

# **The Effect of Darkness on Visual Reaction Time and its Physiological Basis**

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Key words: breathing, dark, darkness, EDA, GSR, heart rate, light, reaction time, respiration, response time, visual

Word Count: 3502

## **Abstract**

Car accidents are a leading cause of death that primarily occur at night. There are many characteristics of night time driving that have been proposed to explain this phenomenon. Our group set out to determine if reaction time was one of the factors that were affected by darkness. Darkness has been known to cause stress and result in a sympathetic arousal that can enhance various physiological variables. Specifically, we predicted there would be increased heart rate, respiration rate, and sweat production while in dark conditions compared to light conditions. This increase in physiological response, we hypothesize, would result in a quicker reaction time in the dark compared to in the light. Subjects performed a reaction time test, under light and dark conditions, while their respiration rate, sweat production, and heart rate were measured. After testing twenty individuals (n=20) our results showed that there was no significant difference in the mean reaction time or any of the physiological variables when going from light to dark. Our results suggest that darkness alone is not sufficient to elevate the physiological responses associated with a sympathetic response and does not change reaction time, indicating that other factors are responsible for elevated car accidents at night.

## **Introduction**

Car accidents are one of the leading causes of death in America. Out of these accidents, three out of four occur at night (Bella *et al.*, 2014). Researchers have proposed several explanations for this statistic, including fatigue, alcohol, and visual factors. Driving is considered a visuomotor task, meaning that the brain must coordinate the visual information it receives with a physical response (Plainis and Murray, 2002). In the dark, vital elements of vision are impaired, including depth perception, color recognition, peripheral vision, and visual acuity (Fors and Lundkvist, 2009). Ultimately, this may delay reaction time, which is important because

nearly half of the time it takes for a driver to stop a car is due to reaction time. Many variables negatively affect reaction time, including the visual contrast, location of the stimulus in the visual field, and distraction (Welford, 1980). Our group set out to investigate if light is one variable that affects reaction time.

Previous literature has exposed the relationship between light and stress responses. In high stress situations, our body activates a “fight or flight” response. In this “fight or flight” state, the sympathetic nervous system initiates a cascade that, ultimately, has several physiological effects. Some of those effects include accelerated heart and lung function, increased blood flow to muscles, and dilation of the pupils (Jansen *et al.*, 1995). Darkness is a stimulant that can induce stress, and in turn, lead to an increase in these physiological processes (Grillon *et al.*, 2007). Because of this, it can be proposed that darkness would quicken one’s reaction time. Our experiment is designed to test if a decrease in the amount of light leads to an increase in physiological stress response (heart rate, respiration, sweat production), which in turn may correlate with a quickened reaction time in comparison to a lack of physiological stress response associated with a well-lit environment. By investigating this question, our experiment will allow us to deduce if visual reaction times decrease in the dark and what physiological effects may correlate with these changes in reaction time.

Currently there are not many studies on reaction time in night time conditions, and these studies have contradicting results. For example, one study suggests that reaction times are fastest in daylight. Green reported that while driving at night in urban areas, vision operates in the mesopic range causing an activation of a mixture of rods and cones. According to this study, reaction time sharply increases as the rods become the primary photoreceptor (Green, 2000). Even some photoreceptors are non-visual and require no light to function. These photoreceptors

are linked to circadian rhythms affecting the release of the hormone melatonin (Vigh *et al.*, 2002). Thus, it is possible that darkness could increase a driver's reaction time due to sleepiness from an increase in melatonin. However, Green also showed that a decrease in the amount of light has a minimal effect on reaction time; another study found that under scotopic conditions there was an increase in reaction time by only 20-25 msec (Green, 2000). Green argues there are some situations in which a response is faster in low light such as light emitting sources, such as rail-highway crossing signals or brake lights. Lastly, he reasons that without the sun or skylight to reflect off the fixture and with a darker background, the signal has higher contrast and greater visibility.

Physiological responses to darkness, however, demonstrate less conflicting results. Darkness has been shown to increase startle response and cause an increase in blood pressure, heart rate, and subjective distress (Grillon *et al.*, 2007). This indicates an increase in stress levels resulting in anxiety-like symptoms. Based on these studies, we predict there will be an increase in heart rate, respiration rate, and sweat production while in dark conditions compared to light conditions. This increase in physiological response, we hypothesize, would result in a quicker reaction time in the dark compared to in the light.

To understand how reaction rates in the day differ from those at night, we will measure the reaction time of participants in response to visual cues in both a well-lit and a dark room. The three physiological measurements we will be collecting are as follows: respirations via measurement of number of respirations per unit of time, pulse via fingertip pulse oximeter, and galvanic skin conductance (GSR) via the electrodermal activity (EDA) and polygraph procedure. Respiration rate, pulse, and GSR have previously been used as stress-detecting physiological sensors (Healey and Picard, 2005). By measuring reaction rate in response to visual cues in both

light and dark, we will be able to quantify how different light conditions affect reaction rate, if there is indeed an effect. Furthermore, by measuring the aforementioned physiological factors, we can reveal what internal physiological perturbations may be correlated to any observed discrepancy in reaction time.

## **Methods**

### *Testing*

The experiment was conducted in a room with no windows in order to control the amount of light during the different control phases. The room was set up in such a way that two computers were side-by-side in the room: one for data collection and one for conducting the University of Washington “Red Light-Green Light Reaction Time Test. Connected to the data collection computer was the BSL Respiratory Effort XDCR (model number SS5LB, part number 13116916) to track respiration and the BSL EDA Finger Electrode XDCR (model number SS3LA, part number 12123840) to track galvanic skin conductance. The software used in parallel with these devices to collect data was the Biopac Student Lab System: BSL 4 Software Computer System (BSL).

Following the timeline in Figure 1, each subject was fitted with the BSL Respiratory Effort XDCR to track respirations and the BSL EDA Finger Electrode XDCR to track GSR on the left ring/middle fingers (with Isotonic Recording Electrode Gel 101 applied to the electrode), in addition to the Pulse Oximeter/CO<sub>2</sub> detector (model number 9843) to track pulse, which was placed on the left index finger. Once these tasks were completed, we tested three conditions with the test subject: negative control, positive control, and experimental group (outlined in Table 1). For each condition, the following data points were collected while the participant took the

reaction time test: duration of reaction test measured in seconds by BSL, reaction time in response to visual stimulus measured in seconds by the University of Washington “Red Light-Green Light Reaction Time Test, respirations measured as a discrete value by BSL, pulse measured as a discrete value every 5 seconds (tracked using stopwatch) by Pulse Oximeter, and galvanic skin conductance maximum, minimum, and standard deviation were measured in microsiemens by BSL (outlined in Table 2).

In the negative control, the lights in the room were on and the monitor was magnified to 200%, while the screen was set to maximum brightness. We began recording the Biopac measurements, as well as manually recording the pulse measurements, as soon as the subject began the reaction time test. The pulse measurements were manually recorded every 5 seconds throughout the duration of the reaction time test. Once the subject was finished with the test, we ceased all recordings.

We then screened the positive control. During this scenario the lights were on, but the computer screen was reduced to 66% magnification and the computer screen was dimmed to minimum brightness. Again, we began recording measurements as soon as the subject started the reaction time test. This scenario also included a list of distracting questions that were read aloud to the subject while they performed the reaction time test (see Supplemental Information). Once the subject finished the test, the recordings were stopped, as well as the reading of the questions. The same results are then saved.

In our experimental group, the lights were turned off. The light emitted from the computer screens, was the only source of light in the room, in order to allow the subject to have visibility of the reaction time test. The computer screen was brought back to maximum brightness and adjusted to 200% magnification. Again, we began recording measurements once

the subject began the reaction time test. Once the subject was finished we ceased recordings and saved the results and data.

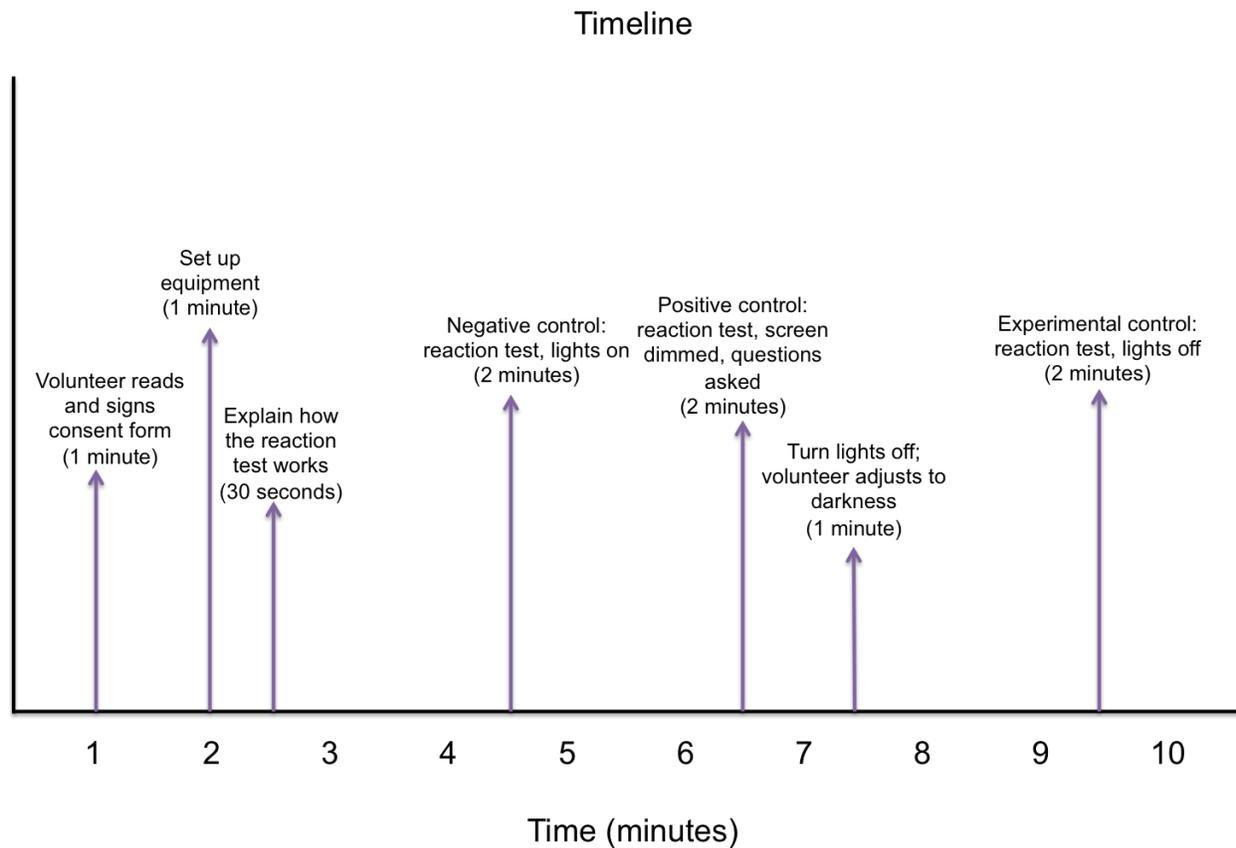


Figure 1: A timeline of the events of the experiment.

### *Data Analysis*

The following variables were recorded for each condition for each participant: mean reaction time, breaths per minute, pulse range, max pulse, min pulse, mean pulse, GSR maximum, GSR standard deviation, and GSR range. These values were averaged to arrive at one representative value for each the positive control, negative control, and experimental group. We then used ANOVA to test for significant differences between group means within the aforementioned variables. Furthermore, Tukey tests were performed to identify between which

specific groups significant difference lies.

## **Results**

### *Reaction time*

ANOVA revealed significant difference the positive control, negative control, and experimental group with  $n=20$  for all conditions ( $p=1.73 \times 10^{-6}$ ) as seen in Table 3. Tukey test revealed significant difference between the positive control/experimental group and positive control/negative control and no significant difference between experimental group/negative control (Graph 3).

### *GSR*

Example GSR data is shown in Figure 2. ANOVA revealed nearly significant difference in GSR standard deviation ( $p=.0546$ ) with the Tukey test revealing significant difference between the positive control/experimental group (Table 3). There was no significant difference observed for GSR maximum or GSR range for all conditions as shown by ANOVA.

### *Pulse*

ANOVA revealed significant difference in pulse range ( $p=.0127$ ), max pulse ( $p=.00982$ ), and mean pulse ( $p=.0281$ ) (Table 3). The Tukey test revealed significant difference between the positive control/experimental group and positive control/negative control for pulse range and max pulse, but not between the negative control/experimental group. For the mean pulse, the Tukey test revealed significant difference between the positive control/experimental group and a near significant difference between the positive control/negative control, but not between the negative control/experimental group. There was no significant difference observed for minimum pulse as shown by ANOVA.

## *Respirations*

Example respirations are shown in Figure 2. ANOVA revealed no significant difference between groups (Table 3).

## **Discussion**

The significant difference in our positive control signifies our experimental procedure could effectively produce changes in reaction time, pulse, and GSR. Both the experimental control and negative control varied from our positive control, indicating that these changes were due to the experiment, not due to chance or other factors. Our negative control acted as our basis for comparison to the experimental group. Since there was no significant difference between the experimental group reaction times and negative control reaction times, we can conclude that darkness alone does not play a significant role in reaction times. Overall, the mean reaction time increased for the positive control, but was relatively equal for the negative control and experimental group (Graph 3). Furthermore, there was no significant difference observed between the negative control and experimental group for any of the physiological factors, indicating that darkness did not initiate a sympathetic response. These results contradict our hypothesis that reaction time would decrease in darkness, and suggests that there are other factors that affect reaction time.

Most of our physiological responses showed a significant difference between the experimental or negative control versus the positive control. Respiration was the only physiological response that showed no significant difference between each group. This result proclaims our respiration data as unusable and therefore, does not contribute to our conclusions about this experiment.

Our GSR results suggest that there was an increase in standard deviation of sweat production during the positive control but no significant difference between the experimental and negative control. This shows that sweat production was unaffected by the change from light to dark and does not contribute to a change in reaction time for these two experimental groups. However, the significant difference in standard deviation during the positive control suggests that distracting a participant while they performed a reaction time test causes a larger fluctuation in sweat production and could possibly be correlated to the increase in reaction time for the positive control as well (Graph 1).

The results for pulse range and max reveal a significant change between the positive control and the experimental and negative control. Our positive control showed a significant increase in pulse over time while our experimental and negative controls were relatively equal (Graph 2). These results signify that the use of distractions (in addition to zooming out and decreasing contrast) in our positive control could have caused a significant increase in reaction time and physiological responses, but overall, our results indicate that there was no significant change in physiological responses in the presence of darkness. It is possible that the reason there was no change in reaction time between the negative and experimental group was because there was no change in physiological response. However, the changes in physiological responses during the positive control suggest that there are more factors affecting reaction time while driving at night than just darkness.

There are various factors that may have compromised the accuracy of our results. Firstly, we occasionally encountered equipment problems with all three of the devices that we used to measure physiological stress response. For example, it is possible that for some of the measurements, the respiration belt was not tight enough or was over too many layers of clothes.

Additionally, respiration measurements may have been less accurate during the positive control, since the subjects were talking through this control but were not talking during the other two conditions. It is also possible that the galvanic skin conductance measurements may have been affected by the amount of gel on the finger electrodes, which may have varied slightly despite our efforts to keep it constant. Another possible source of error could be our difficulty with starting to record the measurements at the exact same time that the subject began the reaction time test. Finally, there may have been person-to-person variation for a given variable within a certain condition, which could have lead to greater associated error for that variable. For example, minimum pulse can vary greatly amongst a group of people. Therefore, there is a high associated error for that variable amongst the conditions, which increases the chance of no significant difference being found when comparing group-to-group. To overcome this, we could have looked at changes in heart rate for each specific person, when going from negative control to positive control, negative control to experimental group, and positive control to experimental group and averaged these values, since the changes in heart rate are more likely to be consistent person-to-person, unlike absolute heart rates.

Since the results contradict our hypothesis that darkness would decrease one's reaction time, it suggests that there are other variables that affect a person's driving and reflexes. Some of these variables that have been the focus of research on driving include visual contrast, location of the stimulus in the visual field, and distraction (Welford, 1980). Another notable factor to consider is the role of darkness on circadian rhythm that in turn can lead to sleepiness. Thus, darkness could result in lower physiological levels than normal and an increased reaction time. Just a change from light to dark does not take into account the visual contrast and visual field location which may be important elements affecting a subject's vision when driving at night.

Future experiments, perhaps, can manipulate the situation to include these factors. Although we believe this experiment plays a significant role in better understanding the physiological responses that lead to a change in reaction time, continued investigations of the different variables that affect night time driving can shed light on why so many accidents occur under these conditions.

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## Acknowledgments

We would like to thank the University of Wisconsin-Madison for allowing us to use their facilities and equipment in the conduction of our research in addition to the volunteers that participated in our study. We would also like to thank Kristin Byrne for her gracious help with the statistical analysis of our data. Finally, we would like to extend our gratitude to Dr. Andrew Lokuta and the UW Physiology Department for their support and the opportunity to publish this research.

## Figures and Legends

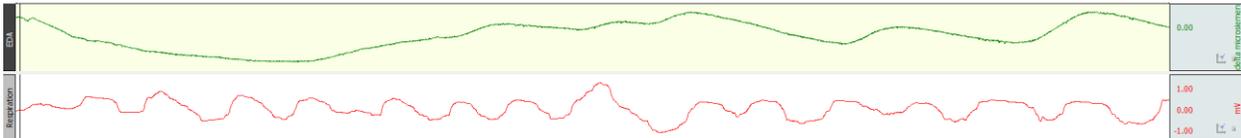
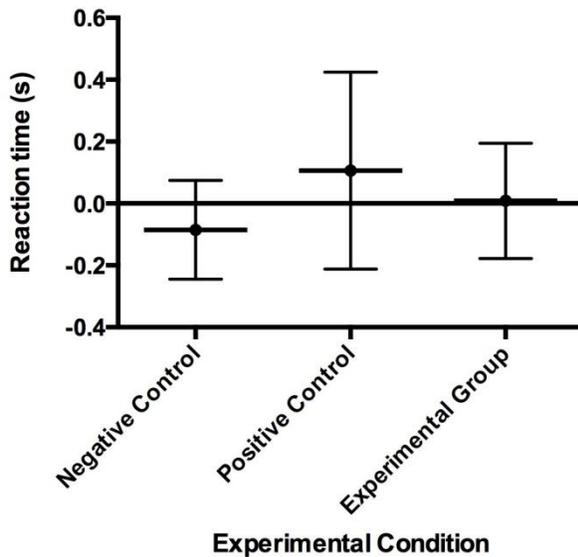
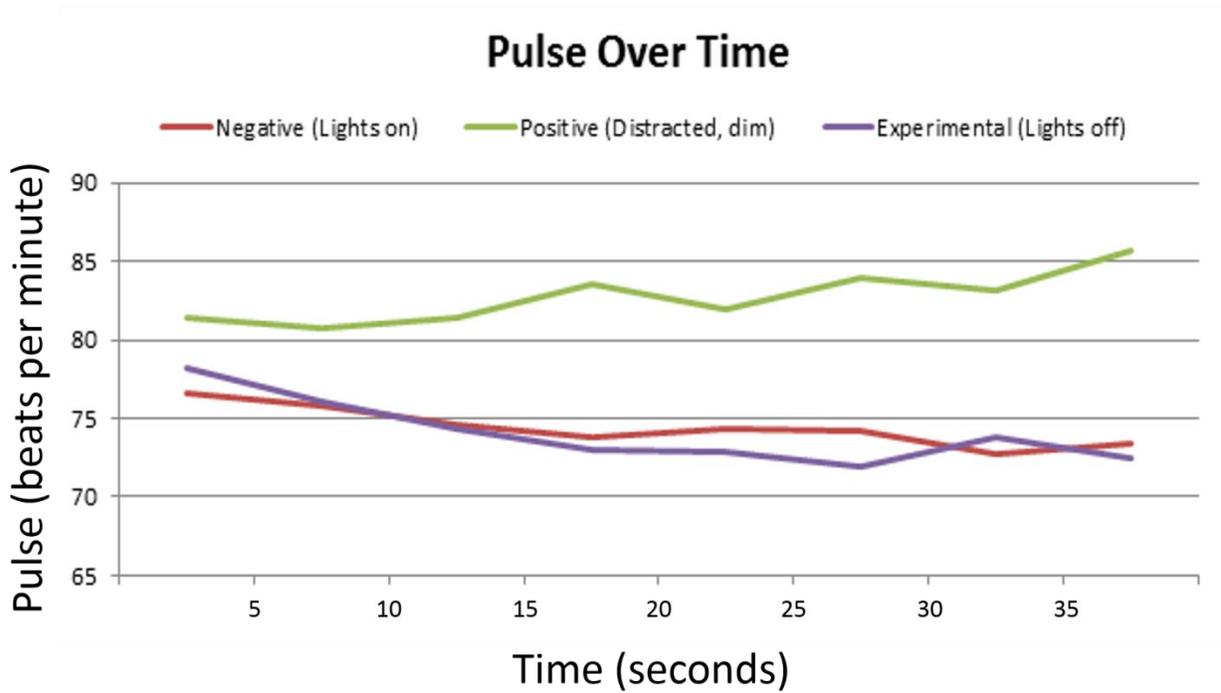


Figure 2: Example data of respirations and galvanic skin conductance (GSR) over time. The green line is representative of galvanic skin conductance changes in  $\mu\text{S}$ . The red line is representative of respirations in mV; each wave represents one respiration.

### Reaction Time in Given Experimental Condition

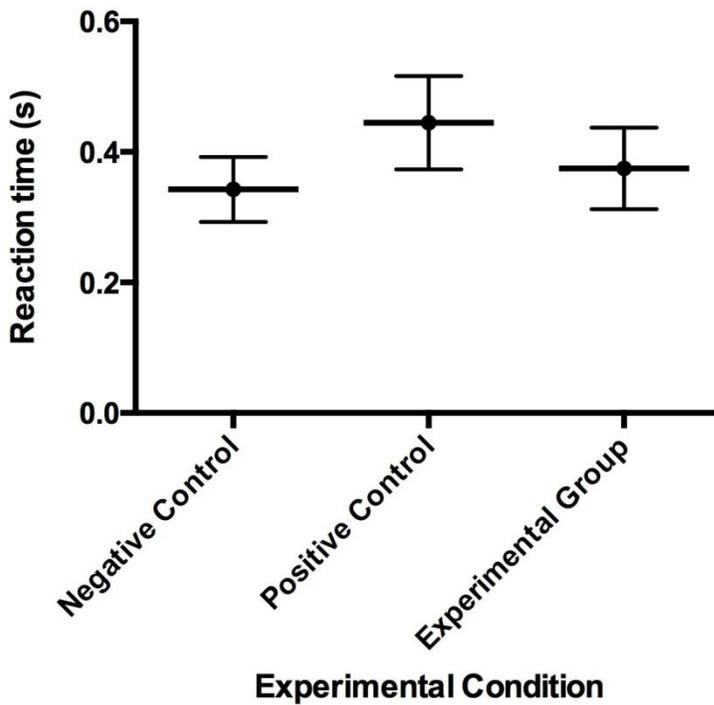


Graph 1: Mean reaction time for a given experimental condition with error bars representing standard deviation.



Graph 2: Pulse Versus Time for negative control, positive control, and experimental group.

### Reaction Time in Given Experimental Condition



Graph 3: Mean reaction time for a given experimental condition with error bars representing standard deviation.

## Tables

	Lights	Monitor Brightness	Monitor Zoom
<b>Negative Control</b>	ON	MAXIMUM	200%
<b>Positive Control</b>	ON	MINIMUM	66%
<b>Experimental Group</b>	OFF	MAXIMUM	200%

Table 1: The experimental conditions regarding lights, monitor brightness, and monitor zoom for the negative control, positive control, and experimental group.

	Test duration (s)	Reaction time (s)	Pulse (beats)	Respiration	GSR
<b>Collection Tool</b>	BSL computer software	Reaction time test	Pulse oximeter	BSL respiratory belt	BSL finger electrode

Table 2: Collection tools used to collect test duration, reaction time, pulse, respiration, and GSR.

Measured variable	P value	Tukey test indicates sig. difference between these groups:
Mean reaction time	<b>1.73e-06</b>	<b>Pos-exp, pos-neg</b>
Breaths per minute	.714	
Pulse range	<b>.0127</b>	<b>Pos-exp, pos-neg</b>
Max pulse	<b>.00982</b>	<b>Pos-exp, pos-neg</b>
Min pulse	.319	
Mean pulse	<b>.0281</b>	<b>Pos-exp, <i>pos-neg</i></b>
GSR maximum	.0876	
GSR standard deviation	<i>.0546</i>	<b>Pos-exp</b>
GSR range	.0806	

Table 3: P Values and Tukey Tests for each measured variable. Bold text indicates significant difference ( $p < .05$ ). Italicized text indicates nearly significant difference.

## **Supplemental information**

### List of Questions used during the Positive Control

1. What is your heritage?
2. What is your major?
3. How many siblings do you have?
4. What is your blood type?
5. What is  $7 \times 6$ ?
6. What is the capital of Wisconsin?
7. What state are you from?
8. What is  $2 \times 4$ ?
9. How many pets do you have?
10. When was the last time you ate?
11. How tall are you?
12. What was the last thing you ate?
13. How many credits are you taking?
14. What is your favorite class this semester?
15. When was the last time you've taken a math course?
16. What is your favorite color?
17. When is your birthday?
18. What is  $2 \times 2$ ?
19. What is your favorite season?
20. Where was the last place you traveled?
21. Where'd you go to middle school?
22. What was your high school mascot?