An Analysis of Physiological Arousal in Response to Electronic and Verbal Communication and in Response to "Guilty Knowledge"

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Abstract

As communication evolves, the criminal justice system will face new challenges in terms of lie detection. To date, it is unknown how physiological responses vary between face-to-face and electronic communication in evolving polygraph technology. In this study, 15 female college students between the ages of 20-24 participated. Each participant was asked a battery of control and anxiety-provoking survey questions through both electronic and verbal surveys. Participant skin conductance and heart rate (HR) were measured during both surveys. Paralleling the advancements in communication, polygraph technology is also evolving. The current study also sought to replicate and extend previous findings isolating the P3 response using the Guilty Knowledge Test. When comparing the mean electronic Galvanic Skin Response (GSR) of participants who completed the electronic survey first to the mean electronic GSR of participants who completed the verbal survey first, no statistical significance was observed. However, there was significant statistical evidence to suggest the range of HR values were different between the electronic and verbal modes of communication. Additionally, there was a significant difference between EEG P3 response for participants who did or did not have “guilty knowledge”. These results highlight the importance of advancements in communication when considering the future of polygraph testing.

Introduction

The ability to detect deception is of utmost importance when convicting criminals and protecting national security. Despite the prohibition of polygraph technology in court, the efficacy of the existing polygraph technology is debatable. This technology is widely used when investigating crimes (Saxe, Dougherty, & Cross, 1985), pre-screening during government interviews (Hermann III, 1971), and testing sexual offenders in treatment, on parole, or in prison (Hindman & Peters, 2000). Therefore, the precision and reliability of the measure of deception is relevant and research should focus on improvement.

A polygraph machine that records multiple continuous measures of autonomic nervous system arousal can be used to measure physiological changes. Early polygraphs measured changes in blood pressure, pulse, and respiration patterns (Trovillo, 1935). Today, the typical polygraph measures sweating from the palm of the hand (Galvanic Skin Response), relative blood pressure (arm cuff), and respiration (volumetric sensors placed on the chest or abdomen) (Honts, 2004). Research suggests that liars experience heightened states of sympathetic arousal compared to truthful controls (deTurck & Miller, 1985; Waid & Orne, 1981). In the context of polygraph testing, increased sympathetic arousal is interpreted as reflecting guilt or fear, primary indicators of deception (Ekman, 2009). Although differentiating between states of physiological arousal (e.g., fear and guilt from anxiety) is difficult, research indicates that deception is accurately detected in 73% of trials that measure heart rate or blood pressure and in 90% of trials that measure electrodermal responses (conductance and resistance) (Lykken, 1979; Podlesny & Raskin, 1977).

A major shortcoming of the traditional polygraph test is the inability to assess the complex brain processes that are fundamental during deception. Current research highlights the possibility of using electroencephalography (EEG) to measure electrical brain activity during lying. Using raw EEG data, researchers are able to isolate stimuli-associated time points to create event-related potentials (ERP). A specific ERP, known as the P3 response, has been recently used to detect deception. The P3 response is evoked in response to obscure stimuli and is used in conjunction with the Guilty Knowledge Test (GKT) (Bauer, 1984). During the GKT, interrogators identify P3 response changes due to a participants' recognition of publicly undisclosed information (Abootalebi et al., 2009). The recognition of publicly undisclosed information is referred to as "guilty knowledge". The general assumption during the GKT is that a person with "guilty knowledge" will have a greater level of physiological arousal in comparison to subjects with no knowledge of undisclosed information. The use of EEG in lie detection offers an opportunity to bypass confounds, such as the difficult differentiation of guilt, fear, and anxiety in association with heightened physiological responses.

Paralleling the advances in polygraph technology, the mediums in which we communicate have also evolved. In today's society, electronic communication has become a more common style of interaction (Herring, 1996). Research suggests that responses to electronic and verbal communication differ due to the absence or presence of social context cues (i.e. tone of voice, facial expression, eye contact), respectively. Given the lack of social context cues, electronic communication establishes a greater sense of anonymity and constitutes a much lower sense of social interaction (Weisband & Atwater, 1999). The implications of this are high in the context of lie detection. Specifically, if deception is not physiologically arousing (i.e., resulting in fear or guilt) via electronic communication, it may cause a desensitization of the nervous system, and consequently, become undetectable by traditional polygraph technology.

Therefore, the aim of the current study is twofold: to investigate evolving polygraph technology and to investigate the impact of modern electronic communication on traditional polygraph testing. First, we hypothesize that a heightened P3 response will be observed when participants have “guilty knowledge”. Second, we hypothesize that physiological arousal will be dampened in the electronic communication condition compared to direct verbal communication.

Materials and Methods

Participants

Volunteer participants were recruited based on their enrollment in Physiology 435 in Spring, 2015. Fifteen women between the ages of 20-24 who were enrolled in this course were randomly chosen to participate in this study. Participants were randomly assigned a letter/number identification code before entering the experiment room to ensure their identity was kept confidential. The letter of the identifying code, either A or B, determined if the participant would take the electronic or verbal survey first. For the EEG portion of the study, participants assigned an odd-number code were prompted to open the box. After signing a consent form and receiving a code, participants were instructed to complete a basic demographic survey to help the experimenters with the analysis of collected data. (Refer to Figure 1 for an experiment timeline).

Equipment

Physiological measurements were collected via an Electroencephalogram (EEG), Galvanic Skin Response (GSR), and Heart Rate Monitor. A BIOPAC Systems, Inc. EEG was used to measure electrical brain activity. Skin conductance was measured using the BIOPAC

Systems, Inc. Finger Electrode (Model SS3LA) and heart rate was measured using a Nonin Pulse Oximeter and Carbon Dioxide Detector (Model 9843). Qualtrics Survey Hosting Service was used to administer the electronic survey.

Guilty Knowledge Test

First, a Guilty Knowledge Test was conducted. The data collector set up the EEG using a consistent three-step procedure of site identification, site preparation, and electrode placement. The experimenter used the 10/20 System Positioning to place the Pz electrode for P3 response measurement (Trans Cranial Technologies, 2012). Site preparation consisted of alcohol cleaning and exfoliation. The experimenter then filled the electrodes with electrode gel. The ground sensor was placed on the mastoid portion of the temporal bone, and the signal sensor was placed on the previously determined Pz region (Figure 2). Once the equipment was set up, the interviewer gave a short introduction, explaining the logistics of the experiment and allowing the participants to ask any questions before proceeding. Participants who were assigned an odd-number code were then instructed to open a box containing a picture of an obscure rock. Participants, regardless of their code, viewed a 20-page slideshow with a picture of an ordinary rock on each slide except for one, which pictured the obscure rock. Participants who were directed to open the box and view the obscure rock before the slideshow are predicted to have had an excited EEG response, a potential indication of “guilty knowledge” (Abootalebi et al., 2009). Those who did not open the box should not have had a heightened EEG response caused by “guilty knowledge”. Throughout the experiment, the data collector recorded continuous data, which was then transferred to an Excel spreadsheet for later analysis.

Verbal and Electronic Survey

After the EEG was measured, participants proceeded with either the electronic or verbal survey, both of which consisted of the same questions in the same order. The electronic survey was created under Qualtrics, a web-based survey available for use by all UW-Madison faculty, staff, and students. Each survey was created under a Qualtrics-generated anonymous link warranting that participants remain unidentified. Participants were seated and hooked up to GSR and heart rate monitors. The GSR sensors were attached to the participant's index and middle fingers of their non-dominant hand. The heart rate monitor was secured on the person's non-dominant thumb. They were then instructed to place their hand on a table to help minimize movement that may affect the data collection.

The survey order was counterbalanced according to each participant's identifying code. The survey consisted of two categories of questions: baseline (negative control) and expected anxiety-inducing (positive control). If the verbal survey was given first, the interviewer and data collector stayed in the room and the interviewer began the questioning. If the electronic survey was administered first, the interviewer set up the survey before exiting the room. Upon completion of the first survey, the participant switched to the other version of the survey.

A video camera recorded the data monitoring screen to assist the researchers in connecting a certain physiological response with each question. The participant's identity was not revealed in the video.

Data Analysis

To determine the physiological change in heart rate, the absolute range was calculated (maximum peak minus minimum peak) for both the electronic and verbal results. GSR was analyzed in association with ten questions for each participant. Survey questions two and three for each mode of communication served as the baseline questions. Three anxiety-inducing questions were also chosen for each mode, identified by the three greatest peaks in the data. The amplitude of GSR peaks was measured from the second before the question was asked to the second after the question was asked. These three peaks were averaged to isolate a value for each mode of communication per subject as were the two baseline peaks. Statistical analyses were then used to investigate the differences in physiological arousal between modes of communication. Deception was indicated by deviations in physiological arousal across question types. Lastly, EEG measurement began one second before and ended one second after the target slide was presented. The P3 wave amplitude was calculated using the largest peak-to-peak amplitude during the target slide presentation.

Results

All statistical analyses were conducted using a 2-sample t-test. Comparing the mean skin conductance values in Figure 3 for the three greatest peaks to the values for the two control peaks verified that the anxiety-inducing survey questions caused significant changes in skin conductance as intended. The skin conductance averaged 0.27 microSiemens (µS) (SD 0.16) during the electronic anxiety-inducing questions as opposed to only 0.13 µS (SD 0.15) during the electronic baseline questions. This difference between question types was statistically significant (p-value <0.05 indicates rejection of the null hypothesis, which states that there is no statistical relationship within our data) with a p-value of 0.00575. The mean skin conductance values for the verbal survey, 0.37 µS (SD 0.21) for the anxiety-inducing and 0.19 µS (SD 0.18) for the baseline questions, revealed the same statistical significance with a p-value of 0.00017.

When analyzing the mean electronic GSR, 0.11 μS (SD 0.21), of participants who completed the electronic survey first to the mean electronic GSR, 0.18 μS (SD 0.15), of participants who completed the verbal survey first, no statistical significance was observed. The p-value of 0.51 validated our attempt to minimize the effects of priming by instructing half the participants to complete the verbal or electronic survey first. Comparing the mean verbal GSR, 0.12 μS (SD 0.12) for electronic first and 0.24 μS (SD 0.14) for verbal first, showed the same statistical insignificance with a p-value of 0.11. This validation was also apparent from the heart rate data. Comparing the mean electronic heart rate, 16.1 bpm (SD 6.8), of participants who completed the electronic survey first to the mean electronic heart rate, 14.6 bpm (SD 8.6), of participants who completed the verbal survey first, no statistical significance existed as shown by a p-value of 0.60. Comparing the average verbal heart rates, 26.7 bpm (SD 7.7) for electronic first and 19.5 bpm (SD 8.6) for verbal first, showed the same statistical insignificance with a p-value of 0.11.

Analyzing the peak-baseline difference for GSR values and comparing those differences between verbal and electronic modes of communication resulted in a p-value of 0.32. This suggested that there was no statistically significant difference in skin conductance as a result of being surveyed electronically or verbally.

Figure 4 illustrates that the mean range of heart rate (HR) values during the electronic survey was 15.3 beats per minute (SD 4.9) as opposed to 22.9 beats per minute (SD 8.7) during the verbal survey. In other words, the mean range of verbal heart rates was higher by an average of 7.6 beats per minute (bpm). Given a p-value of 0.00812, there was significant statistical evidence to suggest the range of HR values were different between the electronic and verbal groups.

As shown in Figure 5, the mean EEG P3 wave amplitude for participants who opened the box during the Guilty Knowledge Test was 7.61 μV (SD 2.35) as compared to 4.07 μV (SD 2.93) for participants who did not open the box. With a p-value of 0.019, there was a statistically significant difference between EEG P3 waves for participants who did or did not have "guilty knowledge."

Discussion

We hypothesized that a heightened P3 response would be observed when participants had "guilty knowledge". We also hypothesized that physiological arousal would be dampened in the electronic communication condition compared to direct verbal communication. Based on the results, there was sufficient statistical evidence to suggest that there was a difference in heart rate between electronic and verbal communication. However, there was not a statistically significant difference in GSR between the modes of communication. Additionally, the results suggested that there was a heightened P3 response in participants who had "guilty knowledge" as compared to those who did not.

This study was able to adequately test our research hypothesis. The experimental methods were precisely designed to measure the differences in heart rate and skin conductance between the two modes of communication. As hypothesized, there were observable and statistically significant differences in the range of heart rates among participants when surveyed verbally and electronically. Analysis among participants who were surveyed verbally first and electronically first showed no statistical differences in heart rates, eliminating the possibility of priming or bias. Data from the GSR showed the highest peaks were observed in response to anxiety-inducing questions and lowest peaks were observed in response to baseline questions, validating that anxiety-inducing questions were competent at causing arousal.

One of the flaws during the experiment was that GSR values for one participant were measured in a different unit than the GSR data for the rest of the participants; therefore, that data set was excluded from analysis. Additionally, the participant population for this experimental research was limited to female college students at the UW-Madison. Therefore, the findings can only be generalized to all female college students. Additionally, only a small sample size was studied which may have skewed the results.

Our EEG analysis validated the Guilty Knowledge Test by observing a difference in P3 wave amplitudes between “guilty” and “not-guilty” participants. Since a major shortcoming of the traditional polygraph test is the inability to assess the complex brain processes associated with lying, implementing electroencephalography and the Guilty Knowledge Test could increase the precision and reliability of crime investigation methods. Given the limited population included in this study, additional research should focus on validating EEG measures further by utilizing both females and males of various ages and backgrounds.

This was the first study that investigated the differences in physiological arousal in relation to different modes of communication. Observed physiological differences between verbal and electronic modes of communication suggest that there is a higher level of anxiety when people communicate verbally. The evolution of society toward electronic-based communication has increased anonymity and facilitated ease in lying. The direct results of and the mechanism underlying this change remain unknown; however, the current study suggests that physiological desensitization to anxiety/deception may occur during repeated exposure using electronic communication. Additionally, it would be beneficial to explore additional variables in association with verbal and electronic communication. For example, one might examine blood pressure, respiratory rate, or pupil dilation. Additionally, one could further investigate why GSR did not differ significantly between electronic and verbal survey.

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Figures

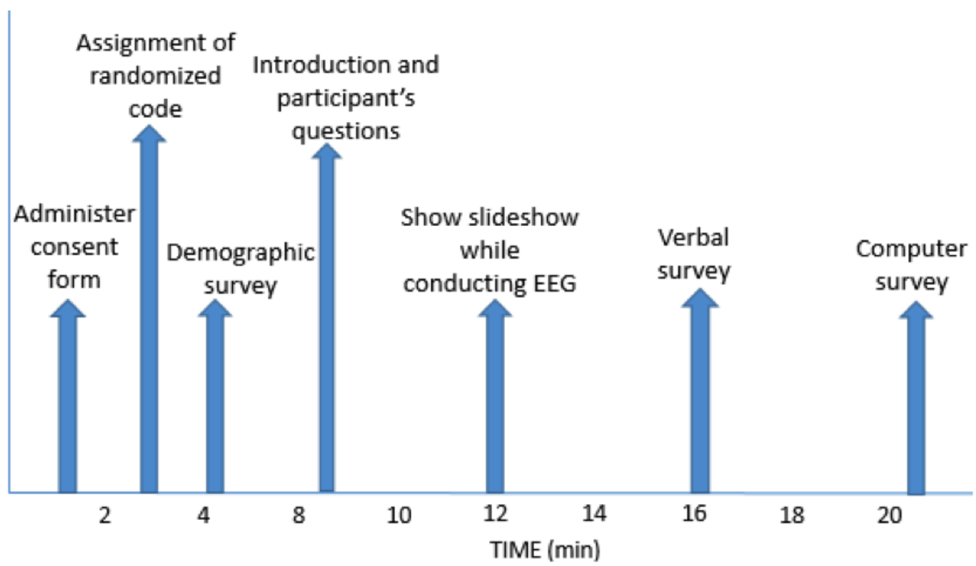

Figure 1. Experiment Timeline

After signing a consent form, the participant was assigned a randomized identifying code and directed to complete a demographic survey. The interviewer introduced the experiment and allowed the participant to ask any questions regarding her involvement. Next, the experimenter conducted an EEG while the participant viewed a slideshow. Finally, half of the participants were randomly assigned to complete the verbal survey first followed by the electronic survey. The remaining participants completed the surveys in reverse order.

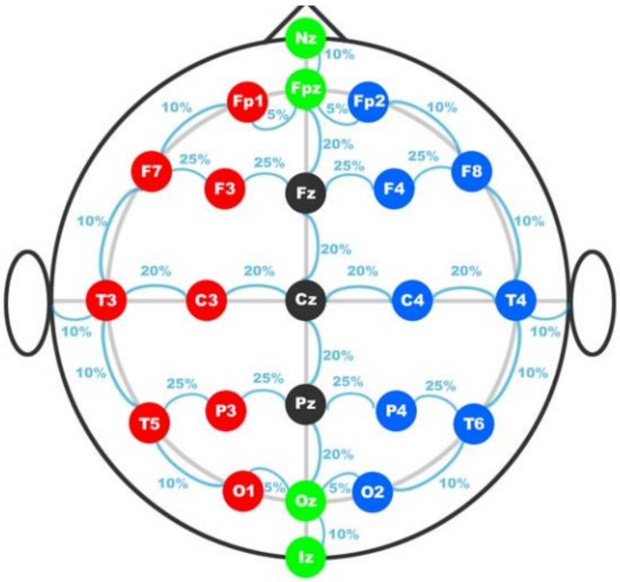

Figure 2. 10/20 System Positioning

The experimenter used the 10/20 System Positioning to place the Pz electrode for P3 response measurement (Trans Cranial Technologies, 2012).

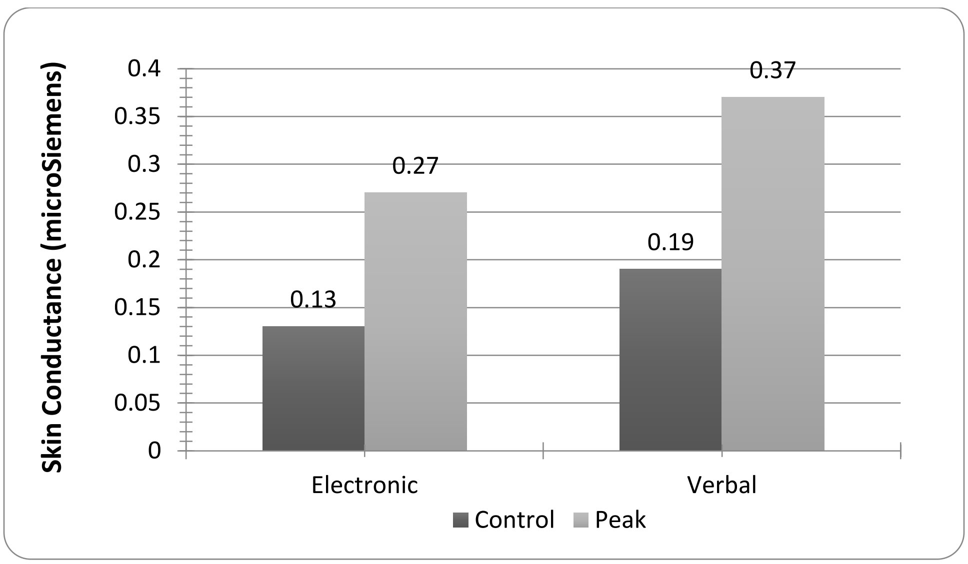

Figure 3. Participant Skin Conductance during Electronic and Verbal Survey

The graph compares GSR results found in the electronic and verbal surveys. For the electronic survey, skin conductance averaged 0.27 µS (SD 0.16) during the anxiety-inducing questions and only 0.13 µS (SD 0.15) during the baseline questions. For the verbal survey, the skin conductance averaged 0.37 µS (SD 0.21) for the anxiety-inducing and 0.19 µS (SD 0.18) for the baseline questions. The skin conductance test gave a p-value of 0.32, which is not statistically significant. This illustrates that there is no difference in GSR response between modes of communication.

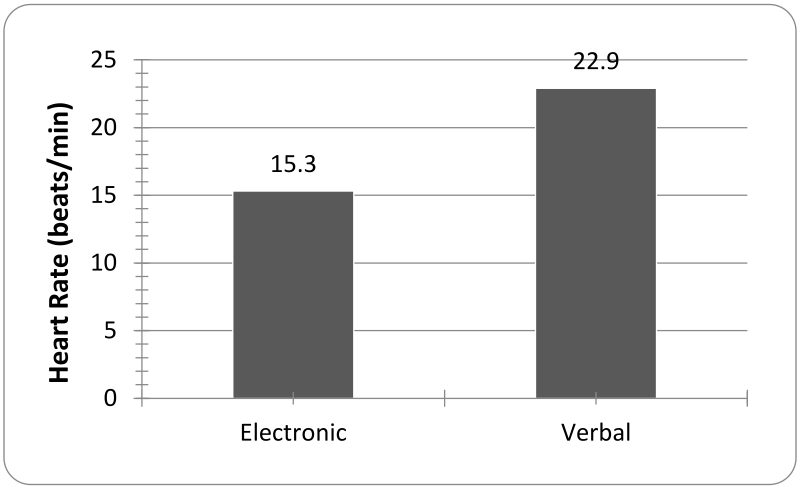

Figure 4. Participant Heart Rates during Verbal and Electronic Survey

Heart rates during the verbal and electronic survey were compared. The mean range of heart rate values during the electronic survey was 15.3 bpm (SD 4.9) as opposed to 22.9 bpm (SD 8.7) during the verbal survey. The p-value for this comparison is 0.00812. Since the p-value is less than 0.05, it is statistically significant, indicating that participants had greater increases in heart rate during the verbal survey as compared to the electronic survey.

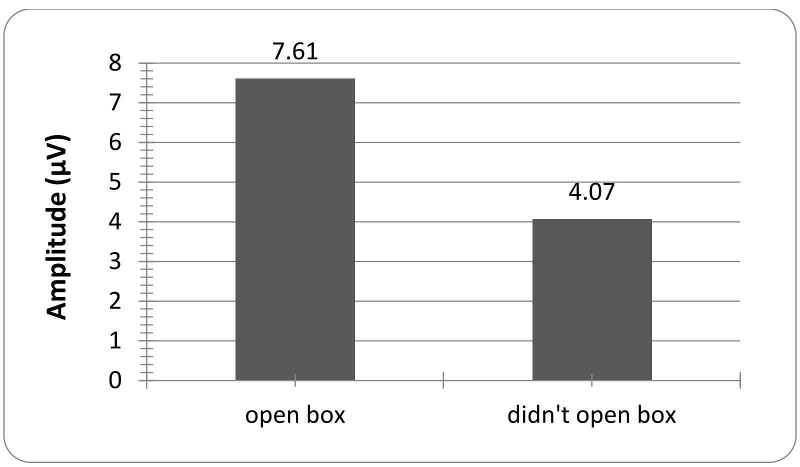

Figure 5. P3 Wave Amplitude of Participants With or Without "Guilty Knowledge"

For the EEG, half of the participants opened a box containing a picture and half of them did not open the box. The mean EEG P3 wave amplitude for participants who opened the box was 7.61 µV (SD 2.35) as compared to 4.07 µV (SD 2.93) for participants who did not open the box. With a p-value of 0.019, there was a statistically significant difference between P3 waves for participants who did or did not have "guilty knowledge". This finding supports the Guilty Knowledge Test.

Appendix

Electronic and Verbal Survey Questions

1. Is your identifying code _________?
2. Are you a student at UW-Madison?
3. Are you in Physiology 435 this semester?
4. Have you ever forged someone signature?
    a. If yes
        i. Did the person give you permission to forge their signature?
        ii. Was it forged on a legal document?
5. Have you ever used tinder?
    a. If yes
        i. Have you ever met with a tinder match in person?
        ii. Have you ever had sex with a tinder match?
6. Have you puked in public?
7. Are you currently on your period?
8. Are you between the ages of 18 and 22?
9. Have you ever received a ticket or a fine?
    a. Have you ever gotten a DUI?
    b. Have you ever been arrested?
10. Do you have any piercings?
11. Have you ever shoplifted?
    a. If yes
        i. Was it worth more than $50?
        ii. Did you shoplift anything this year?
    b. If no
        i. Have you ever thought about shoplifting?
12. Do you think I am attractive?
    a. If yes
        i. Would you go on a date with me?
        ii. Would you spend the night at my house?
13. Have you ever physically harmed someone?
    a. Have you ever thought about punching someone?
    b. Have you ever thought about killing someone?
14. Are you graduating this May?
15. Do you use protection when having sex?
16. Have you ever viewed pornography?
    a. If yes
        i. Have you viewed pornography this month?
        ii. Have you viewed pornography this week?

            iii. Have you viewed pornography in the last 24 hours?
    b. If no
            i. Have you ever thought about viewing pornography?

17. Have you ever caught your parents having sex?
18. Do you eat meat?
19. Have you ever cheated on clicker question points?
    a. Have you ever cheated on a homework assignment?
    b. Have you ever cheated on an exam?
        i. If no
            1. Have you ever thought about cheating on an exam?
20. Did you eat breakfast this morning?
21. Have you ever consumed alcohol before the age of 21?
    a. Have you ever used marijuana?
    b. Have you ever used illegal or non-prescription drugs (such as cocaine, adderall, ritalin, etc.)
    c. If no (to either a or b)
        i. Have you ever thought about using marijuana or any illegal or non-prescription drugs?
22. Have you ever skinny dipped?
23. Do you like olives?
24. Have you ever had sex?
    a. If yes
        i. Have you had sex this month?
        ii. Have you had sex this week?
        iii. Have you had sex in the last 24 hours?
25. Are we currently in the Medical Sciences Building?
26. Have you ever cheated on a significant other?
    a. If yes
        i. Did you cheat on your significant other more than once?
    b. Have you ever danced with someone other than your significant other while you were in a relationship?
    c. Have you ever kissed someone other than your significant other while you were in a relationship?
    d. Have you ever had sex with someone other than your significant other while you were in a relationship?
27. Have you ever had braces?
28. Have you ever danced in the street drunk?
29. Have you ever fantasized about a professor during class?
    a. Have you ever had a sexual dream about a professor?
30. Do you plan to attend graduate school?