Analyzing Fluctuations in Heart Rate, Respiration, and Perspiration as Physiological Indicators of Deception

KEYWORDS

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Abstract

This experiment tested the hypothesis that there are physiological differences that manifest when a person tells a lie compared to when they tell the truth. It was predicted that when a person lies, their sweat production would increase, while their respiratory rate and heart rate would decrease. Thirty subjects were asked to tell four truths and one lie by looking at a set of colored cards and answering questions about what card they chose. The subjects were tested for their EDA conductance, respiratory rate, and heart rate and those values were compared to baseline. It was found that there was a significant increase in sweat conductance when they lied compared to when the subjects told the truth. Heart rate and respiratory rate showed no significant difference when compared with the baseline measurements. The conclusions drawn from this study might help us develop instruments which are more sensitive and reliable at detecting falsehoods in comparison to the polygraph test.

Introduction

Nearly every day, people suspected of criminal involvement or legal misconduct are taken in for questioning by the authorities. After the initial interview has taken place, police examiners and other law enforcement officials collaborate to determine whether the statements provided by these individuals are indeed true. However, even highly trained investigators and supposedly impartial juries are prone to misjudge a person's credibility. When someone lies, they exhibit different cues including physiological, psychomotor, and linguistic changes (George, J. F. et. al., 2008). This study addresses the physiological changes that occur. According to Elizabeth Preston's 2002 article in the Observer, tests are oftentimes accompanied by some measure of heart rate, respiration, blood pressure, galvanic skin response, or brain wave patterns.

The polygraph test is one example of a physiological test that may be administered to suspects on trial or during an investigation. This particular test takes and records measurements of an individual's pulse, respiratory rate, and perspiration. These are the same factors measured in this experiment. Although exam results are open to interpretation by the examiner, oftentimes fluctuations in the measured variables are interpreted as incriminating evidence of deceit. The purpose of this study is to determine

the extent and direction of fluctuations regarding these variables when a subject tells a lie.

Heart rate is an involuntary physiological function that is controlled by the autonomic nervous system. This makes it a potential indicator of deception because it usually cannot be controlled voluntarily. However, many studies have shown opposing results regarding the correlation between heart rate and deceit. For instance a study by Hira and Furumitsu in 2009 resulted in increased heart rate in guilty people. Conversely in 2008 Gamer et. al. indicated that lying would decrease the heart rate of the subjects. In Podlesny and Raskin 1978 found, similar to Gamer et al. 2008, a deceleration in heart rate for subjects who responded with a guilty (deceptive) response in a guilty knowledge test. These inconsistencies could potentially be the result of opposing forces from the sympathetic and parasympathetic nervous systems. Depending on individual factors, one of these systems will override the other, eliciting a change. However the vast majority of studies find that heart decreases during deception (Gamer, Matthias, 2011).

In a study measuring electrodermal activity (EDA), Pennebaker and Chew found that skin conductance levels increased in subjects when they responded deceptively during a guilty knowledge test (GKT) (Pennebaker & Chew 1985). The subjects were divided into two groups, and each subject was asked a series of seven questions based on an index card they drew. Subjects were instructed to answer "no" to each question, therefore making one of their responses a lie. In one group of subjects, no observer was present, only the individual asking the questions. In the second group, and observer told subjects that he would be monitoring the subjects during the test for changes in eye movement and facial expressions. The results of this study showed a significant increase in skin conductance levels (SCL) in the 2-4s range after a subject gave a deceptive answer as opposed to giving truthful answers. This was the case in the both the observed and non-observed groups. Also, the study found that the overall SCL was higher in subjects that were being observed as opposed to those who were not being observed (Pennebaker & Chew 1985).

A study by Gamer et al. (2008) provided evidence that lying changes multiple physiological processes. In the study, a group of "guilty" participants were instructed to steal items placed in a box in the waiting room. The "innocent" group did not take

anything. After the mock crime, each participant was asked six questions and was told to respond "no" for each. Only one of the questions was related to the crime, and the other five were for control. If the participants were found "innocent", they received 10 Euros. The study had shown that lying while attached to a polygraph machine increased skin conductance, but lowered heart rate and breathing rate. In the innocent group, none of the measurements had any discernible pattern. The research group believed that breathing rate slowed because the participants were deliberately trying to stay calm, which also slowed the heart rate. The results indicated that skin conductance was the best way to determine deceitful answers because it is only regulated by the central nervous system, and not cognitively controlled.

Some testing techniques have shown better results than others. A meta-analysis of 80 laboratory studies by Shakhar, Gershon, Eitan (2003) concluded that the use of deceptive verbal responses and asking at least five questions increased efficacy overall. Because of the more conclusive results, these techniques were used in this study.

An extensive review of experiments performed using the concealed information test (CIT) up through 2012 summarized "the huge number of studies on autonomic measures in the CIT that have been conducted in the last decades. Taken together, it is now well established that the recognition of crime-related items results in larger skin conductance responses, respiratory suppression, heart rate deceleration and reductions of pulse volume amplitudes when compared to neutral control items." This large review of studies found that respiratory rates were reduced when lie detector tests since the 1950s (Gamer, Matthias, 2011). Although there are conflicting results for heart and respiration rates, in general both of these factors seem to decrease when lying. Because of this, it was predicted that heart rate and respiration rate will decrease when an individual is lying compared to when an individual is telling the truth. There is more conclusive evidence to suggest that skin conductance increases during a lie, which is why it was predicted that sweat production will increase when the subject is lying.

Hypothesis: When a person lies, will their sweat production increase, while their respiratory rate and heart rate decrease?

Methods

In this experiment, the effects of truth and lie telling on respiration rate, skin conductance at the finger tips, and heart rate were measured. To make these measurements, the BIOPAC Respiratory transducer (BIOPAC Systems, SS5LB, CA), BIOPAC EDA unit (BIOPAC Systems, SS3LA, CA), and BIOPAC pulse transducer (BIOPAC Systems, 9843, CA), were used respectively, in conjunction with the BIOPAC software. The measurements (obtained using the previously mentioned devices) were used to look for deviations in respiration rate, skin conductance, and heart rate from baseline measurements while telling truths or lies.

Each of the aforementioned BIOPAC devices were connected to 30 physiology 435 students from the University of Wisconsin-Madison. Of the 30 participants 16 were male, while the remaining 14 participants were female. All of the subjects were between the ages of 20 and 40 with no discernible symptoms of color-blindness. Before any questioning took place, baseline measurements for respiratory rate, skin conductance, and heart rate were taken for each subject 15 seconds before the experimental measurements were taken. This baseline measurement was taken over a period of 15 seconds. The same measurements taken after questioning were compared back to the baseline measurement to determine the extent of deviation from the subject's baseline. Overall, the timing of this procedure remained consistent between participants.

Each subject was informed that they would be participating in a lie detection test and that they would need to respond 'no' to each question asked. It was explained to them that four of the five answers they would be giving would be truthful and the remaining answer they gave would be a lie. There were three different interviewers, and each interviewer conducted their questioning the same way. Each interviewer read their questions off a prepared script and was facing the interviewee. For questioning, the subject was seated in front of a table that had five cards face down in front of them. Each card had a single color on its face: red, yellow, green, blue, or black. The subject was instructed to draw one of these five cards and remember the color that was picked. The researcher asked the subject a series of five questions regarding which color they chose. These questions were stated as "Did you pick the color_____?" asking one question for each of the five colors (a total of five questions). Respiration rate, skin conductance,

and pulse were measured for a period of 15 seconds after the question was asked and the subject gave his or her answer. The subject was instructed to answer "No" to each question; therefore, the subject gave four true answers and one false answer.

As a positive control, subjects performed 20 pushups (or enough to significantly increase respiration rate, skin conductance, and pulse, according to the subject's ability) and these areas were measured over a period of 15 seconds beginning immediately after completion of the pushups. After all measurements were recorded, the subject reported the color he or she drew in order to determine which question was answered with a lie.

In analysis of each of the three measurements, values obtained from truthful answers were averaged to give one "average truth value." For analysis of heart rate, the peak value attained during the 15 second interval after each question was asked was compared to the average heart rate over the 15 second baseline period. This was done to determine the change in peak heart rate after questioning (or pushup control) compared to baseline (resting). The same procedure was used in analysis of skin conductance. The peak skin conductance value measured during the 15 second interval after each question was compared to the average skin conductance over the 15 second baseline period. The change in peak skin conductance after questioning (or pushup control) was compared to baseline (resting). For respiratory rate, the number of breaths over each 15 second interval (baseline, questioning, and pushup control) were counted and converted to a breaths per minute quantity. The average respiratory rate after each questioning period was compared to the average respiratory rate over the 15 second baseline period, and the change was measured between these two categories.

A high degree of variance than expected may have been inadvertently introduced into the procedure due to the disparity between the ratio of truth responses to lie responses (4:1). Because participants were instructed to lie only once, only one set of data for the lie was interpreted in comparison with the four sets of data obtained from truth-telling. This was done to avoid having the participant tell a second or third lie, because the second or third lie might not produce as physiologically salient data as the first.

Paired T-tests were performed for each of the three categories (heart rate, skin conductance, and respiratory rate) using baseline changes after a truthful response and

baseline changes following a lying response. Likewise, paired T-tests were performed for each of the three categories using baseline measurements and changes from these baseline values after doing multiple pushups (positive control).

Results

Based on previous studies, it was predicted that there would be a decrease in heart rate following a lying response compared to a truthful response. A one-tail t-Test between lying vs truth peak heart rates was used. Data from this experiment did not show a significant change in peak heart rate following truthful and lying responses ($p=0.072$). Average peak heart rate of the sample of subjects following a truthful response was 79.59 beats per minute (bpm) with a standard deviation of 14.21. An average peak heart rate following a lying response was 80.57 bpm, and the standard deviation was 14.99. As a control, the average baseline heart rate of subjects was compared to average peak heart rate following the period of pushup exercise. Average baseline heart rate was 78.13 bpm (st dev 15.03) compared to average peak heart rate following exercise period 108.3 with a standard deviation of 17.59. This demonstrated a significant change $p=1.647\text{x}10^{-12}$. (See Figure 1.) To show that significant changes could be measured, pushups were picked as a positive control to increase the measurements. As expected, it was during this time that all three categories increased the most.

For skin conductance, it was hypothesized that there would be an increase in conductance at the finger tips following a lying response. A one-tail t-Test between lying vs truth peak skin conductance was used. The data showed an increase in peak conductance following a lying response compared to a truthful response ($p=0.0249$). The average peak conductance of individuals following a truthful response was 0.142 microsiemens (st dev 0.089), while average peak conductance measured from individuals following a lying response was 0.186 microsiemens (st dev 0.131). Baseline peak skin conductance was also compared to peak conductance following a period of exercise as a control, with $p=6.669\text{x}10^{-5}$ (See Figure 2.) After exercise the mean peak skin conductance was 0.463 microsiemens, with a standard deviation of 0.361. The baseline peak skin conductance was significantly lower with a value of 0.165 microsiemes and a standard deviation of 0.124.

Data for respiratory rate did not show any significant change in breathing rate

between rate after a truthful response compared to rate after a lying response (p=0.080). Average rate of the subjects following a truthful response was 16.4 breaths/minute (st dev 4.21), while average rate following a lying response was 15.7 breaths/minute (st dev 4.59). In the control, a significant change in respiratory rate was measured between baseline respiratory rate and respiratory rate following the period of exercise ($p=8.19x10^{-7}$). Average baseline respiratory rate for the subjects was 15.4 breaths/minute with a standard deviation of 4.40, and this increased to 23.4 breaths/minute (st dev 8.66) following the exercise period. (See Figure 3.)

Discussion

As a part of this "lie detector" experiment, measurements of heart rate, skin conductance (perspiration), and respiratory rate were measured. From previous studies, it was predicted that heart rate would decrease after a lying response as opposed to heart rate after a truthful response. Data showed essentially no change in heart rate between the two responses (p=0.072). Past studies have shown an increase in perspiration following a lying response, thus it was hypothesized that skin conductance would increase in subjects after they gave a lying response. Data showed an increase, (p=0.0249), which indicates that the increase was statistically significant. Finally, for respiratory rate, no significant change was detected in the experiment (p=0.080). A study conducted by Hira, S., & Furumitsu, I. (2009), observed increased perspiration and decreased heart rate in individuals participating in acts of deceit. In this experiment, a significant change was not found in heart rate, although heart rate was expected to drop as a result of increase of parasympathetic activity on the heart (Vandenbosch, K., & et al., 2009). Additionally, although it was predicted that an increase in respiratory rate would be observed, no statistical significance was found. This was also observed by Hira, S., & Furumitsu, I. in 2009.

Figure 4 displays the results from Subject 5's skin conductance results. This subject displayed the general reaction to each of the conditions that he/she endured. The lowest skin conductance value was measured during the baseline (negative control) presumably because stress was lowest at this time. When the subject exercised, their sweat production increased, and this change was measured by the EDA. This positive control indicates that the skin conductance measurements were valid throughout the

subjects test. Subject 5's skin conductance increased slightly from the baseline even when giving truthful answers. The subject had the largest increase in skin conductance (i.e. sweat production) shortly after the lie. This was the expected result because lying usually elicits a nervous feeling from people, which can cause the individual to sweat.

This experiment was designed to measure differences in the physiological responses of heart rate, respiratory rate, and skin conductance while lying and telling the truth. However, the results showed a striking similarity in both degree and direction for the lie and truth categories in both respiratory and heart rates. The subjects may have been "nervous" just by being hooked up to the sensors, which was not effected by giving a truthful or deceptive answer. It also could be due to the fact that the subjects did not have to think about the lie, and the lie was not meaningful enough to elicit a strong response. These two factors may have been the reason why the subjects had such similar responses regardless if they told a lie or truthful answer.

Several areas regarding the design of this experiment may have contributed to the lack of significance found in the respiratory and heart rate measurements. The methods in which a lie was obtained from the subjects (by the color they chose) may not have been meaningful enough to elicit a physiological change. Prior studies (Martha, J. F., & et al., 2014) have shown that questions involving greater personal risk elicit a more emotional and thus greater physiological response. Likewise, because each subject was instructed to answer "no" for each question, they may not have felt the sense that they were lying, but rather following instructions. A period of 15 seconds between questioning may not have been an adequate interval over which to measure the physiological factors in this experiment. Also, the order in which subject told truths and lies may have affected the results. Subjects may initially have been nervous, so the physiological responses measured after the first truthful response may have been different than those responses after questions later in the test, when the subject had settled down.

Furthermore, physiological responses could have been skewed by the subject's expectancy to lie, rather than by the actual testing conditions. Prior studies such as that conducted by Abel & Larkin in 1990 show that anticipation of a potentially stressful event can induce an increased heart rate, for example. A less significant contributor could have been the precision with which response times were recorded. Because the BIOPAC

recording device only recorded in 4 second intervals, and were manually recorded by hand afterward, it is possible that the raw data gathered is slightly more variable than that which was calculated. Limitations of the equipment's detection for more minute changes may also have factored into an inability to find statistically significant results. The galvanic skin response equipment, for example, was not always consistent in its ability to record participant data. Data for these individuals therefore had to be excluded from the data analysis.

Further experiments could be proposed to adjust for the discrepancies listed previously. Specifically, more personally meaningful truths and lies could be used to try and elicit a greater difference in response to the two. A greater number subjects could be tested in a new study as well, since a larger sample size would more accurately reflect the population mean. Continuing experiments should also consider taking a more diverse sample, since the data and conclusions derived from this study were taken from a convenient pool of UW Madison students enrolled in Physiology 435, and therefore cannot be extended to the general population.

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Figures

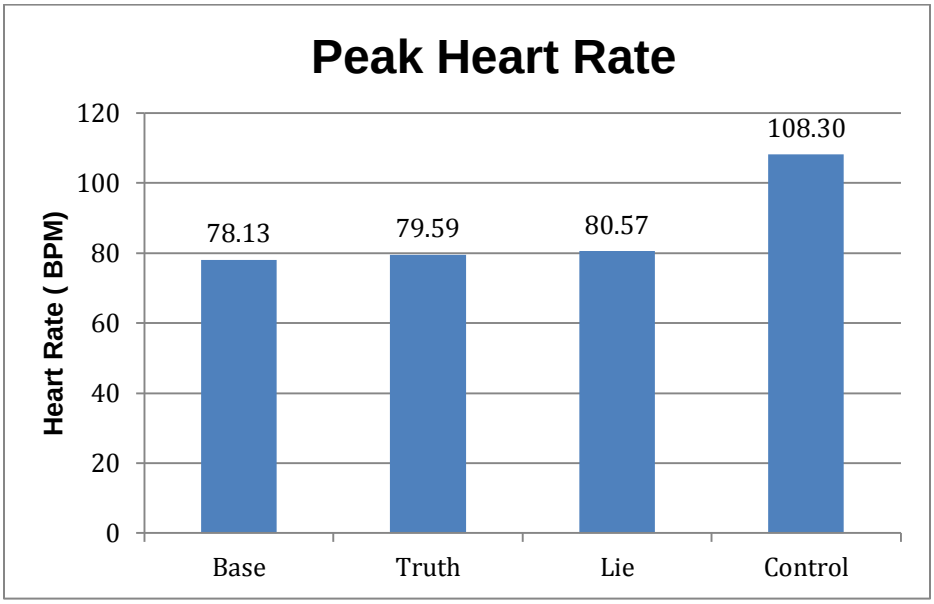

Figure 1. Average heart rate for all subjects at baseline, after truthful response, after lying response, and following control exercise period.

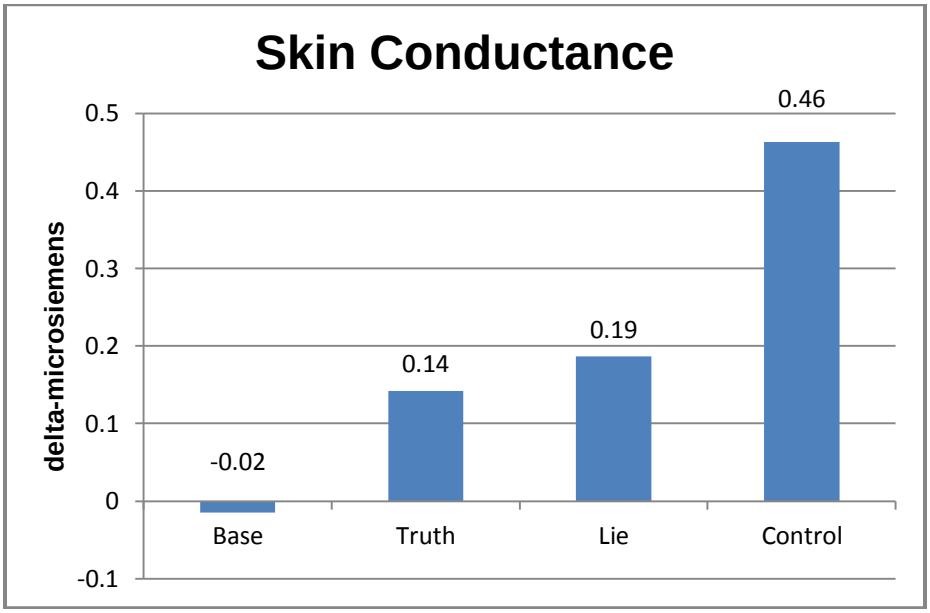

Figure 2. Average peak skin conductance for all subjects at baseline, after truthful and lying responses, and following control exercise period.

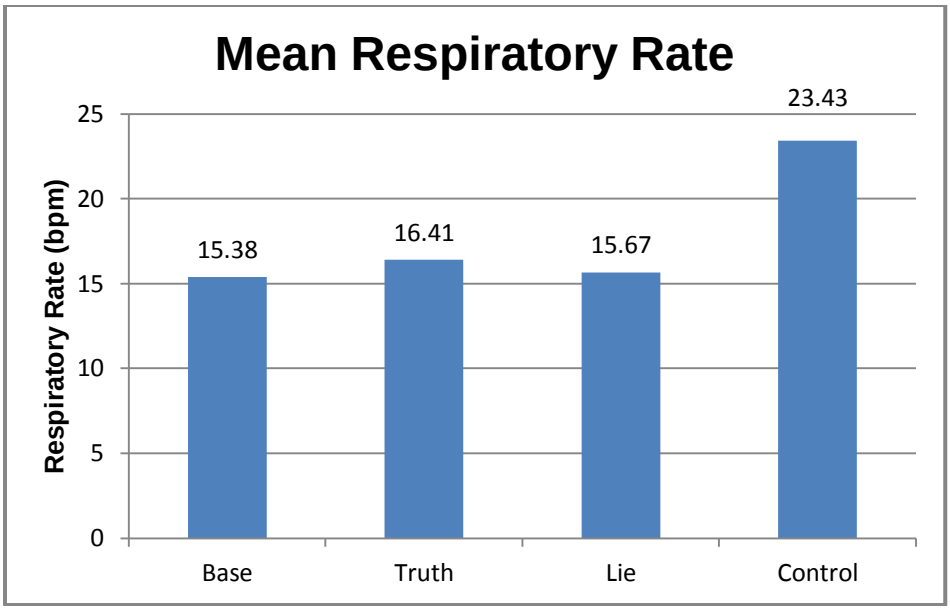

Figure 3. Average respiratory rate for all subjects during baseline period, following truthful and lying question responses, and after control exercise period.

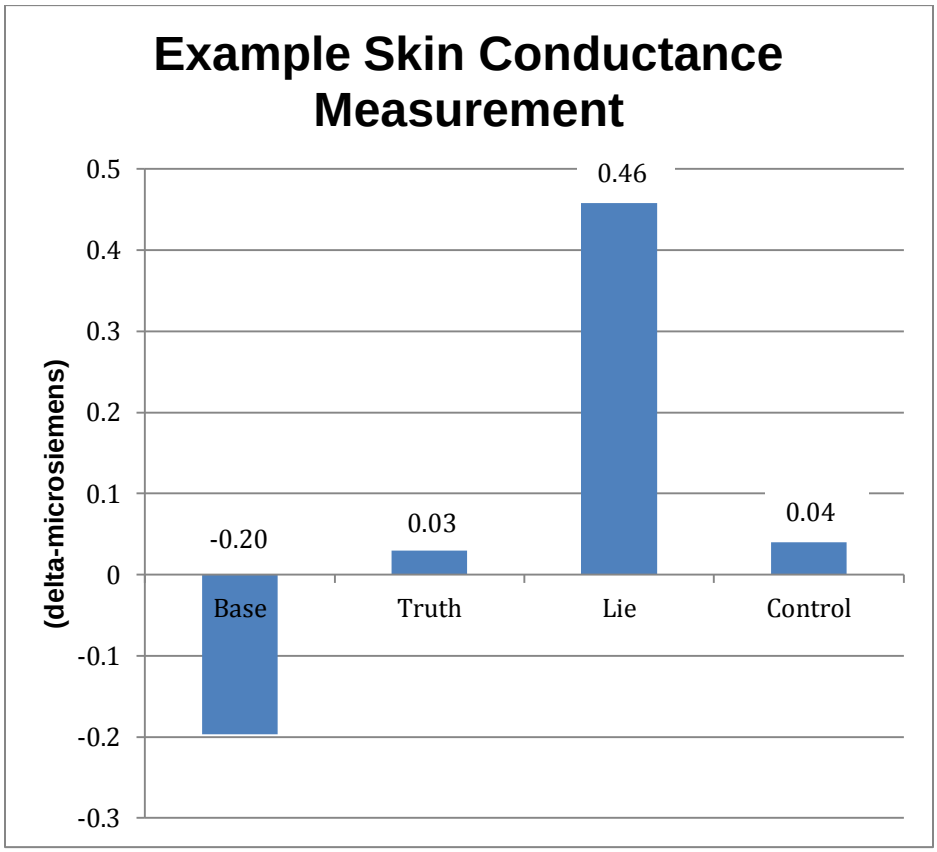

Figure 4. Peak skin conductance of an example subject (subject 5) during baseline period, following true and lie responses, and after control exercise period.