 a.m. of the test day.

_____

(Signed)

TABLE VII

DAILY CHRONOSCOPE TOTALS FOR STARTING TIMES
WITH CAFFEINE AND WITH A PLACEBO
(Each figure represents the total chronoscope reading in 1/120 second units)

No. 1		No. 2		No. 3		No. 4	
Caff.	Plac.	Caff.	Plac.	Caff.	Plac.	Caff.	Plac.
*458	486	450	456	417	418	563	609
504	471	471	437	418	439	491	463
446	451	377	420	411	426	436	447
495	475	430	449	395	444	449	442
474	449	425	512	391	391	424	472
**2377	2332	2153	2274	2032	2118	2363	2433
No. 5		**No. 6**		**No. 7**		**No. 8**	
420	402	487	441	600	533	474	518
406	471	406	366	541	548	580	496
408	361	391	414	568	535	436	477
408	412	466	436	569	504	428	488
421	434	447	437	530	522	457	466
2063	2080	2197	2094	2808	2642	2275	2445
No. 9		**No. 10**		**No. 11**		**No. 12**	
433	433	553	467	440	438	468	461
475	453	456	474	424	482	493	493
456	412	454	482	425	435	526	478
453	451	435	360	474	480	462	464
481	464	395	410	444	456	518	532
2298	2213	2293	2193	2207	2291	2457	2428
No. 13		**No. 14**		**No. 15**		**No. 16**	
433	450	480	470	477	511	504	485
435	430	496	480	455	467	475	480
461	437	482	485	457	452	471	483
424	442	519	511	463	451	487	507
410	393	495	486	468	462	530	485
2163	2152	2471	2432	2320	2343	2467	2440
No. 17		**No. 18**		**No. 19**		**No. 20**	
456	458	478	522	502	560	491	481
460	481	473	443	479	439	444	470
448	459	482	429	463	467	429	438
473	495	433	474	459	504	465	453
452	434	474	444	468	473	481	468

TABLE VII (Continued)

No. 21		No. 22		No. 23		No. 24	
Caff.	Plac.	Caff.	Plac.	Caff.	Plac.	Caff.	Plac.
476	463	476	480	520	544	497	460
438	459	443	498	541	518	462	491
461	464	419	483	477	480	504	491
484	448	498	515	513	503	477	537
515	491	534	493	526	529	530	563
2374	2325	2370	2460	2577	2574	2470	2542
No. 25		**No. 26**		**No. 27**		**No. 28**	
436	429	501	466	521	571	458	447
436	441	511	509	515	558	452	442
432	450	446	505	581	560	443	425
408	511	506	483	537	500	453	452
428	449	484	440	469	509	429	401
2140	2280	2448	2403	2623	2698	2235	2167
No. 29		**No. 30**		**No. 31**		**No. 32**	
466	471	431	547	335	347	431	471
440	451	449	428	375	380	467	513
439	465	467	475	404	411	481	486
428	450	454	478	406	348	321	509
434	482	466	465	410	383	451	498
2207	2319	2266	2393	1930	1869	2151	2477
		No. 33		**No. 34**			
		494	665	525	528		
		447	469	495	497		
		500	459	421	438		
		405	437	383	403		
		447	456	376	377		
		2293	2486	2200	2243		

* Each figure in column is total of 12 starts

** The total of the column is sum of five testing periods (60 starts)