THE EFFECT OF TEMPERATURE AND EXPOSURE DURATION ON VISUAL REACTION TIME

by

LLOYD STUART CURTIS

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George F. Schrader
Major Professor

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STATEMENT OF THE PROBLEM AND BACKGROUND

Statement of the Problem

As anyone will agree who has conducted performance research in thermal environments, the number of variables that must be considered are many. Fredrick H. Rohles of the Environmental Laboratory at Kansas State University (20) mentioned several of them in his "Standard Man" concept. This concept included such factors as temperature, humidity, exposure time, age, sex, diet, activity, clothing, and area-volume.

Needless to say, a complete investigation of all these factors as they affect performance will take many years to complete. However, it is hoped that this investigation will serve as a starting point in this endeavor by studying temperature and exposure time as they effect performance.

Stated differently, the purpose of this study was to determine the effect of exposure time and temperature on visual reaction time after a pre-test adaptation to different temperatures for different lengths of time.

Background

<u>History of Reaction Time</u>. The importance of reaction time as a meaningful measure of psychomotor functioning has its roots in the late 1700's in what has now become known as

the "personal equation". It was then, while conducting astronomical observations, that Maskelyne relieved Kinnebrook of his duties. He was dismissed because he consistantly had a time error in observing when a particular astronomical event occurred. As was discovered later in Wundt's laboratory (1879), this error was not due to negligence but instead, differences in reaction times between Kinnebrook and Maskelyne.

Helmholtz conducted the first reaction time experiments (1850) when attempting to determine the speed of conduction in motor nerves. In this experiment, he would stimulate the skin far from the brain by an electrical shock and measure the time it took for a subject to do a simple hand reaction. Next he ran a series of tests by stimulating the skin close to the brain and measuring the time it took for the reaction. This method proved unsatisfactory for finding nerve conduction speed, because of the relatively long time needed for reaction time and the variability of reaction time.

In 1861-65, Hirsch measured what he called "physiological time" of the eye, ear, and sense of touch. These values of simple reaction time have remained fairly standard ever since.

A Dutch physiologist, Donders, in 1868 originated the concept of the disjunctive reaction time experiment and found the reaction time to be about 100 milliseconds longer than the simple reaction time. This extra time he associated with differences in the time required for the mental process.

Austrian physiologist, Exner, in 1873 pointed out the importance of preparatory set and introduced the term, "reaction time".

Wundt and his students conducted many simple and complex reaction time studies and psychologists such as Cattell, Kulpe, Pieron, and many others have made many important contributions to reaction time research.

Types of Reaction Time. There are two types of reaction times. The first, which is known as simple reaction time, consists of a ready signal which remains the same throughout the course of the experiment; a stimulus, either visual or auditory, and like the ready signal, is the same throughout the study; and a response which remains the same throughout the experiment. The second type of reaction time is complex reaction time. In this case many factors may be involved that govern the response. For example, a response might depend on the color of the ready light, the color of the stimulus light, or a combination of both of these variables. The sensory modality, be it visual, auditory, or tactual has also been examined in reaction time studies and it has been found that auditory reaction time is faster than visual reaction time.

Temperature and Reaction Time. In evaluating the experimentation that has been conducted in the area of response or reaction time, it is felt that the studies and literature survey accomplished by Warren H. Teichner (24) provide an indication of the progress to 1954 on this subject. His summary of results, "The Effects of Ambient Temperatures Upon Reaction Time", is recorded below.

Reaction Time as a Function of Temperature

> A number of studies (11, 18, 27) have been done to determine the effect of climatic stress, temperature in particular, on the reaction time. The general result of these studies is that ambient temperatures between a range of -50°F. and 117°F. have little or no effect on either reaction time or more complex reaction times. This conclusion was reached by Forlano, Barmack, and Coakley (10) after a careful review of the effects of ambient and body temperatures on reaction time. Most of the studies available for evaluation are distinguished by the degree with which several main variables are confounded in one experiment, and consequently are given to difficulty of interpretation. Such a conclusion, therefore, should not be accepted as firmly established.
>
> Reaction times have also had a little attention with regard to skin temperatures. Craik and Macpherson (5) report that cooling of the hand with which the response is made may increase reaction time by 10-15 per cent. This conclusion is not reasonable on the basis of their study since an increase of this much turns out to be an increase of 0.02 to 0.06 seconds, a change which has little significance in terms of the likely error of measurement and the size of the sample (two subjects).
>
> A few reaction time studies have been done with body temperature and/or time of day as the independent variable. In general, these studies (12, 13, 15) suggest that reaction time exhibits a slight diurnal variation, but with large individual differences. The data may also be interpreted to indicate that reaction time is a function of body temperature and is only spuriously correlated with time of day (10).

Teichner (25) in 1958, conducted a reaction time experiment at temperatures of -15°F. and -35°F. and with wind speeds of five, ten, fifteen, and twenty miles per hour. He found that reaction time did not vary significantly between -15°F. and -35°F. at a five miles per hour wind speed. However, reaction time did vary significantly between -15°F. and -35°F. at the higher wind speeds. This would definitely indicate interaction between wind and temperature, but the statistical analysis demonstrated no interaction.

In this section, the history of reaction time experiments and experiments dealing with the effects of ambient temperature on reaction time, have been reviewed. These past experiments indicate the inability to conclusively prove the effects of ambient temperature on reaction time. The purpose of this investigation was to provide conclusive evidence as to the effect of adaptation at one temperature and time on the performance of a human subject at a subsequent temperature and time. This effect will be noted as a difference in reaction time.

METHOD

Subjects

The subjects were five male college students. Prior to this investigation, they had no previous experience in studies of this nature. During the testing, they wore only shorts and socks.

Apparatus

The visual response stimulating apparatus was placed on a table that was twelve feet long and thirty inches high. The subjects were seated along the table and were separated by a 54 inch high plywood partition. In front of each subject was a .375 inch diameter red light and centered two inches below this was a .375 inch diameter green light. Centered four inches below the green light was a push button switch. The lights and switch were mounted on a 3/8 inch thick, two feet wide, and ten feet long piece of plywood which was placed on a 30° angle on top of the table. The partitions were attached to this board. This is better shown on Plate VIII in the appendix.

Programming of the light presentation was accomplished with commercial operant-type equipment which was modified for this study. Reaction times were recorded to 1/100 of a second on Standard Electric Timers.

The reaction time test consisted of several segments. First, a red light was presented and served as a ready signal.

The times between the ready light presentations were randomly varied between eight and fourteen seconds at one second intervals. Once the ready signal came on, it remained on for five seconds. Between 1.7 and 2.3 seconds after the ready light came on, the stimulus light was activated. To avoid temporal conditioning and anticipation, the time between the ready light and the stimulus light was manipulated manually to vary irregularly. The ready light and stimulus light were turned off at approximately the same time. If one of the subjects started prematurely during these tests, the series of trials started at the beginning again until ten unbiased trials could be accumulated. A subject's premature trial would be observed when he prematurely lifted his finger from the switch, because he could not depress the switch fast enough to move the hand on the clock. The reason he could not activate the clock is because the relay would have already cycled the clock circuit to open position.

All relays, timers, clocks, and the rest of the electrical apparatus were in a room completely separated from the environmental adaptation and test rooms. A cable connected the reaction test stalls to the electrical apparatus. Sound from the relays, timers, and clocks could not be heard in the test room.

All tests were conducted in the KSU-ASHRAE Environmental Research Lab. The pre-test room is ten feet wide and twenty feet long. Temperature is not controlled in the walls, but a wide range of temperatures can be obtained by circulating conditioned air through the room. The conditioned air enters through ducts in the ceiling and leaves through apertures in the floor. Temperature is automatically controlled by a thermostat. The test

> ...room is twelve feet wide and 24½ feet long. The interior surface consists of aluminum panels. The surface temperature of each panel is controlled by circulating heated or chilled liquid through copper tubes attached to the back of each panel. Surface temperatures of 20 to 150°F. can be obtained. Conditioned air enters through a continuous slot at the floor around the perimeter of the room. Complete instrumentation for measurement of surface and air temperatures and automatic control of all room variables is provided. (1)

The three adaptation temperatures maintained by the pretest room were 65°F., 80°F., and 95°F. These temperatures were maintained for either 30 or 60 minutes. The test temperatures were the same as the adaptation temperatures and the test times were the same as the adaptation times. A relative humidity of fifty per cent was maintained as standard so that all the tests were run on an equal basis.

Experimental Design

Basic Design. The basic design is a factorial arrangement of treatments with two factors of temperature having levels of 65°F., 80°F., and 95°F. and two factors of time having levels of 30 and 60 minutes. This produces $3^2 \times 2^2 = 36$ treatment combinations or necessary tests to insure all factors at all levels are fully crossed. This might better be illustrated by Table 1. This table also specifies the actual random order that the tests were run.

Statistical Model Design. The mathematical model for this experiment is a fixed effects model or Model I (23). This means that the levels of adaptation temperature, adaptation time, test temperature, and test time were fixed by the experimenter and are not a random sample of all possible levels of each effect. The levels were evenly spaced to determine linear and quadratic effects. This model is represented by the equation: $X_{ijklm}= U+A_i+B_j+C_k+D_l+AB_{ij}+AC_{jk}+AD_{il}+BC_{jk}+BD_{jl}+CD_{kl}+ABC_{ijk}+ABD_{ijl}+ACD_{ikl}+BCD_{jkl}+ABCD_{ijkl}+S_m+E_{ijklm}$

where: $U=$ the grand average of all X_{ijklm} conceivable for these specific adaptation temperatures, adaptation times, test temperatures, and test times

$A_i=$ the true additive effect of the i^{th} adaptation temperature as a deviation from U with these specific adaptation times, test temperatures, and test times. Therefore, $\sum_i(A_i)=0$ and $E(A_i)=A_i$

$B_j=$ the true additive effect of the j^{th} adaptation time as a deviation from U with these specific adaptation temperatures, test temperatures, and test times. Therefore, $\sum_j(B_j)=0$ and $E(B_j)=B_j$

$C_k=$ the true additive effect of the k^{th} test temperature

EXPLANATION OF TABLE 1

This table displays the random or actual order in which the tests were run.

TABLE 1

ADAPTATION TEMPERATURE	ADAPTATION TIME	SUBJECT	65° TEST TEMPERATURE		80° TEST TEMPERATURE		95° TEST TEMPERATURE	
			TEST TIME		TEST TIME		TEST TIME	
			30'	60'	30'	60'	30'	60'
65°	30'	1 2 3 4 5	14	14	2	2	8	8
65°	60'	1 2 3 4 5	12	12	4	4	6	6
80°	30'	1 2 3 4 5	3	3	1	1	5	5
80°	60'	1 2 3 4 5	16	16	11	11	7	7
95°	30'	1 2 3 4 5	10	10	9	9	18	18
95°	60'	1 2 3 4 5	15	15	17	17	13	13

as a deviation from U with these specific adaptation temperatures, adaptation times, and test times. Therefore, $\sum_k (C_k)=0$ and $E(C_k)=C_k$

D_l= the true additive effect of the l^{th} test time as a deviation from U with these specific adaptation temperatures, adaptation times, and test temperatures. Therefore, $\sum_l (D_l)=0$ and $E(D_l)=D_l$

(AB_{ij})= the true additive effect of combining the i^{th} adaptation temperature with the j^{th} adaptation time as a deviation from $U+A_i+B_j$ with these specific test temperatures and test times. Therefore, $\sum_i (AB_{ij})=\sum_j (AB_{ij})= \sum_{ij} (AB_{ij})=0$

(AC_{ik})= the true additive effect of combining the i^{th} adaptation temperature with the k^{th} test temperature as a deviation from $U+A_i+C_k$ with these specific adaptation times and test times. Therefore, $\sum_i (AC_{ik})= \sum_k (AC_{ik})= \sum_{ik} (AC_{ik})=0$

The remaining two way interactions are similarly defined.

(ABC_{ijk})= the true additive effect of combining the i^{th} adaptation temperature with the j^{th} adaptation time with the k^{th} test temperature as a deviation from $U+A_i+B_j+C_k+AB_{ij}+AC_{ik}+BC_{jk}$ with these specific test times. Therefore, $\sum_i (ABC_{ijk})= \sum_j (ABC_{ijk})= \sum_k (ABC_{ijk})= \sum_{ijk} (ABC_{ijk})$

The remaining three way interactions are similarly defined.

$(ABCD)_{ijkl}$= the true additive effect of combining the i^{th} adaptation temperature with the j^{th} adaptation time with the k^{th} test temperature with the l^{th} test time as a deviation from $U+A_i+B_j+C_k+D_l+AB_{ij}+AC_{jk}+AD_{jl}+BC_{jk}+BD_{jl}+CD_{kl}+ABC_{ijk}+ABD_{ijl}+ACD_{ikl}+BCD_{jkl}$. Therefore, $\sum_i(ABCD_{ijkl})=\sum_j(ABCD_{ijkl})=$

$$\sum_k(ABCD_{ijkl})=\sum_l(ABCD_{ijkl})=\sum_{ijkl}(ABCD_{ijkl})=0$$

S_m= the additive effect of the m^{th} subject for a treatment combination. Therefore, $E(S_m)=0$, $E(S_m^{\ 2})=\sigma_s^2$

E_{ijklm}= the random error of observation

and

i goes from 1 to t= 3 and represents the level of adaptation temperature

j goes from 1 to r= 2 and represents the level of adaptation time

k goes from 1 to s= 3 and represents the level of test temperature

l goes from 1 to v= 2 and represents the level of test time

m goes from 1 to q= 5 and represents the number of subjects

The analysis of variance for the four factor, fixed effects experiment with q samples per A,B,C,D combination of main effects is shown on Plate II. The error mean square is the denominator for use in the F test when interpreting the significance of interaction and main effects. Using the same subjects in an experiment is common practice and the subjects sum of squares is subtracted from the error term just like the treatments sum of squares. If the group of five subjects is looked upon as the experimental unit, then this is a non-replicated experiment. In this case, if the three and four way interactions are small, they can be pooled as an estimate of error. If they are not small, they will at worst over estimate the error mean square. The subject by treatment mean square measures the variability of subject by treatment combinations over treatment and subject effects and appears to be the same source of error, because the mean square is very similar to that described above. This implies that the individual subject by time to subject by time variation summed over subjects among treatments is the main source of error. Therefore it was used as the error mean square in the analysis. The more conservative test using the three and four way interactions as error may be used. However, this gave essentially the same conclusions and only test temperature was not quite significant. Since the results are comparable, and σ^2 is estimated more precisely by "subject by treatment", it was used for all tests. The H_o's being tested to determine the degree of interaction and main effect are:

H_{o_A} (A_i=0 for every i) against H_{a_A} (some $A_i \neq 0$)

H_{o_B} (B_j=0 for every j) against H_{a_B} (some $B_j \neq 0$)

H_{o_C} (C_k=0 for every k) against H_{a_C} (some $C_k \neq 0$)

H_{o_D} (D_l=0 for every l) against H_{a_D} (some $D_l \neq 0$)

$$H_{o_{AB}}(AB_{ij}=0 \text{ for every } ij) \text{ against } H_{a_{AB}}(\text{some } AB_{ij}\neq 0)$$

The remaining H_o's that tested two way interaction are similarly determined.

$$H_{o_{ABC}}(ABC_{ijk}=0 \text{ for every } ijk) \text{ against } H_{a_{ABC}}(\text{some } ABC_{ijk}\neq 0)$$

The remaining H_o's that tested the three way interaction are similarly determined.

$$H_{o_{ABCD}}(ABCD_{ijkl}=0 \text{ for every } ijkl) \text{ against } H_{a_{ABCD}}(\text{some } ABCD_{ijkl}\neq 0)$$

In this experiment, Type I and Type II errors are equally pernicious. Type I error is rejecting a true hypothesis, while Type II error is accepting a false hypothesis. When the alpha level is at .01, the experimenter rejects only one true hypothesis out of 100. However, he may be accepting higher than 80 per cent false hypotheses. When exploratory research is conducted, the primary interest is potential areas for later more detailed research. By increasing the alpha level, the probability of a Type I error increases, the probability of a Type II error decreases, and the power of the test increases. This investigation used an alpha level of .10 as opposed to .05 or .01. This .10 alpha level has a larger power and will allow more potential areas of research to be discovered.

Hypotheses. This experiment was designed with several hypotheses in mind and for this reason, the following hypotheses were tested:

1) H_{o_1} (The reaction time of a human subject will not vary with time at a test temperature after being exposed to an adaptation temperature) against

H_{a_1} (The reaction time of a human subject will vary with time at a test temperature after being exposed to an adaptation temperature)

2) H_{o_2} (Different adaptation times at some temperature will not affect the reaction time of a human subject at different test temperatures and times) against

H_{a_2} (Different adaptation times at some temperature will affect the reaction time of a human subject at different test temperatures and times)

3) H_{o_3} (Different adaptation temperatures will not effect the reaction times of a human subject at a subsequent test temperature) against

H_{a_3} (Different adaptation temperatures will effect the reaction times of a human subject at a subsequent test temperature)

4) H_{o_4} (Different test temperatures will not effect the reaction times of a human subject) against

H_{a_4} (Different test temperatures will effect the reaction times of a human subject)

Procedure

The tests were all conducted in the afternoon and evening (between 3:00 P.M. and 9:00 P.M.). The subjects were trained under actual conditions for three complete trial runs before the experiment started. The procedure for the experiment was that the subjects entered the adaptation or pre-test room at the same time and disrobed except for their shorts and socks. They remained in the pre-test room at a set adaptation temperature for a prescribed time. They were taken into the adjoining environmental room and seated at the test table. The environmental room was at a set ambient test temperature and the subjects were tested at 30 and 60 minutes. However, the subjects were tested as soon as they entered the room for training only and this test consisted of a series of ten trials just like the experimental tests. Although only ten trials were recorded, no less than fifteen trials were run each test. The tests were started but the clocks were not used for several trials. After this test was accomplished, the subjects could talk, read, or write except when being tested at 30 and 60 minutes.

A chronology of a test at pre-test temperature of 65°F., pre-test time of 30 minutes, a test temperature of 95°F., and test time of 60 minutes would appear as follows:

I. 3:00 P.M.

   A. Subjects enter adaptation room
      1. Adaptation temperature of 65°F.
      2. Adaptation time of 30 minutes
   B. Subjects remove clothing except shorts and socks.

II. 3:30 P.M.

A. Subjects leave adaptation room and enter test room
   1. Test temperature of 95°F.
   2. Test time of 60 minutes
B. Subjects tested on reaction times for training only

III. 4:00 P.M.

A. Subjects tested for reaction times
B. Ten accumulated trials for each subject recorded on data sheet

IV. 4:30 P.M.

A. Subjects tested for reaction times
B. Ten accumulated trials for each subject recorded on data sheet
C. Subjects leave test room
D. Next test at 7:00 P.M.

RESULTS AND DISCUSSION

Results

An analysis of variance was computed and the resulting values are presented in Plate I. The actual Sum of Squares, Mean Squares, Table F ratio, Experimental F ratio, and the decision that was reached concerning the interaction and main effects are given in this analysis of variance. Tables of means (Table 4) and graphs were constructed to help determine the nature of the interactions and main effects. Only the terms that showed a significant F ratio were plotted. The mean reaction time was plotted on the vertical axis and the levels of main effects were plotted on the horizontal axis.

Discussion

The terms that have shown significance with the F test are of primary interest. Since main effects are best interpreted after an evaluation of interaction effects, the graphs will be explained in reverse order that they appear in the analysis of variance on Plate I.

Since A,B, and C interact significantly, it is necessary to examine all three factors together to arrive at any valid conclusions in this experiment. The two way interactions and main effects are only averages and obscure the true inter-relationships of the results. Most of the discussion will be

EXPLANATION OF PLATE I.

Analysis of variance for main effects and interaction of treatment main effects are calculated on the following plate.

PLATE I

Source	D/F	Sum of Squares	Mean Square	Table F Ratio	Experimental F Ratio	Decision
Treatments	35	16012				
Adaptation Temp. (A)	2	1809	904.50	2.34	5.03	Reject H_{o_A}
Adaptation Time (B)	1	379	379.00	2.74	2.11	Accept H_{o_B}
Test Temp. (C)	2	1515	757.00	2.34	4.22	Reject H_{o_C}
Test Time (D)	1	17	17.00	2.74	.009	Accept H_{o_D}
AB	2	2488	1244.00	2.34	6.93	Reject $H_{o_{AB}}$
AC	4	669	167.25	1.98	.93	Accept $H_{o_{AC}}$
AD	2	433	216.50	2.34	1.20	Accept $H_{o_{AD}}$
BC	2	2263	1131.50	2.34	6.30	Reject $H_{o_{BC}}$
BD	1	1181	1181.00	2.74	6.57	Reject $H_{o_{BD}}$
CD	2	217	108.50	2.34	.60	Accept $H_{o_{CD}}$
ABC	4	2592	648.00	1.98	3.61	Reject $H_{o_{ABC}}$
ABD	2	357	178.50	2.34	.99	Accept $H_{o_{ABD}}$
ACD	4	669	167.25	1.98	.93	Accept $H_{o_{ACD}}$
BCD	2	363	181.50	2.34	1.01	Accept $H_{o_{BCD}}$
ABCD	4	1060	265.00	1.98	1.47	Accept $H_{o_{ABCD}}$
Subjects	4	126484				
Subjects by Treatments (Error)	140	25120	179.5			
Total	179	167616				

over the three way interaction (ABC) on Plate II and the (BD) two way interaction. All of the other interactions and main effects are averages of these. Plate II gives the graphical presentation of the results for the (ABC) factors in terms of the mean reaction time and adaptation temperature. However, factors (A) or (C) could have been used just as well for horizontal axis of the graph. Discussions of the graphs are as follows:

1) The graph on Plate II denotes the interaction of adaptation temperature, adaptation time, and test temperature. When the test temperatures were the same as the adaptation temperatures, the mean reaction times remained almost constant with adaptation times of 30 and 60 minutes. When the adaptation temperatures and test temperatures were both 80°F., the mean reaction time was somewhat faster than when both were 65° or 95°. When the test temperature was lower than the adaptation temperature, the mean reaction time again remained fairly constant at adaptation times of 30 and 60 minutes. The one exception to this was the adaptation temperature of 80°F. and test temperature of 65° which indicated some interaction. Most of the interaction is shown by the adaptation temperature of 65°F. and test temperature of 80°F. The mean reaction time increased greatly between adaptation time of 30 and 60 minutes. The other two adaptation temperatures and test temperatures of 65°, 95°, and 80°, 95° indicated some

interaction.

2) The graph on Plate III denotes the interaction of adaptation time and test time. Since there are only two times, only the linear components of the observed effects can be determined. The effects of an adaptation time of 30 minutes on reaction time of a human subject has a positive slope upward as it goes from a test time of 30 minutes to a test time of 60 minutes. The effect of an adaptation time of 60 minutes on reaction time has a negative slope as it goes from a test time of 30 minutes to a test time of 60 minutes. This is a good example of two way interaction where the main effects disappear because of the reversal of the trend.

3) Plate IV denotes the interaction of adaptation time and test temperature and can be looked at as an average over the test temperature on Plate II. At an adaptation time of 30 minutes, a quadratic effect of reaction time of a human subject is shown between ambient test temperatures of 65°F. and 95°F. For a test time of 60 minutes, the effect of the test temperatures on reaction time is mostly linear, as was shown on Plate II of the ABC interaction.

4) As is shown on Plate V, at the adaptation time of 30 minutes, the reaction time of a human subject greatly increases between adaptation temperatures of 65°F. and 80°F., while at the 60 minutes adaptation time, it decreases. When going from the adaptation temperature of 80°F. to 95°F. at an adaptation time of 30 minutes, the reaction time de-

creases as the temperature increases. At adaptation time 60 minutes, the opposite is true, Again these effects are only averages of the ABC interaction, and are plainly shown on Plate II.

5) Test temperature as shown on the graph of Plate VI denotes a large quadratic effect and very small linear effect. Reaction time of a human subject is at its slowest when the ambient test temperature is at 65°F. and decreases considerable when the test temperature approaches 80°F. As the test temperature leaves 80°F. and approaches 95°F., the reaction time again decreases appreciably. This quadratic effect may also be seen very clearly on Plate II, the ABC interaction.

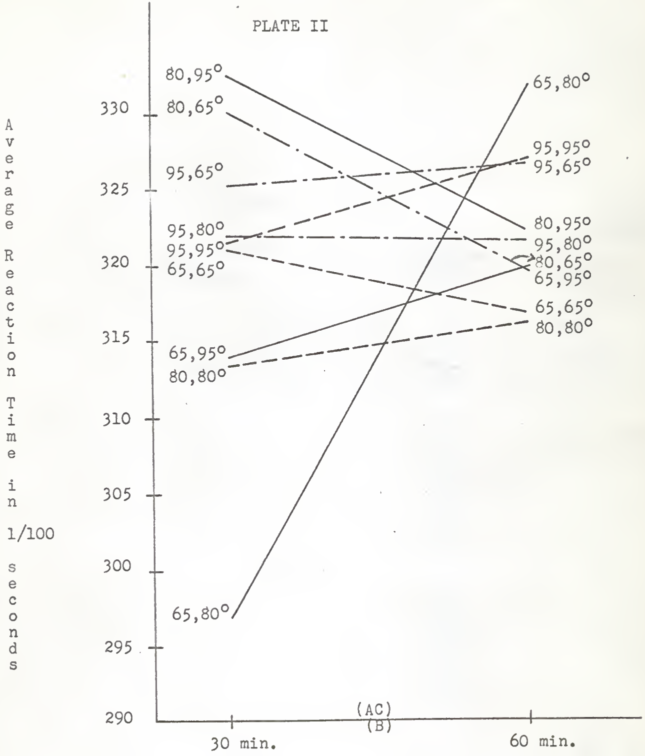
6) The adaptation temperature, as shown on the graph of Plate VII, denotes a linear trend. It would indicate that reaction time of a human subject varies linearly when an ambient adaptation temperature precedes a test temperature. This reaction time is slower as the temperature increases from 65°F. to 95°F. The slope of the trend is larger between 65°F. and 80°F. than it is from 80°F. to 95°F. Because of ABC interaction, no conclusive statement can be made about adaptation temperature alone.

Reaction time in past experiments has varied with body temperature. (12,13,15) In the past, subjects have worn protective clothing in ambient temperature experiments dealing with reaction time under these conditions, body temperatures are not likely to fluctuate unless the temperatures were extremely hot or cold. If reaction time is dependent on body temperature, then protective clothing should not be worn and body temperature should be monitored as well as the ambient temperature. It would be desireable in further experiments of this nature to monitor body temperature by use of rectal thermometers. This would allow the use of analysis of covariance for removing the effects of body temperature.

For further refinement in this experiment, more subjects should be used and each test run several times to give the effect of true replication. Using three well chosen times instead of two would determine whether the time effects were linear or quadratic. Due to the complicated nature of the interaction, it may be advisable to hold one or more factors constant and study fewer facts over a wider range or in greater detail.

EXPLANATION OF PLATE II

This plate denotes the interaction of main effects, adaptation temperature (A), adaptation time (B), and test temperature (C). It indicates the effect that these main effects have on reaction time. The reaction time is averaged over the main effects (ABC), which represent two treatment combinations of data at each of the eighteen points on the graph.

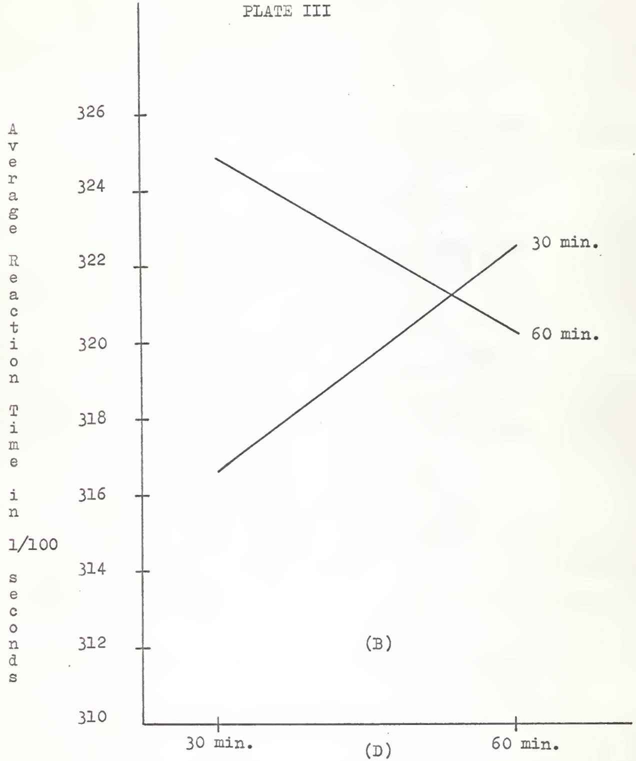


Adaptation Temperature (A), Adaptation Time (B), and Test Temperature (C) Interaction (ABC)

EXPLANATION OF PLATE III

This plate denotes the interaction of main effects, adaptation time (B) and test time (D). It indicates the effect that these main effects have on reaction time. The reaction time is averaged over the main effects (BD), which represents nine treatment combinations of data at each of the four points on the graph.

PLATE III

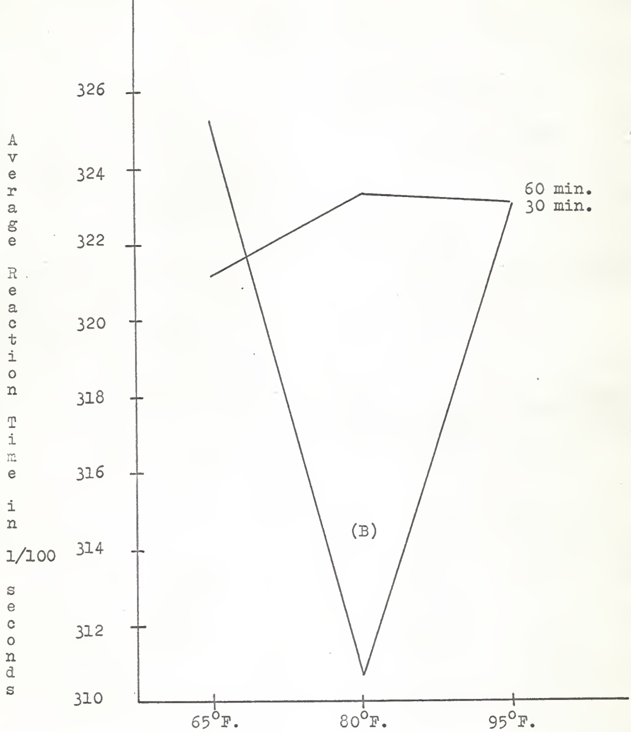


Adaptation Time (B) and Test Time (D) Interaction (BD)

EXPLANATION OF PLATE IV

This plate denotes the interaction of main effects, adaptation time (B) and test temperature (C). It indicates the effect that these main effects have on reaction time. The reaction time is averaged over the main effects (BC), which represents six treatment combinations of data at each of the six points on the graph.

PLATE IV

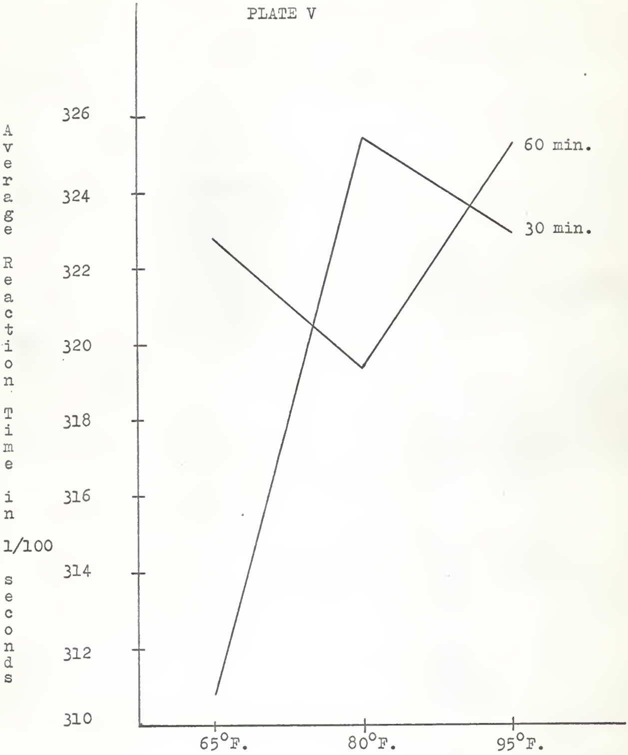


Adaptation Time (B) and Test Temperature (C) Interaction (BC)

EXPLANATION OF PLATE V

This plate denotes the interaction of main effects, adaptation temperatures (A) and adaptation time (B). It indicates the effect that these main effects have on reaction time. The reaction time is averaged over the main effects (A) and (B), which represents six treatment combinations of data at each of the six points on the graph.

PLATE V

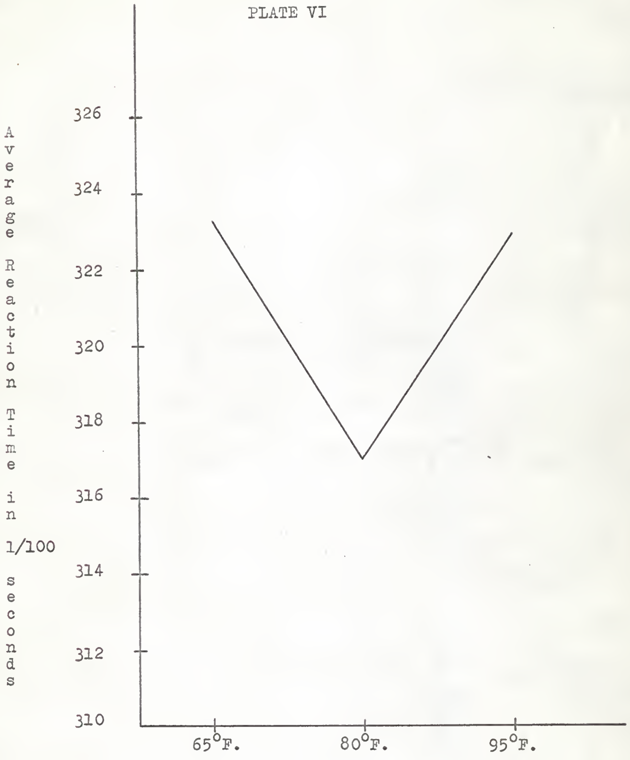


Adaptation Temperature (A) and Time (B) Interaction (AB)

EXPLANATION OF PLATE VI

This plate denotes the quadratic effect, that the main effect test temperature (C) has on the reaction time of a human subject. The reaction time is averaged over the main effect (C), which represents twelve treatment combinations of data at each of the three points on the graph.

PLATE VI

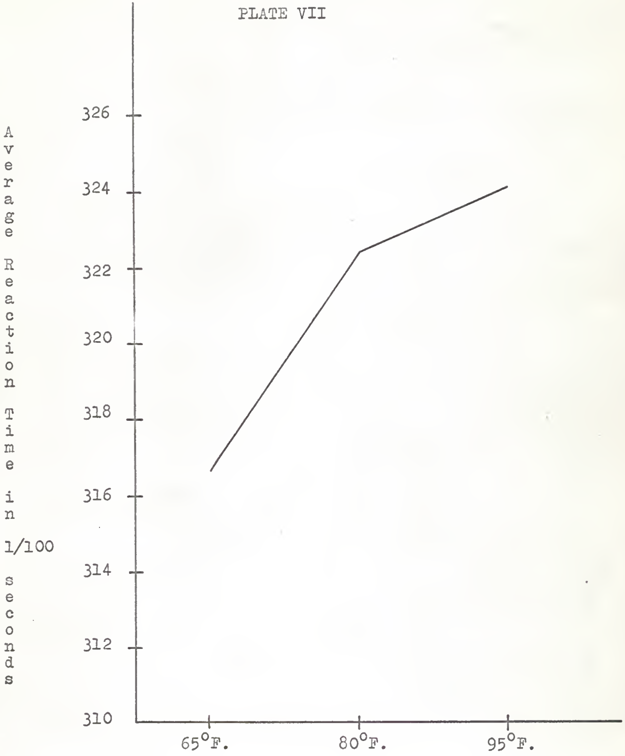


Test Temperature (C) Main Effect

EXPLANATION OF PLATE VII

This plate denotes the linear effect, that the main effect adaptation temperature (A) has on the reaction time of a human subject. The reaction time is averaged over the main effect (A), which represents twelve treatment combinations of data at each of the three points on the graph.

PLATE VII



Adaptation Temperature (A) Main Effect

CONCLUSION

From this study, the following conclusions were made.

1) Adaptation temperatures and test temperatures of the same level do not show a significant change in average reaction time from the adaptation time of 30 minutes to 60 minutes. When the test temperatures are lower than the adaptation temperatures, either no change in average reaction time from adaptation time of 30 minutes to 60 minutes or a slightly faster trend is indicated. Most of the interaction stems from having a adaptation temperature lower than the test temperature. Most of this interaction is from the 65° adaptation temperature and 80°F. test temperature. In this case, the average reaction time greatly increased from 30 minutes adaptation time to 60 minutes.
2) For an adaptation time of 30 minutes, an increase in test time tends to decrease average reaction time. For the 60 minute adaptation time, this effect appears to be reversed.

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APPENDIX

EXPLANATION OF TABLE 2

The following table consists of the data gathered throughout the experiment.

TABLE 2

ADAPTATION TEMPERATURE	ADAPTATION TIME	SUBJECT	65° TEST TEMPERATURE TEST TIME 30'	65° TEST TEMPERATURE TEST TIME 60'	80° TEST TEMPERATURE TEST TIME 30'	80° TEST TEMPERATURE TEST TIME 60'	95° TEST TEMPERATURE TEST TIME 30'	95° TEST TEMPERATURE TEST TIME 60'
65°	30'	1	356	350	306	325	363	370
		2	331	330	316	306	306	319
		3	333	327	298	311	330	319
		4	313	290	281	295	299	287
		5	282	298	256	272	275	274
65°	60'	1	362	341	370	375	390	377
		2	312	320	358	363	367	305
		3	339	311	339	337	323	296
		4	307	308	299	301	283	297
		5	286	283	294	282	282	278
80°	30'	1	361	394	355	360	379	399
		2	304	347	343	342	349	353
		3	335	361	318	298	350	334
		4	303	296	296	308	289	308
		5	275	325	250	265	284	282
80°	60'	1	356	336	355	348	347	360
		2	350	335	332	316	332	320
		3	334	317	323	336	359	351
		4	319	300	297	307	300	301
		5	274	277	269	280	280	273
95°	30'	1	351	363	338	351	348	349
		2	340	350	330	340	343	350
		3	333	320	347	349	315	313
		4	297	323	303	282	318	310
		5	281	294	294	286	281	288
95°	60'	1	357	370	350	328	360	350
		2	348	344	332	353	348	346
		3	325	339	328	333	331	350
		4	308	308	326	304	317	304
		5	290	282	281	283	277	288

EXPLANATION OF TABLE 3

The following table consists of the average reaction time for the five subjects in each test.

TABLE 3

ADAPTATION TEMPERATURE	ADAPTATION TIME	SUBJECTS	65° TEST TEMPERATURE		80° TEST TEMPERATURE		95° TEST TEMPERATURE	
			TEST TIME		TEST TIME		TEST TIME	
			30'	60'	30'	60'	30'	60'
65°	30'	1 2 3 4 5	323.0	319.0	291.4	301.8	314.6	313.8
65°	60'	1 2 3 4 5	321.2	312.6	332.0	331.6	329.0	310.6
80°	30'	1 2 3 4 5	315.6	344.6	312.4	314.6	330.2	335.2
80°	60'	1 2 3 4 5	326.6	313.0	315.2	317.4	323.6	321.0
95°	30'	1 2 3 4 5	320.0	330.0	322.4	321.6	321.0	322.0
95°	60'	1 2 3 4 5	325.6	328.6	323.4	320.2	326.6	327.6

EXPLANATION OF TABLE 4

The following table consists of the data from which the graphs were constructed that illustrated the main effects and interactions of the main effects.

TABLE 4

		A						
		65°F.		80°F.		95°F.		
	B	30 min.	60 min.	30 min.	60 min.	30 min.	60 min	
C	65°F.	321.0	316.7	330.1	319.8	325.2	327.1	323.3
C	80°F.	296.6	331.8	313.5	316.3	322.0	321.8	317.0
C	95°F.	314.2	319.8	332.7	322.3	321.5	327.1	322.9
		310.6	322.8	325.4	319.4	322.9	325.3	
		316.7		322.4		324.1		

		B	
		30 min.	60 min.
C	65° F.	325.4	321.2
C	80°F.	310.7	323.3
C	95°F.	322.8	323.0

		B	
		30 min.	60 min.
D	30 min.	316.7	324.8
D	60 min.	322.5	320.2

EXPLANATION OF PLATE VIII

The following photograph is of the reaction time booths used in the experiment.

PLATE VIII

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THE EFFECT OF TEMPERATURE AND EXPOSURE DURATION ON VISUAL REACTION TIME

by

LLOYD STUART CURTIS

B.S., Kansas State University, 1963

AN ABSTRACT OF A MASTER'S THESIS

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1965

Research in thermal environment has many variables with which to contend. In addition to temperature and humidity, there are exposure time, age, sex, diet, activity, clothing and area-volume. The purpose of this investigation was to determine the effect of exposure time and temperature on visual reaction time after a pre-test adaptation to different temperatures for different lengths of time.

Five male college students were tested on a simple visual reaction time test during six different thermal conditions. Three temperatures of 65°, 80°, and 95°F. at each of two times of 30 minutes and 60 minutes were used as the test conditions and pre-test exposure conditions. Factorial arrangements of treatments insured exposure to all treatment combinations.

In the analysis of variance it was shown that visual reaction time was influenced by changes in temperatures between 65°F. and 95°F. Reaction time varies linearly when affected by adaptation temperature at a subsequent test temperature. Reaction time varies quadratically when effected by the test temperatures. Neither adaptation time or test time significantly varied the reaction time.

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