Concealed Information and its Effect on Heart Rate, Respiration Rate, and Electrodermal Activity

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Abstract

Testing the efficacy of polygraphs can be especially difficult because it is hard to make someone lie in the same way one would during a criminal polygraph. We designed a simplified way of creating guilt and detecting deception. In this study, 22 UW-Madison students participated, and their respiratory rate, heart rate, and electrodermal activity were monitored to assess any significant changes from a negative control or baseline value. Using a simplified procedure, subjects were given a concealed information test (CIT). The CIT involved showing test subjects a two minute PowerPoint with words and pictures, having the subject choose a closed bag and examine an object inside, and view another two minute PowerPoint similar to the first but in a different order. It was expected that upon seeing the words that correlated with the object they "stole", the subjects would respond with a measurable physiological change. Both respiratory and heart rates did not show a statistically significant change between the negative control and experimental conditions; however, electrodermal activity did show a statistically significant change (p-values: 0.00941, 0.0162, and 0.0157) for all three words used to probe for concealed information. These findings show that while time-intensive procedures for assessing guilty knowledge are more sensitive, the procedure featured in this study could be improved and used to replace the commonly used methods, or used as a pilot study to assess for any significance in a new physiological marker that hasn't been studied.

Introduction

The detection of concealed information can be done using a concealed information test (CIT), also called the guilty knowledge test. The concealed information test indicates that knowledge of critical information of an event is enough to elicit a physiological response in the test subject (Zvi *et al.*, 2012). The CIT usually involves a mock-theft experiment and motivates guilty test subjects to avoid detection by offering a reward. Our experiment was designed based on the CIT studies performed by Podlesny and Raskin (1978), including a mock-theft and a reward. There have been previous studies that have integrated the CIT into experimental design as well in an effort to find a simplified alternative to a polygraph (Langleben *et al.*, 2016). Interferences with physiological measurements in the CIT have been found to take place in the following two weeks after a mock crime, so to prevent time lapse from being a confounding variable, our experiment will be performed immediately after the mock crime (Gamer *et al.*, 2010). Our experiment tested recognition related to concealed information, rather than testing deception and guilt as done in the guilty knowledge test. A study conducted by Gamer and Berti (2010) has shown that test subjects elicited an increased physiological response upon recognition of an object, or probe, associated with the mock-theft in comparison to responses given due to irrelevant items. The significant findings of the experiment performed by Gamer and Berti (2010) and its specificity to probe recognition, instead of guilt or deception, were used to formulate the study's testing procedure.

A study performed by Ambach *et al.* (2008) used heart rate, respiratory rate, and electrodermal activity (EDA) to measure physiological changes in test subjects as a way to detect guilt. Another study analyzed the same three variables and while EDA was raised significantly, heart rate and respiratory rate both decreased in frequency (Rosenfeld *et al.*, 1991). A study by Orne and Thackray (1967) corroborated the EDA increase in response to deception using the CIT. Pennebaker and Chew **(**1985**)** showed that behavioral changes, which signify deception, are often accompanied by increases in skin conductance levels which can be measured by electrodermal activity. Test subjects that attempt to conceal the possession of an object upon recognition of the word may exhibit increases in skin conductance levels similar to those who show behavioral changes related to deception.

Rosenfeld *et al.* (1991) concluded that an increase in EDA and a decrease in heart rate and respiratory rate would be shown in response to guilt. Thus it is expected that there will be a similar, significant response when subjects are presented with a word or picture associated with an object that they took.

Materials and Methods

Participants

22 test subjects were selected based on availability and enrollment in UW-Madison during the spring semester of 2016. Before taking part in the study, the subjects were given a consent form informing them of the requirements of the study.

Equipment

Heart rate, respiratory rate, and EDA measurements were used in this study based on the previously mentioned studies' relevance to probe recognition instead of guilt. The EDA was collected through BIOPAC Systems, Inc. Finger Electrodes and transducer (Model SS3LA) connected to the subjects' index and middle fingers, also using BIOPAC Systems, Inc. Gel 101. The respiration rate was collected through a BIOPAC Systems, Inc. respiratory belt (Model SS5LB) placed immediately below the subject's armpits. Lastly, heart rate was collected by finding the frequency of heartbeats from an ECG using BIOPAC Systems, Inc. leads (Model SS2L) and BIOPAC Systems, Inc. electrodes (Model EL503). All of the data collection equipment was BIOPAC brand and made in Goleta, CA. For the ECG, the VIN- electrode was placed medially on the right forearm, the VIN+ electrode was placed medially above the left ankle, and the GND electrode was placed medially above the right ankle. Since all three of the variables were collected relatively non-invasively, these conditions aren't expected to affect the outcome significantly. The data shown in Figure 1 was taken in a pilot study to verify the equipment used could properly measure changes in the physiological variables to be analyzing. The subject used a stepping block while three variables were continuously measured, and verified that all three apparatus were functioning.

Negative Control

Subjects were first shown a PowerPoint with slides played in what appears to the test subject as a randomized order of fifteen words, three words that each can be associated with one of five possible objects each in their own closed, non-see-through bag for use later in the study. The objects used were a stress ball, stapler, candle, rubber tooth, and hand sanitizer. The words used to indicate each object are as follows:

Stapler: Blue, Black, Stapler
Stress Ball: Aqua, Stress, Ball
Tooth: White, Rubber, Tooth
Hand Sanitizer: Pink, Antibacterial, Sanitizer
Candle: Red, Heart, Candle

Pictures representing each word were included on the slides to increase the physiological response to the slide beyond the response from the words alone. A recent study by Cutmore *et al.* (2009) has shown that pictures elicit a greater physiological response compared to words alone. In order to view evenly distributed responses, the three words associated with each object were evenly distributed throughout the PowerPoint presentation.

The three measurements listed above were recorded continuously during the time the subjects viewed the slides. Figure 2 represents the timeline of what occurred.

The subjects read and recited aloud each word to ensure maximal engagement and consciousness of the words on the screen. The slides were spaced ten seconds apart to allow time for mental processing and physiological response to the word. The long interval time is required to allow for a delay between recognition that the slide pertains to the object that the subject selected, and is also required for the same physiological variables to return to normal before the next slide is shown. There were also two introductory slides at the beginning of the PowerPoint instructing the subject to read each word aloud. Each of these slides was ten seconds long, and allowed time for the subject's physiological responses to stabilize before the test slides began. The first viewing of the PowerPoint was used as a negative control, since the subjects hadn't been exposed to any of the objects in paper bags yet, and therefore shouldn't have had any significantly different responses to any of the words.

Concealed Information Test

The subjects were then instructed to choose a bag from a selection of five brown paper bags. The objects were concealed in separate bags, so the subjects didn't see or touch any of the other objects, preventing any response they might have to words pertaining to objects they didn't take. The subjects were instructed to take the object out of their bag, and hold it in their hand while viewing the second PowerPoint to increase their awareness of the object during the test. All subjects were then shown a similar PowerPoint to the first one they were shown before taking an item; however the words pertaining to the objects appeared in a different order. The same three physiological measurements were taken continuously while they read the words presented to them. The timeline was exactly the same as the timeline represented by Figure 2.

Subjects were informed that they would receive a reward if they could successfully keep the researchers from finding out what item they took in order to increase subject engagement in the study.

Survey

After the data collection had finished, the subjects were given an online survey asking which test subject they were, how comfortable they were with the study, how engaged they were, how successful they thought they were in hiding the object's identity, and what their object was. The survey included recording the test subject's number so that it was possible to look for reasons certain subjects had smaller measured responses, possibly due to less engagement or not being comfortable while testing.

Data Analysis

To determine if there were significant differences between the negative control data and the experimental data, all of the continuously collected data were recorded into a Microsoft excel spreadsheet to perform statistical analyses. For respiration rate, the number of complete breaths per ten second slide interval was counted, excluding any incomplete or abnormal breaths. Incomplete or abnormal breaths included inhalations that were stopped before the subject reached peak air intake, exhalations that were stopped before the subject reached minimum air output, or any inhalations or exhalations that contained multiple large peaks looking like smaller breaths. To measure heart rate from the ECG, the number of QRS waves per ten second slide interval was counted. To measure EDA, the value before an EDA response was recorded as the negative control or baseline, and the peak of an EDA response was recorded as the experimental value. This data was collected from the three slide intervals corresponding to the three relevant words for each test subject's object. Paired t-tests were used to assess any possible differences between the negative control and experimental data of respiratory rate, heart rate, or EDA.

Results

As displayed in table 1, the respiratory rate negative control data sets had averages of 2.455, 2.136, and 2.333 breaths per ten second interval, for the first, second, and third words respectively. The experimental data sets showed averages of 2.619, 2.286 , and 2.318 breaths per ten second interval, again for the first, second, and third words respectively. With p-values of 0.693, 0.329, and 0.576 respectively for the first, second, and third words relevant to the chosen objects.

Data regarding the changes in heart rate during the experiment are also shown in table 1. The negative control data set for heart rate showed averages of 79.14, 77.14, and 77.18 beats per minute during the ten second intervals recorded. The experimental data set averages were 79.36, 77.18, and 79.91 beats per minute during the recorded ten second intervals. After using paired t-tests, p-values of 0.874, 0.724, and 0.162 were obtained.

Electrodermal activity showed statistically significant results. With negative control averages of 8.525, 8.442, and 8.643 microsiemens before the EDA response, and experimental averages of 8.618, 8.634, and 8.945 microsiemens at the peak of the EDA response, the averages are seen to be higher for each word in the experimental group. After conducting the paired t-tests for each word, p-values of 0.00941, 0.0162, and 0.0157 were obtained from the EDA responses.

The positive control measurements in Figure 1 show respiration, ECG, and EDA data that were collected while the subject used a stepping block. The measurements exhibited the expected response, an increase in respiratory rate, heart rate, and EDA. The lowest EDA measurement was taken before exercising and the EDA increased throughout the period of exercise as sweat production increased.

Discussion

In this experiment, respiratory rate, heart rate, and electrodermal activity were measured. When presented with a word and picture pertaining to the object that the subject took, the heart rate and respiratory rate were expected to decline based on previous studies (Ambach *et. al.,* 2008). The data showed no significant change in respiratory rate when comparing the negative control and experimental values, and the p-values greater than 0.05 failed to reject the null hypothesis. The average respiratory rate values of both the negative control and experimental data for each probe word are shown in Figure 3, and the visibly similar values and overlapping error bars corroborate the insignificance shown by large p-values. We also could not conclude any statistical significance in heart rate when the control and experimental values were compared. The average heart rate values of both the negative control and experimental data for each probe word are shown in Figure 4, and the similar values and overlapping error bars again authenticate the insignificance.

From previous studies, EDA was expected to increase after word and picture recognition on the probe slides that pertained to the object taken. This measurement was expected to be the most significant indicator of deception among subjects, and was helpful in visually determining what object was taken from the set of five objects. From paired t-tests, p-values were obtained and showed a statistically significant difference between the negative control and experimental EDA responses (Figure 5).

The positive control measurements shown in Figure 1 resembled the response in EDA that was seen post-deception during the experiment; however, it did not resemble the responses seen in heart rate and respiratory rate. A positive control such as this one only indicates that the respiratory rate, heart rate, and skin conductance measurements taken from the other subjects were valid throughout the study. A positive control that exactly matched the experimental procedure would have been impossible to produce because it would have introduced bias to the subjects if they were blatantly told to lie and the same responses may not have been recorded.

Design errors of this experiment could have resulted in receiving no significant data for respiration rate and heart rate. The methods in which the subjects were asked to conceal information of which object they were holding in their hand may not have been meaningful enough for them to elicit a response in respiration or heart rate. An interesting study to conduct would be to ask subjects questions about their personal lives and be instructed when to lie or not. It would be fascinating to see if a greater physiological response would be elicited from this information instead. Other possible sources of error in this experiment could have resulted from the test subject being initially nervous due to the fact they were under testing conditions. Their sweat response may have increased even at neutral times when they were not concealing information. Additionally, according to responses received from the post experimental survey, some subjects did not feel particularly engaged in the study. This could have led to irrelevant data and no significant response in respiratory rate or heart rate measurements. Another possible source of error was how the testing equipment was connected to each subject. In certain subjects, EDA showed no response or sometimes the respiratory rate showed very little response as well. This could be attributed to the equipment not being connected correctly or some sort of equipment or computer malfunction. Additionally, the heart rate and respiratory rate may not have been significant due to a sample size that was too small because of time constraints.

Future improvements include a less subjective way of recording heart rate and respiratory rate, possibly by using different equipment that could compute those values. In addition, the sample size would ideally be much larger to reduce possible sources of error from taking measurements from a smaller sample. Insertion of an unrelated probe word before the beginning of each trial during data collection could also be used to decrease the physiological response of the test subject during the start of the trial. Using a thirty second slide interval instead of the ten second interval used in our study could also yield more significant or more accurate results by more effectively isolating the physiological responses to each slide. Thus, if a subject had a delayed response in heart rate to an associated word slide, it would show up in the corresponding time interval instead of confounding the data and changing the measured heart rate during the ten second interval of the next slide. Lastly, an analysis of the non-associated words' effect on EDA could be carried out to assess whether or not the EDA response found in experimental condition probe words is also found in non-probe words, or the negative condition. This would strengthen the conclusion that our study would yield a significant EDA response at the appropriate times, and not when subjects shouldn't be responding. Upon improvement of the methods and verification of the increased sensitivity using variables known to change, such as heart rate or respiratory rate, the modified procedure based on this study could be used to carry out pilot studies examining other physiological variables, or even be used in place of the current procedures that are more time consuming and labor intensive.

Designing a more accurate and producible procedure to create and detect deception is possible. The significant results found in this study regarding EDA show that this procedure has already been partially successful. While the procedure may actually be more sensitive than the discussed results, this study was limited by the data collection software available. Whether or not the data collection lead to less sensitive and therefore insignificant results is not known. However, it seems that with slight improvements this procedure could be used by experimenters looking to test new physiological markers that may be related to recognition, deception, or guilt.

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Tables

	Probe Word	Group	Mean (Breaths/10 seconds)	Standard Deviation	P-value
Respiration Rate	1	Negative Control	2.455	0.9117	0.693
		Experimental Group	2.619	0.7222	
	2	Negative Control	2.136	0.8335	0.329
		Experimental Group	2.286	0.8248	
	3	Negative Control	2.333	0.7766	0.576
		Experimental Group	2.318	0.7162	
	Probe Word	Group	Mean (BPM)	Standard Deviation	P-value
Heart Rate	1	Negative Control	79.143	12.506	0.874
		Experimental Group	79.364	11.553	
	2	Negative Control	77.143	12.041	0.724
		Experimental Group	77.182	12.324	
	3	Negative Control	77.182	11.899	0.162
		Experimental Group	79.919	12.336	
	Probe Word	Group	Mean (Microsiemens)	Standard Deviation	P-value
Electrodermal Activity	1	Negative Control	8.525	5.768	**0.00941**
		Experimental Group	8.618	5.8445	
	2	Negative Control	8.442	5.512	**0.0162**
		Experimental Group	8.634	5.643	
	3	Negative Control	8.643	5.842	**0.0157**
		Experimental Group	8.945	6.23	

Table 1: Mean, standard deviation, and calculated p-values of given experimental treatments (*n*=22). Bold numbering denotes significant t-test results.

Figures and Legends

Figure 1: Data showing a positive control for all variables, with respiration, ECG, and EDA from top to bottom respectively. This is also a representative picture of what the experimental measurements looked like.

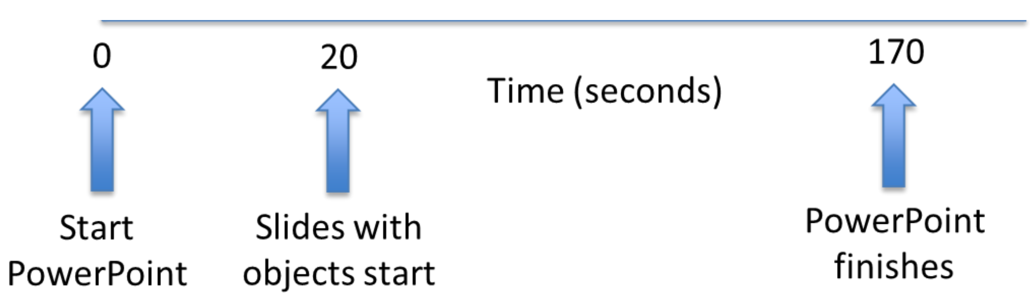

Figure 2: Timeline showing the chain of experimental events as they happen in respect to time.

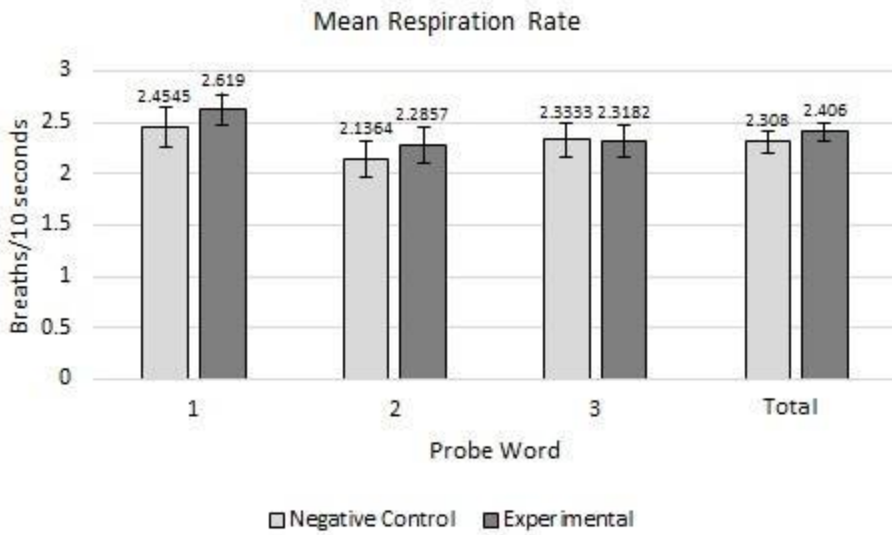

Figure 3: Mean breaths per ten seconds of recorded responses to each probe word within given experimental conditions (*n*=22), and mean breaths per ten seconds of all recorded responses to all three probe words (*n*=66). Error bars represent standard error.

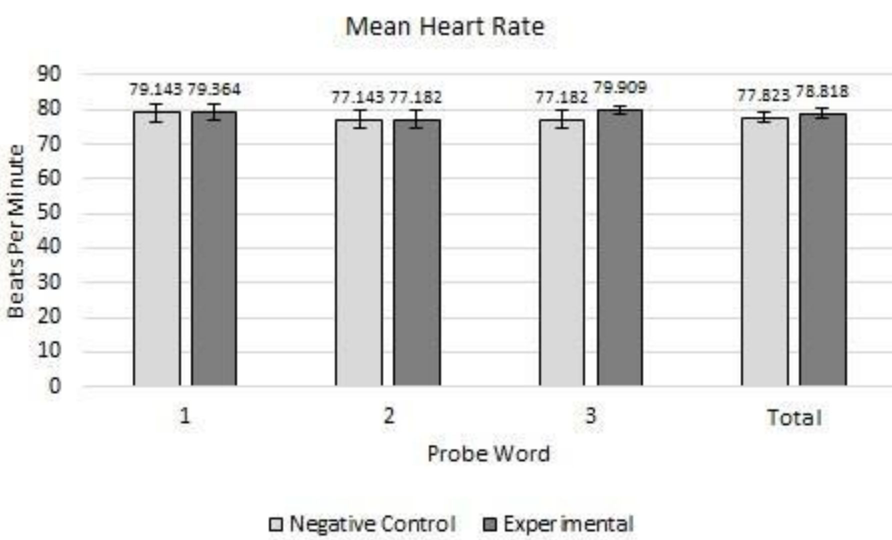

Figure 4: Mean beats per minute of recorded responses to each probe word within given experimental conditions (*n*=22) and mean beats per minute of all recorded responses to all three probe words (*n*=66). Error bars represent standard error.

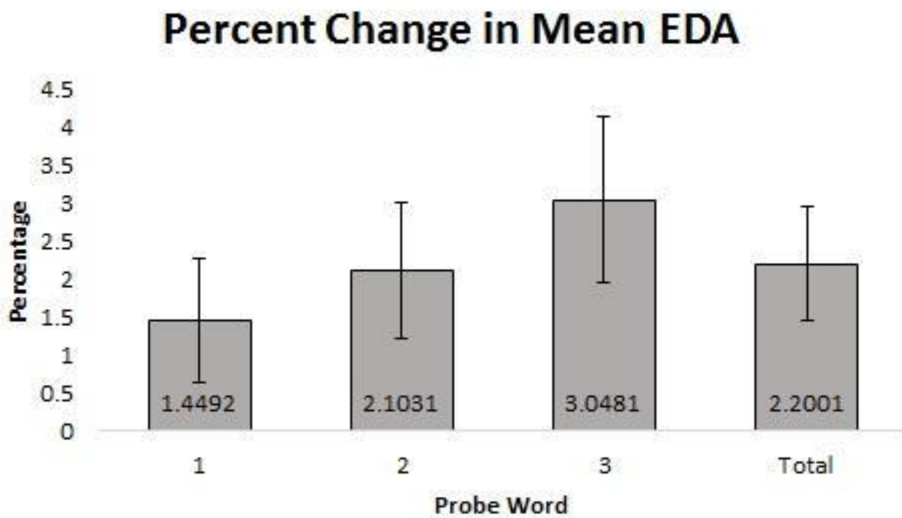

Figure 5: Percent change in the average skin conductance levels among the subjects in response to each probe word (*n*=22) and percent change of the mean EDA of all recorded results (*n*=66). Percent change reflects the difference between the experimental trials in comparison to the negative control trials. Error bars depict the standard error values of each word's data.