The Effect of the Difference in the Perception of Temperature Between Sexes on the Academic Performance of Chapin High School Students

Tiffany Phan

Chapin High School, Chapin ,SC

Mental performance and mental functions may be negatively affected by decreases in thermal comfort as a result of large differences in temperature. Additionally, females are seen to be less content with room temperatures and actually prefer rooms with higher temperatures in comparison to males. This investigation explored the potential effect that sex plays in thermal perception and the impact it may yield on academic performance within a high school population. It was hypothesized that female students would experience an increase in academic performance as the temperature increased while males would experience the opposite effect. A quasi-experimental approach was used to address the potential correlation. A SAT preparation class at Chapin High School was asked to complete a Google form that recorded their sex and contained 24 SAT style questions. This process was repeated on three different days within the same classroom setting where the temperature was manipulated to 67, 72, and 78 degrees Fahrenheit on each day. Analysis of Variance (ANOVA) and Tukey's method tests were performed to analyze the relationship between thermal perception and academic performance. The ANOVA test resulted in a p-value of 0.049 between the means of temperature and sex, which indicated that there was statistical significance regarding correlation between differences in thermal perception and academic achievement. Additionally, through Tukey's method, the results calculated three significant T-values that served as evidence against the null hypothesis. Based on these findings, it is concluded that male academic performance increased as temperature increased, while female academic performance increased as temperature decreased.

Introduction

There is evidence suggesting that mental performance and mental functions may be negatively affected by thermal stressors.[1] A major factor that contributes to mental performance and mental functions is thermal comfort.[2] Thermal comfort is defined as "that condition of mind, which expresses satisfaction with the thermal environment." [3]

A current debate regarding thermal discomfort, commonly known as the "Battle of the Thermostat," pertains to findings that current office temperature regulations are not appropriate for the female population and may impact their productivity.[4] Current indoor climate regulations are based on the average male thermal comfort. As a result, female metabolic rates are overestimated by up to 35%, and females experience a lack of thermal comfort as buildings are essentially non-energy-efficient. [5] This indicates that the current temperature regulations in buildings may negatively impact female productivity due to the lack of thermal comfort. This claim is also supported by evidence that in comparison to males, females are less content with room temperatures and favor higher room temperatures.[6] According to Karjalainen, a researcher at Technical Research Centre of Finland, this dissatisfaction with room temperature may cause females to feel both uncomfortably colder and uncomfortably hotter in more instances than males. [6] The human body maintains thermal comfort through heat, convection heat, the radiation and absorption of heat loss, and by removing retained heat that is produced by the human metabolism.[7] Through these processes, the human body can maintain thermal equilibrium with the environment. However, if there are any gains or losses outside this range, the heat will cause thermal discomfort.[7] The difference in female and male thermal comfort may be caused by physiological and psychological factors. These factors could include body composition, metabolic rate, and adaptation to thermal environments.[8]

Not only can thermal discomfort caused by temperature impact females in the workplace, but it can also impact the female high school population in a classroom environment.The brain constantly reminds the body when temperatures are too hot or too cold. Therefore, large differences in classroom temperatures can negatively impact student performance due to a lack of focus and concentration interruptions.[1] There is evidence that explains the potential differences in thermal perception between genders and indicates that classroom temperature affects academic performance. However, researchers have yet to explore the potential link between differences in thermal perception between genders and the impact this may have on academic performance in high school students. In order to address this gap and explore the potential variable of gender perception, the question asked is: to what extent does the difference in the perception of temperature between sexes affect the academic performance of high school students?

Literature Review

The Effect of Temperature on Academic Performance

Temperature may have a significant impact on academic performance in students according to Jisung Park, a researcher at Harvard University.[9] Park claims that the physiological and cognitive effects of heat stress caused by high temperatures may have significant consequences. In order to prove his claim, Park performed a study to test the effect of heat stress on academic performance by using administrative data from New York City public schools, the nation's largest school district. The study resulted in data that indicated that heat exposure during an exam employs a causal and economically significant impact on academic achievement. In the experiment, the average student taking a NY State Regents exam on a hot day led to a decrease in performance by 0.22% per one °F above room temperature (72°F).[9] According to Park's results, a 90°F day reduced exam performance by 15% compared to exam performance on a 72°F day. Park also found both short and long term effects of the temperature as cumulative heat exposure resulted in a 12.3% higher chance of failing a subject exam and a 2.5% lower chance of attending high school graduation.[9] Cumulative heat exposure over the course of the preceding school year may decrease the rate of learning based on the exit exam scores in the study. Although Park's study addresses the correlation between outside temperature and academic performance, it indicates that overall temperature has an impact on academic performance. The purpose of the experiment outlined in this manuscript is to expand upon the effect of temperature on academic performance by testing the impact of the classroom temperature itself rather than the outside temperature. Park also claimed that the consequences of heat stress could yield economic impacts which relates to a study conducted by Alan Hedge, a professor in the Department of Design and Environmental Analysis at Cornell University.[10] Hedge claims that there is a correlation between office productivity and indoor temperature conditions. The results of the study suggest that office performance improves as conditions approach a predicted thermal comfort zone. Additionally, when the temperature was raised from 20 ° C to 25 °C, it yielded positive effects such as a reduction in energy consumption, a reduction in costs, and an increase in keying output by 150%.[10] Although the experiment in this manuscript won't address the economic impact that indoor temperatures may yield, it will explore the idea that indoor temperature impacts productivity as discussed in Hedge's study.

Student Thermal Discomfort

Processes occur in the body to maintain thermal equilibrium with the environment which the body perceives as thermal comfort. Thermal comfort is affected by heat, convection heat, and radiation and absorption of heat loss.[7] Heat can cause thermal discomfort when there are heat gains or losses outside of equilibrium. In a study conducted by Marzita Puteh, who has conducted various research pertaining to Student's learning style and students' self directed learning behaviour, a preliminary survey was given to students to investigate the student's perceptions towards classroom thermal comfort by using The Teaching and Learning Classroom Thermal Comfort Inventory (TLTCI) instrument.[7] The results of the study indicate that the surveyed students have a high level of awareness regarding temperature change.[7] Based on Puteh's data that indicated that students were highly aware of temperature changes, it can be inferred that large differences in temperature could possibly hinder their thermal comfort and their productivity. This can also be supported from the previous study mentioned that was performed by Alan Hedge. The results from his study support this inference as office productivity reached its highest peak when a thermal comfort zone was reached.[10] Since large differences in temperature may impact productivity according to Hedge's study,and students are highly aware of temperature differences based on Puteh's data, the academic productivity of students may be negatively impacted by large differences in classroom temperature.

Psychological and Physiological Effects of High Temperatures

The physiological and cognitive effects of heat stress may have significant consequences. According to Dr. Glen Kenny who has a doctorate in physiology at the University of Ottawa and holds a University Research Chair in Human Environmental Physiology, at extreme levels, heat exposure can be deadly as the body becomes dehydrated, and as a result, hyperthermia can result in dizziness, muscle cramps, and fever.[11] These symptoms can eventually lead to acute cardiovascular, respiratory, and cerebrovascular reactions. Exposure to heat is also associated with increases in blood viscosity and blood cholesterol levels, which can increase the chances of morbidity in the form of heat exhaustion and stroke, however, this mostly applies to the elderly population.[11] Additionally, at mild temperatures, heat can also affect human physiology and psychology. Mild temperatures can result in the brain producing a disproportionate amount of body heat[12], which can reduce neural processing speed and result in impaired memory.[13] This indicates that temperature can reduce cognitive and physical function at higher levels. Due to the psychological effects that are associated with high temperatures, it can be inferred that temperature does play a psychological role in humans and that temperature can impact their cognitive performance at both psychological and physiological levels.

Metabolic Rate

Thermal comfort is a major factor that contributes to mental performance and functions. Metabolic rate is one of the variables that contribute to thermal comfort.[7] According to Professor Kingma from the Department of Human Biology at Maastricht University, current indoor climate regulations overestimate female metabolic rates by up to thirty-five percent. This is due to the fact that these regulations are commonly based on the average male.[5] This indicates that buildings may be intrinsically non-energy-efficient in providing comfort to females. Additionally, Professor Kingma conducted a study in which the results of the study indicate that the metabolic rate of young adult females performing light office work is significantly lower than the standard values for the same type of activity. The study argues that current temperature regulations should be adjusted according to the actual values in regard to metabolic rates of females in order to reduce gender-discriminating bias in thermal comfort predictions.

Differences in Perception and Performance Between Sexes

There are significant gender differences in thermal comfort and temperature preference according to Sami Karjalainen, a researcher at Technical Research Centre of Finland.[6] In a study conducted by Karjalainen in 2007, Karjalainen examined gender differences in thermal comfort through a quantitative interview survey with a total of 3094 respondents. The study was conducted in Finland and common thermal environments: homes, offices and a university were considered. The results of the study showed significant gender differences in thermal comfort and temperature preference. In comparison to males, females were less satisfied with room temperatures, prefered higher room temperatures, and felt both uncomfortably cold and uncomfortably hot more often.[6] These differences in perception play a significant role in thermal discomfort which plays a significant role in academic performance. According to a study known as the "Battle of the Thermostat," women were seen to perform better on the math and verbal tasks while the men performed lower in these areas at higher indoor temperatures.[4] In the study, 500 individuals were placed in an environment where the indoor temperatures were manipulated and were asked to perform a set of cognitive tasks which included math, verbal and cognitive reflection. The data illustrated that the increase in female performance in response to higher temperature was significantly larger than the corresponding decrease in male performance. However, in contrast to math and verbal tasks, they found that temperature had no impact on cognitive reflection, which is the measure of an individual's ability to engage in a more intensive reflection to find a correct answer, for either gender.[4]

Hypothesis

According to the studies of Park and Hedge, it can be inferred that academic achievement and classroom temperature correlate with one another.[9,10] Additionally, in the studies conducted by Karjalainen[6] and Chang[4], males and females may interpret these temperatures differently. Based on these findings, it is assumed that the difference in perception of temperature between males and females will yield different effects on their thermal comfort within varying temperature settings. However, the gap in research is apparent as there is a lack of evidence of the effect that these differences in perception of temperature between sexes have on the adolescent population within a classroom setting. The differences in thermal comfort are hypothesized to impact their academic performance due to potential result of a lack of focus and interruption of concentration. However, due to Karjalainen's study findings of preference for higher temperatures in females, females are hypothesized to experience an increase in academic performance as the temperature increases while males will experience the opposite effect.

Methods

In the investigation, data was collected through a Quasi-experimental approach. Quasi-experimental research involves the non-random assignment of participants to conditions with a manipulation of one or more independent variables. A Quasi-experimental approach was used in this experiment due to the study's involved participants who were chosen based on their age group: adolescents. In this study, the participants were students in an SAT prep class at Chapin High School. One SAT Prep class was tested during the experiment, and the same class was tested on three different days in the same classroom. Each day, participants were given a sample of 24 questions from Khan Academy that were modeled after SAT questions and written by CollegeBoard.[14] The samples of the SAT- inspired questions were different each day and were looked over by the SAT preparation teacher in terms of difficulty to ensure that the questions on each day were the same level of difficulty and did not impact their mean scores. The sample of questions included 6 questions from each of the four sections of the SAT: Reading, Writing, Math (No calculator), and Math (calculator). On day 1 of the experiment, students were given Practice Test #1 (see **Appendix H**) and assigned questions #1-6 in all four sections. On day 2 of the experiment, students were given Practice Test #3 (see **Appendix I**) and assigned questions #1-6 in the reading and math (no calculator) sections as well as questions #3-8 in the math calculator section and questions #12-17 in the language section. Lastly, on day 2 of the experiment, students were given Practice Test #6 (see **Appendix J)** and assigned questions #1-6 in all four sections. Each day, students were given 7.5 minutes to complete the Reading Section, 4.5 minutes to complete the writing section, 9 minutes to complete the Math no calculator section, and 7.5 minutes to complete the Math calculator section. Each of these times were calculated proportionally to the amount of time given to students taking the SAT. Students were also asked to record their answers on a Google form that included answer choice options (A,B,C,D) for each question (see Appendix A) and to record their sex with the options: male, female, other. The first day had a controlled temperature setting (72 degrees Fahrenheit which is the average classroom temperature), the second day had a high temperature setting (77 degrees Fahrenheit), and the third day had a low temperature setting (67 degrees Fahrenheit). On each day, the temperature was recorded using a thermometer. The names of the students were not collected to ensure the privacy and confidentiality of the participants. Each participant was identified using the email they used to complete the Google form. The email addresses consisted of only numbers and didn't include the names or any content that could be used to identify the participant. Additionally, data of the participants that reported "other" for their sex, and those who were not present for any of the three days of testing weren't accounted for in the data analysis. After the data was acquired, the results were analyzed to find if there was a correlation between female participants' scores and the classroom temperature and if males participants exhibit the same pattern through an Analysis of Variance (ANOVA) using Minitab Software.[15] The ANOVA test was used to analyze the differences among group means and the significance of the independent variables, such as gender and temperature, on the mean test scores. Additionally, a Post-hoc Tukey Method test was used to analyze the differences between the means from the results of the ANOVA test. The Post-hoc test was performed to further analyze the difference between specific mean test scores as the ANOVA test only provided data on the significance of independent variables. By looking at the specific differences between mean test scores, the mean test scores under each condition could be compared to one another. The factor of clothing was considered an extraneous variable in the experiment, and students were asked to wear clothing they would wear on a normal school day. The factor of clothing was not considered within this experiment as the aim of this experiment was to replicate a normal, typical classroom experience for the students, and students within public classroom settings are typically allowed to wear any type of clothing as long as it follows the guidelines within the school.

Results

The data from the investigation was collected from 13 participants in total in the SAT preparation class. Each of these participants were present amongst all three days of testing. The sample of participants included 6 females and 7 males that were tested under 67, 72, and 78 degrees Fahrenheit classroom settings on three different days. An Analysis of Variance of Means (ANOVA) test with repeated measures was used to analyze the means between temperature and sex based on **Appendix A**. A repeated measures ANOVA test was used as the experiment contained two inependent variables: sex and temperature. A linear regression model was also used to show the correlation between the two independent variables and the dependent variable (test score). The ANOVA test yielded results that indicated significant differences in thermal perception between sexes on academic achievement within the participant group. Based on the results of the ANOVA test, a post-hoc Tukey Method test was performed. Through Tukey's method test, the results calculated statistically insignificant T-values that served as evidence to support the null hypothesis.

Part I of Analysis: Analysis of Variance (ANOVA) Test

In **Appendix B**, the results of the ANOVA test are shown. The results of the ANOVA test yield data that indicate whether or not the individual variables within the experiment had a significant impact on the results. In this case, the individual variables are sex and temperature while the results are the test scores that the students received. The results of the ANOVA indicated that the interaction of temperature itself did not have a significant effect on the score achieved by the students as a whole as indicated by the p-value of 0.432. However, the interaction of sex*temperature had a p-value of 0.049 which indicated that the relationship between temperature and sex depended on the individual subjects. This indicates that the interaction between temperature and sex is statistically significant as a p-value of 0.05 or less indicates statistical significance.

Based on the results of **Appendix B**, it can be inferred that 79.3% of the data aligns with the graph shown in **Appendix C**. The graph in **Appendix C** is a main effects plot for the score of the participants. The main effects of the score were the two independent variables, sex and temperature. On the left, it is illustrated that males scored statistically lower than females. On the right, it is illustrated that the participants as a whole achieved higher scores in the medium temperature (72 degrees Fahrenheit) with a mean score of approximately 14.6. Although the investigation did not determine the individual effects of these factors on the academic achievement of the students, it supports evidence in the literature that performance is shown to be highest in a controlled temperature environment

The graph shown as **Appendix D** is an interaction plot of sex*temperature on the score of the participants. The graph illustrates the fact that males performed statistically lower in the lower classroom setting of 67 degrees Fahrenheit while females performed significantly higher in the lower classroom setting. Additionally, males had the greatest mean score in the medium temperature setting of 72 degrees Fahrenheit while females had the greatest mean score in the lower classroom setting of 67 degrees Fahrenheit.

Part II of Analysis: Post-Hoc ANOVA Test: Tukey Method Test

A post-hoc test was conducted on the data that was analyzed in the ANOVA test. As displayed above, the p-value for sex*temperature, 0.049, indicated that the interaction of sex*temperature had a statistically significant impact on the number of correct answers that the participants earned in the study (as seen in **Appendix B**).The ANOVA test was used to analyze the significance of the variables, whereas the Tukey Method test was used to analyze the differences between the results.Therefore, the Tukey method test was used to futher analyze the impact of the interaction of sex*temperature between specific mean groups.

Based on the results of the ANOVA test that showed a significant interaction between sex and temperature, a Post-Hoc Tukey Method test was performed to analyze the differences between the means of the scores based on the interaction of sex*temperature (as seen in **Appendix E**). The T-values provide numerical data to further analyze the difference between each combination of mean test scores of each group. The Tukey Method test yielded T-values that served as evidence to support the null hypothesis. The T-values were statistically insignificant as they are close to 0, and the closer the T-value is to 0, the greater the support for the null hypothesis. However, three T-values were quantitatively higher in comparison to other T-values: Female-Low and Female-High, Male-Low and Female-Low, and Male-Medium and Male-Low with T values 1.19, -1.44, and 1.19 respectively. These T-values indicate that despite being statistically insignificant, there was a higher difference in mean test scores between the groups. In **Appendix F,** the P-values for the difference of means are also given which further support the fact that the t-values are statistically insignificant as they are all greater than 0.05.

Conclusion

The ANOVA test resulted in a p-value of 0.049 for the interaction of sex*temperature and the mean score of the participants. Based on the results of the ANOVA test, a Post-Hoc Tukey Method test was performed. Since the Anova Test only calculated the significance of each interaction within the experiment, a Post-Hoc Tukey method test was performed to further analyze the differences between the mean scores based upon the variable of sex*temperature.

Through Tukey's method, the Tukey Method test yielded statistically insignificant T-values that served as evidence to support the null hypothesis. However, three T-values were quantitatively higher, and despite being statistically insignificant, the T-values illustrate that there were higher differences between the average mean test scores between these groups. This indicates that the interaction of sex*temperature impacted the score of the groups more in comparison to the other mean groups. The data collected in this investigation indicate that the males' academic performance increased as temperature increased, while females' academic performance increased as temperature decreased. The results of this investigation rejects the original hypothesis that females would have higher academic performance as the temperature increases and that males would experience the opposite pattern. Based on the results of the investigation, the results also reject the claims made by several works within the literature that indicated females would have an increased academic performance within higher temperature settings. However, the results of the investigation did support evidence presented in the literature that indicated that thermal perception played a significant role in academic performance due to evidence of physiological and psychological factors that are associated with large differences in temperature.

Limitations that may contribute to the discrepancy of the results was the small sample size and the extraneous variable of clothing that were not considered at the time of the investigation. The class investigated in the study originally had 20 students, however over the course of three days, only 13 of the students remained present for all three days of testing which may have hindered the results of the experiment. Additionally, the factor of clothing was considered an extraneous variable within the experiment. Students were not asked to wear specific clothing during the test days in an effort to replicate common workplace and public school environments. The factor of clothing may have impacted the thermal perception of the participants in the investigation.

The implications of this investigation include further evidence to contribute to the ongoing "Battle of the Thermostat" debate within the workplace setting. Most evidence within the literature indicated that females prefer higher temperatures and would, therefore, have higher productivity in warmer temperatures due to an increased thermal comfort level. However, the evidence of this study did not align with the evidence provided within the literature. Therefore, this investigation is able to provide further information on the impact of temperature on the productivity of men and women, more specifically in the adolescent age range. The information provided in this experiment could also be applied to classroom temperature regulations within the local school district as it provides information regarding the effect that these temperature regulations have on the academic achievements of students within the district.

Next Steps

Further research is required on the thermal perception of females and males in order to address the discrepancy in the results of this investigation. As seen in the results of the study, females had a higher academic performance in colder temperatures. However, these results are not supported by current information in the literature that supports the notion that females would have a higher academic performance in higher temperatures.

Future directions in this study include the investigation of the effect of clothing on thermal discomfort since the variable was considered righteous in the investigation. The factor of clothing may have had an unconsidered impact on the academic score due to its possible impact on the thermal perception of the participants within the study.

It is undecided if this study will be further continued. However, if this study were to be continued, a larger participant size would be tested as well as adding the component of thermal comfort levels as a variable. The hypothesis of this investigation was based on the assumption that females had a higher thermal comfort level in warmer temperatures. However, it is highly possible that the comfort level may not correlate with sex. By adding the component of thermal comfort it could further expand on why the participants in this study exhibited a pattern that rejected the original hypothesis and contrasted with evidence provided in the literature. Additionally, the larger sample size would provide further validity to the results of the study as the participant size in this investigation was small.

Notes and References

1. Taylor, L., Watkins, S. L., Marshall, H., Dascombe, B. J., & Foster, J. 2016. The Impact of Different Environmental Conditions on Cognitive Function: A Focused Review. *Frontiers in physiology*, *6*, 372. doi:10.3389/fphys.2015.00372
2. Law, T.-O., & Fay, R. 2009. *Thermal comfort, productivity and energy consumption in the tropical office environment: A critical overview*. Retrieved from http://anzasca.net/wp-content/uploads/2015/12/ANZAScA_2009_Law_Fay.pdf
3. *ISO 7730:1994*. 1994. Retrieved from https://www.iso.org/standard/14567.html
4. Chang, T. Y., & Kajackaite, A. 2019. *Battle for the thermostat: Gender and the effect of temperature on cognitive performance*. Retrieved from https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0216362#pone.0216362.ref001
5. Kingma, B., & Lichtenbelt, W. V.-M. 2015. *Energy consumption in buildings and female thermal demand*. Retrieved from https://www.nature.com/articles/nclimate2741
6. Karjalainen, S. 2007. *Gender differences in thermal comfort and use of thermostats in everyday thermal environments*. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0360132306000242?via%3Dihub
7. Puteh, M. 2012. *Thermal comfort in classroom: Constraints and issues*. Retrieved from https://www.sciencedirect.com/science/article/pii/S1877042812015170
8. Schweiker, M. 2018. *Drivers of diversity in human thermal perception – A review for holistic comfort models*. Retrieved from https://www.tandfonline.com/doi/full/10.1080/23328940.2018.1534490
9. Park, J. 2017. *Temperature, test scores, and human capital production*. Retrieved from http://scholar.harvard.edu/files/jisungpark/files/temperature_test_scores_and_human_capital_production_-_j_park_-_2-26-17.pdf

10. Hedge, A. 2004. *Linking environmental conditions to productivity*. Retrieved from http://ergo.human.cornell.edu/Conferences/EECE_IEQ%20and%20Productivity_ABBR.pdf

11. Kenny, Yardley, J., Brown, C., Sigal, & Jay, O. 2009. *Heat stress in older individuals and patients with common chronic diseases.* Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/19703915

12. Raichle, & Mintun. *Brain work and brain imaging*. 2006. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/16776593

13. Hocking, C., Silberstein, R. B., Lau, W. M., Stough, C., & Roberts, W. 2001. Evaluation of cognitive performance in the heat by functional brain imaging and psychometric testing. Retrieved from https://scite.ai/reports/10.1016/s1095-6433(01)00278-1

14 Khan academy. Retrieved March 1, 2020, from https://www.khanacademy.org/

15. Minitab [Computer software]. Retrieved from http://www.minitab.com/en-US/default.aspx

Appendix A: Data Collection

Subject	Sex	Temperature	Score
A	Male	Medium	12
A	Male	High	14
A	Male	Low	7
B	Male	Medium	20
B	Male	High	14
B	Male	Low	4
C	Male	Medium	8
C	Male	High	3
C	Male	Low	2
D	Female	Medium	20
D	Female	High	20
D	Female	Low	23
E	Male	Medium	13
E	Male	High	17
E	Male	Low	10
F	Male	Medium	16
F	Male	High	17
F	Male	Low	24
G	Female	Medium	11
G	Female	High	10
G	Female	Low	11
H	Female	Medium	14
H	Female	High	11
H	Female	Low	12
I	Male	Medium	15
I	Male	High	19
I	Male	Low	15
J	Male	Medium	20
J	Male	High	13
J	Male	Low	16
K	Female	Medium	19
K	Female	High	12
K	Female	Low	20
L	Female	Medium	5
L	Female	High	3
L	Female	Low	9
M	Female	Medium	17
M	Female	High	15
M	Female	Low	20

Appendix B: General Linear Model: Score versus Subject, Sex, Temperature

General Linear Model: Score versus Subject, Sex, Temperature

The following terms cannot be estimated and were removed:
Sex

Method

Factor coding (-1, 0, +1)

Factor Information

Factor	Type	Levels	Values
Subject	Fixed	13	A, B, C, D, E, F, G, H, I, J, K, L, M
Sex	Fixed	2	Female, Male
Temperature	Fixed	3	High, Low, Medium

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Subject	12	873.23	72.77	6.27	0.000
Temperature	2	20.25	10.13	0.87	0.432
Sex*Temperature	2	80.25	40.13	3.46	0.049
Error	22	255.29	11.60		
Total	38	1229.23			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
3.40645	79.23%	64.13%	35.94%

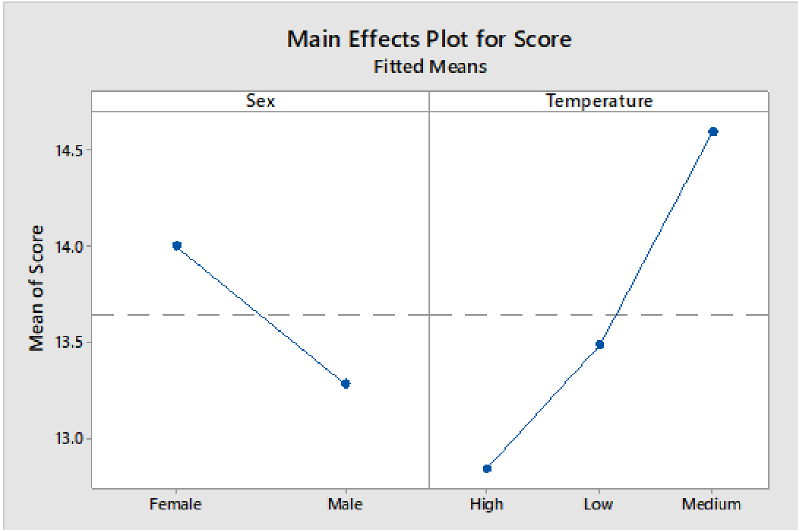
Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	13.615	0.545	24.96	0.000	
Subject					
A	-2.62	1.89	-1.38	0.180	1.85
B	-0.95	1.89	-0.50	0.621	1.85
C	-9.28	1.89	-4.91	0.000	1.85
D	7.38	1.89	3.91	0.001	1.85
E	-0.28	1.89	-0.15	0.883	1.85
F	5.38	1.89	2.85	0.009	1.85
G	-2.95	1.89	-1.56	0.133	1.85
H	-1.28	1.89	-0.68	0.505	1.85
I	2.72	1.89	1.44	0.164	1.85
J	2.72	1.89	1.44	0.164	1.85
K	3.38	1.89	1.79	0.087	1.85
L	-7.95	1.89	-4.21	0.000	1.85
Temperature					
High	-0.798	0.774	-1.03	0.314	1.34
Low	-0.155	0.774	-0.20	0.843	1.34
Sex*Temperature					
Female High	-1.369	0.774	-1.77	0.091	1.34
Female Low	1.988	0.774	2.57	0.017	1.34

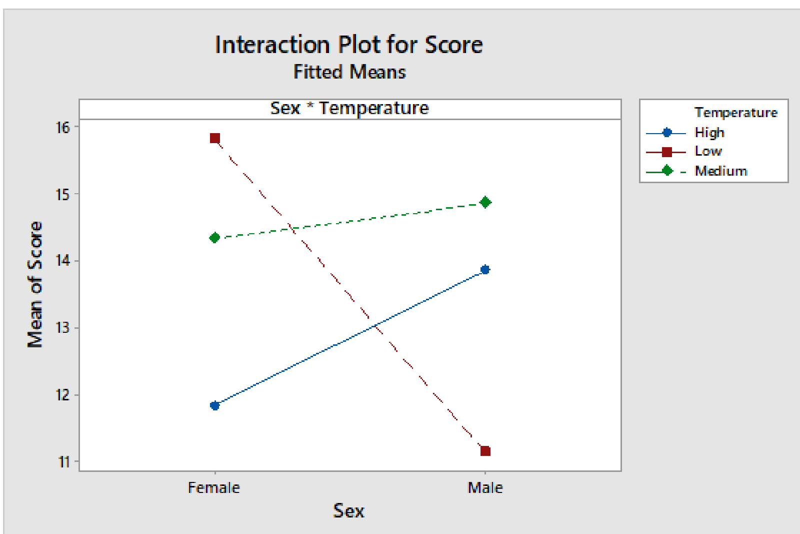
Regression Equation

Score = 13.615 - 2.62 Subject_A - 0.95 Subject_B - 9.28 Subject_C + 7.38 Subject_D
- 0.28 Subject_E + 5.38 Subject_F - 2.95 Subject_G - 1.28 Subject_H + 2.72 Subject_I
+ 2.72 Subject_J + 3.38 Subject_K - 7.95 Subject_L + 3.72 Subject_M
- 0.798 Temperature_High - 0.155 Temperature_Low + 0.952 Temperature_Medium
- 1.369 Sex*Temperature_Female High + 1.988 Sex*Temperature_Female Low
- 0.619 Sex*Temperature_Female Medium + 1.369 Sex*Temperature_Male High
- 1.988 Sex*Temperature_Male Low + 0.619 Sex*Temperature_Male Medium

Appendix C: Main Effects Plot for Score



Appendix D: Interaction Plot for Sex and Temperature



Appendix E: Tukey Pairwise Comparisons: Sex*Temperature

Comparisons for Score

Tukey Pairwise Comparisons: Sex*Temperature

Grouping Information Using the Tukey Method and 95% Confidence

Sex*Temperature	N	Mean	Grouping
Female Low	6	15.8333	A
Male Medium	7	14.8571	A
Female Medium	6	14.3333	A
Male High	7	13.8571	A
Female High	6	11.8333	A
Male Low	7	11.1429	A

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

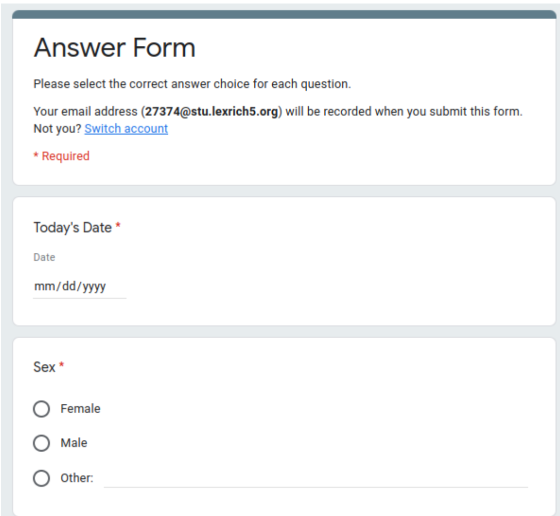
Difference of Sex*Temperature Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value
(Female Low) - (Female High)	4.00	3.37	(-6.20, 14.20)	1.19
(Female Medium) - (Female High)	2.50	3.37	(-7.70, 12.70)	0.74
(Male High) - (Female High)	2.02	3.25	(-7.80, 11.85)	0.62
(Male Low) - (Female High)	-0.69	3.25	(-10.52, 9.13)	-0.21
(Male Medium) - (Female High)	3.02	3.25	(-6.80, 12.85)	0.93
(Female Medium) - (Female Low)	-1.50	3.37	(-11.70, 8.70)	-0.45
(Male High) - (Female Low)	-1.98	3.25	(-11.80, 7.85)	-0.61
(Male Low) - (Female Low)	-4.69	3.25	(-14.52, 5.13)	-1.44
(Male Medium) - (Female Low)	-0.98	3.25	(-10.80, 8.85)	-0.30
(Male High) - (Female Medium)	-0.48	3.25	(-10.30, 9.35)	-0.15
(Male Low) - (Female Medium)	-3.19	3.25	(-13.02, 6.63)	-0.98
(Male Medium) - (Female Medium)	0.52	3.25	(-9.30, 10.35)	0.16
(Male Low) - (Male High)	-2.71	3.12	(-12.15, 6.72)	-0.87
(Male Medium) - (Male High)	1.00	3.12	(-8.44, 10.44)	0.32
(Male Medium) - (Male Low)	3.71	3.12	(-5.72, 13.15)	1.19

Appendix F: P-Values for Tukey Pairwise Comparisons

Difference of Sex*Temperature Levels	Adjusted P-Value
(Female Low) - (Female High)	0.840
(Female Medium) - (Female High)	0.975
(Male High) - (Female High)	0.988
(Male Low) - (Female High)	1.000
(Male Medium) - (Female High)	0.935
(Female Medium) - (Female Low)	0.998
(Male High) - (Female Low)	0.990
(Male Low) - (Female Low)	0.700
(Male Medium) - (Female Low)	1.000
(Male High) - (Female Medium)	1.000
(Male Low) - (Female Medium)	0.920
(Male Medium) - (Female Medium)	1.000
(Male Low) - (Male High)	0.951
(Male Medium) - (Male High)	1.000
(Male Medium) - (Male Low)	0.838

Individual confidence level = 99.52%

Appendix G: Google Form



Answer Form

Please select the correct answer choice for each question.

Your email address (**27374@stu.lexrich5.org**) will be recorded when you submit this form. Not you? Switch account

* Required

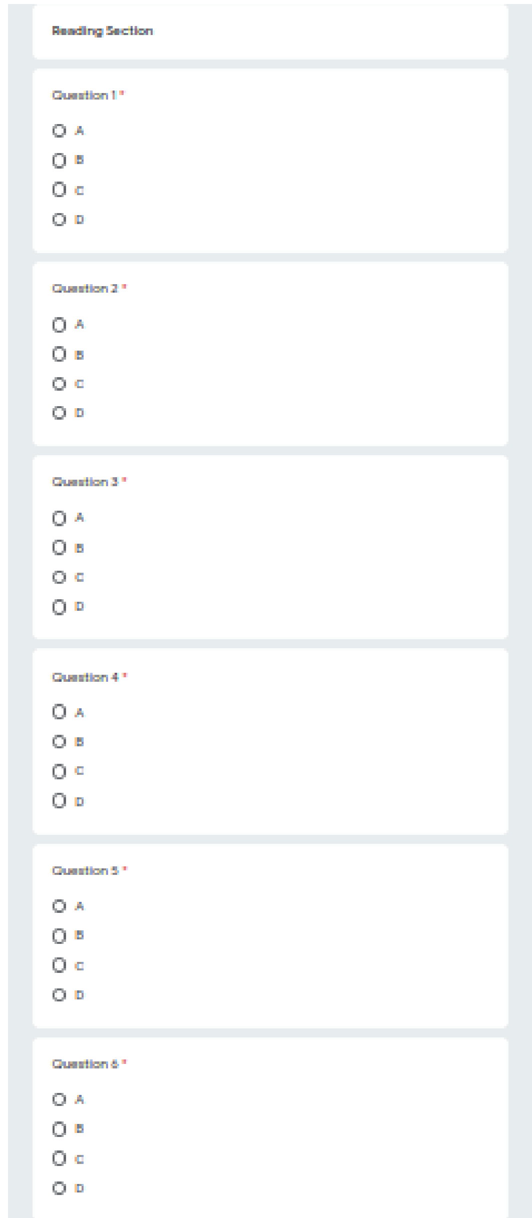
Today's Date *

Date

mm/dd/yyyy

Sex *

- Female
- Male
- Other:



Reading Section

Question 1 *

- A
- B
- C
- D

Question 2 *

- A
- B
- C
- D

Question 3 *

- A
- B
- C
- D

Question 4 *

- A
- B
- C
- D

Question 5 *

- A
- B
- C
- D

Question 6 *

- A
- B
- C
- D

Appendix H: Khan Academy SAT Practice #1

Note: See https://www.khanacademy.org/ for full length test

Appendix I: Khan Academy SAT Practice #3

Note: See https://www.khanacademy.org/ for full length test

Appendix J: Khan Academy SAT Practice #6

Note: See https://www.khanacademy.org/ for full length test

Appendix K: ANOVA Statistical Test for Score VS Subject

General Linear Model: Score versus Subject

Method

Factor coding (-1, 0, +1)

Factor Information

Factor	Type	Levels	Values
Subject	Fixed	13	A, B, C, D, E, F, G, H, I, J, K, L, M

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Subject	12	873.2	72.77	5.31	0.000
Error	26	356.0	13.69		
Total	38	1229.2			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
3.70031	71.04%	57.67%	34.84%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	13.615	0.593	22.98	0.000	
Subject					
A	-2.62	2.05	-1.27	0.214	1.85
B	-0.95	2.05	-0.46	0.648	1.85
C	-9.28	2.05	-4.52	0.000	1.85
D	7.38	2.05	3.60	0.001	1.85
E	-0.28	2.05	-0.14	0.892	1.85
F	5.38	2.05	2.62	0.014	1.85
G	-2.95	2.05	-1.44	0.163	1.85
H	-1.28	2.05	-0.62	0.538	1.85
I	2.72	2.05	1.32	0.197	1.85
J	2.72	2.05	1.32	0.197	1.85
K	3.38	2.05	1.65	0.111	1.85
L	-7.95	2.05	-3.87	0.001	1.85

Regression Equation

Score = 13.615 - 2.62 Subject_A - 0.95 Subject_B - 9.28 Subject_C + 7.38 Subject_D
- 0.28 Subject_E + 5.38 Subject_F - 2.95 Subject_G - 1.28 Subject_H + 2.72 Subject_I
+ 2.72 Subject_J + 3.38 Subject_K - 7.95 Subject_L + 3.72 Subject_M

Fits and Diagnostics for Unusual Observations

Obs	Score	Fit	Resid	Std Resid	
4	20.00	12.67	7.33	2.43	R
6	4.00	12.67	-8.67	-2.87	R

R Large residual

Appendix L: Tukey Pairwise Comparisons for Independent Variables

Comparisons for Score

Tukey Pairwise Comparisons: Sex

Grouping Information Using the Tukey Method and 95% Confidence

Sex	N	Mean	Grouping
Female	18	14.0000	A
Male	21	13.2857	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Temperature

Grouping Information Using the Tukey Method and 95% Confidence

Temperature	N	Mean	Grouping
Medium	13	14.5952	A
Low	13	13.4881	A
High	13	12.8452	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Sex*Temperature

Grouping Information Using the Tukey Method and 95% Confidence

Sex*Temperature	N	Mean	Grouping
Female Low	6	15.8333	A
Male Medium	7	14.8571	A
Female Medium	6	14.3333	A
Male High	7	13.8571	A
Female High	6	11.8333	A
Male Low	7	11.1429	A

Means that do not share a letter are significantly different.