Polygraph

VOLUME 36 2007 NUMBER 2

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Published Quarterly
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P.O. Box 8037, Chattanooga, Tennessee 37414-0037

A Discussion of Two Diagnostic Features of the Polygraph Cardiovascular Channel

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Abstract

The cardiovascular readings observed during a psychophysiological detection of deception examination change following emotion evoking questions. The changes can be observed in the baseline and tracing amplitude waveform recordings. The authors explored the cause of these changes and the physiological phenomena being recorded. The amplitude changes that accompany a change in arterial blood pressure were shown to be related to the relationship between cuff pressure and blood pressure measured at the monitoring site. Changes in tracing baseline were shown to accompany a change in blood pressure monitored at the cuff site. The purpose of this paper is to propose possible explanations for what is actually being displayed on the cardiograph tracing. This paper discusses the duplication of earlier works and the use of modern polygraph instruments to explore physiological changes known to be associated with Sympathetic Nervous System (SNS) arousal. Additionally, this research project may be considered an educational paper intended to assist the reader in understanding the basic principles underlying cardiovascular recordings monitored on the cardiograph tracing during a polygraph examination.

Introduction

Several publications have listed the various features that are considered to be diagnostic when evaluating polygraph tracings. The Defense Academy for Credibility Assessment (DACA), formerly DoDPI, teaches the preferred and standardized evaluation system used throughout the Federal government (DoDPI, 2006). The most recent DACA Test Data Analysis chapter lists baseline arousal as the primary feature and duration of that arousal as a secondary feature. Other publications (Abrams, 1989; Matte, 1998; Reid & Inbau, 1977; Shurany & Ravid, 2005) have listed the various features considered to be diagnostic when evaluating polygraph tracings which include both baseline arousal and amplitude changes.

The cardiovascular circulation is a closed system consisting of the heart muscle, arteries, capillaries, and veins. One of the primary purposes of the cardiovascular system is to transport nutrients and oxygen to body tissues and remove metabolic wastes and carbon dioxide from the body tissues.

In polygraphy, we are primarily concerned with observing changes that occur in the heart muscle and blood vessels. This is generally accomplished through continuous measurements obtained with a partially inflated blood-pressure cuff. Emotion-evoking questions have been shown to produce a change in the cardiograph tracing (Geddes & Newberg, 1977). These changes include baseline rise and sometimes a visually discernable change in pulse-amplitude (Geddes & Newberg). This paper will focus on these two changes in the cardiograph tracings and discuss their origin and diagnostic significance.

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Methods described by Geddes (1970) were used to replicate previous experiments using a modern computerized polygraph instrument.

Modern polygraphs continuously monitor cardiovascular activity by maintaining an inflated cardiovascular cuff during the course of chart recording. One of the diagnostic features routinely discussed in polygraph literature is baseline arousal. Baseline arousal is a rise in diastolic tracings from a pre-stimulus level. Another feature that has been considered diagnostic is changes in the amplitude of the cardiovascular tracing. The authors suggest that pulse amplitude and baseline changes considered diagnostic are primarily due to changes in blood pressure versus blood volume. The paper will discuss experimental methods used to test this hypothesis.

Background

One of the earliest documented applications of the blood-pressure cuff used to detect deception was utilized by Dr. William Marston in 1915. To detect deception, Dr. Marston used a technique of discontinuous blood-pressure measurement to obtain systolic blood pressure readings during questioning of a subject. Dr. Marston would infer guilt or innocence based on these repeated measurements taken over a short period of time. It was Dr. Marston's discontinuous measure of blood pressure that led to the *Frye Decision*. In 1923, the U.S. District Court of Washington, DC concluded the discontinuous method of measuring systolic blood pressure (as a "unigraph" recording vs. the contemporary polygraph) lacked general acceptance by the scientific community. In 1921, John Larson assembled one of the first portable instruments capable of producing a continuous method of recording relative blood-pressure changes.

Emotion-evoking questions are known to cause a baseline arousal and sometimes a change in pulse amplitude. The change in pulse amplitude can be either an increase or decrease in the tracing. It is somewhat of a paradox that most often a decrease in amplitude accompanies a baseline rise. Typically, baseline changes in the cardiograph tracing may occur during a phasic or tonic change.

The polygraph setting is a rather unusual circumstance. A subject is presented a threatening stimulus question while instructed not to move. In a typical physically threatening scenario, the well known "fight, flight or freeze" response would induce acute cardiovascular activity. In a polygraph milieu a decline in heart rate and pulse amplitude may accompany an undulating blood pressure waveform.

The initial cardiovascular response observed after the onset of the stimulus question mimics the physically threatening stimulus response. The subsequent polygraph waveform profile however, reflects a conflict between the CNS and the vegetative output. In the physically threatening milieu, the cognitive and emotionally driven limbic system divisions of the CNS will marshal the body systems to react. Specifically, the cardiovascular system is preparing to deliver more blood to the skeletal muscles for the "fight, flight or freeze" response.

A complete physiologic explanation of this dichotomy of the cardiovascular waveforms observed during a polygraph examination, vis-à-vis, what would be observed during a typical "fight, flight or freeze" response exceeds the mission of this paper. Instead we focused on the changes observed in pulse amplitude and tracing baseline.

Pulse Amplitude Changes

Geddes and Newberg (1977) conducted research that addressed pulse-amplitude change. These researchers demonstrated how oscillation amplitude is related to arterial blood pressure. They and other investigators have shown when cuff pressure exceeds systolic blood pressure, the brachial artery collapses. Blood travels to the upper edge of the cuff and stops. Some small oscillations are transmitted to the upper edge of the cuff as the blood is forced against the occluded portion of the brachial artery. As the cuff pressure was slowly reduced, less of the brachial artery is occluded until cuff pressure equaled systolic pressure. When cuff pressure was reduced below systolic pressure, pulse

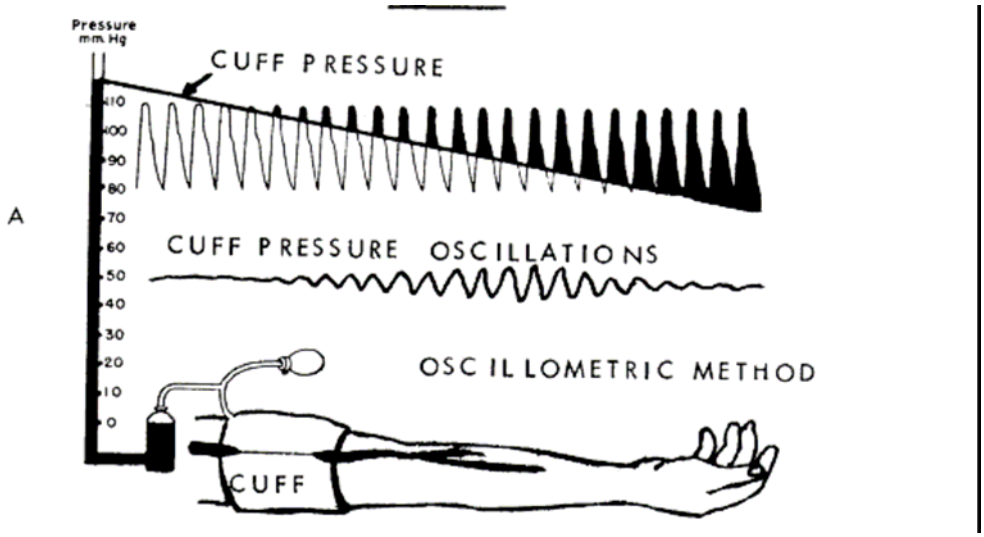


Figure 1. Characteristics of the oscillometric method of measuring indirect arterial blood pressure. The shaded area on the pulses in Figure 1 shows the relative portion of the brachial artery that is open. When the cuff pressure exceeds systolic pressure, the underlying artery is occluded and no blood will flow through the brachial artery. Small oscillations are caused when the blood is pulsating against the partially closed artery and communicated to the cuff. As cuff pressure falls, more blood is allowed to pass through the artery and oscillations increase to a maximum value and then begin to fall. It has been found that cuff pressure for the point of maximum oscillations is approximately equal to mean arterial pressure (Mean Arterial pressure is approximately Diastolic Pressure plus 1/3 of Pulse Pressure for the brachial artery). This graph was previously published in *Polygraph* and is reprinted here with the permission of the American Polygraph Association.

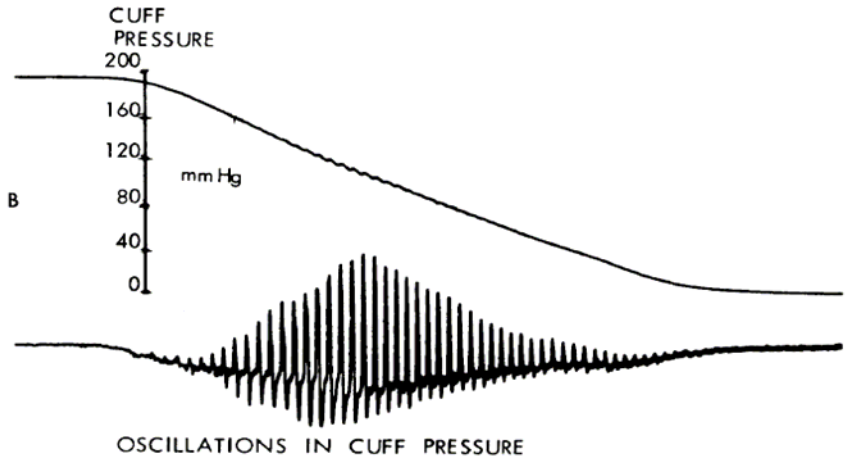


Figure 2. A typical record obtained from a human subject using a 12-cm cuff.
Cuff pressure and amplified cuff oscillations are presented. This graph was previously published in *Polygraph* and is reprinted here with the permission of the American Polygraph Association.

amplitude tracings could be observed in the recordings. The amplitude of the pulse tracings increased as the cuff pressure continued to decline. As the counter-pressure against the tissue continues to fall, more blood passes through the artery and more of the artery is open during the cardiac cycle.

As cuff pressure on the overlying tissue is further reduced the oscillations begin to decrease because the artery wall is less flexible. As the cuff pressure continues to fall, these oscillations decrease until cuff pressure falls to zero. (See Figures 1 and 2)

To understand how the cardiovascular channel of the polygraph works, it is necessary to understand the principle that underlies operation of the oscillometric method of measuring arterial pressure noninvasively. Figure 2 is a record of decreasing cuff pressure and the amplified cuff-pressure oscillations. Note their increase, reaching a maximum and decreasing as cuff pressure continues to decrease. The cuff pressure for maximum-amplitude oscillations was shown to correspond to mean aortic pressure by Posey, Geddes, Williams and Moore (1969).

The foregoing predicts that if cuff pressure is set to a value below the cuff pressure for maximum oscillations, the amplitude of the cuff-pressure oscillations will decrease if the arterial pressure increases. Conversely, if the cuff pressure is set at a pressure above the cuff pressure for maximum oscillation amplitude, a rise in arterial pressure will increase the oscillation amplitude. Since most modern polygraph examiners operate with cuff pressure in the 60 – 80 mm of Hg range, the cuff pressure is below the point of maximum oscillations or below mean arterial blood pressure.

Geddes and Newberg (1977) tested and found support for this hypothesis by applying a stimulus to raise the arterial pressure of a subject and measuring amplitude changes at varying arterial pressures. These investigators first determined the cuff pressure for maximum oscillations by using the method shown above in Figure 2. Once maximum oscillation pressure was determined, the investigators could determine cuff pressures to use to test the hypothesis. In the case demonstrated in Figure 3, the investigators determined the maximum oscillation blood pressure for this individual to be about 95-100mmHg.

The investigators had the subject use a breath holding technique to cause a rise in arterial pressure and measured cuff pressure and oscillations with a two-channel graphic recorder.

Additionally they attached a conventional polygraph instrument via a T-tube to the blood pressure cuff to ensure the same results would be displayed on a polygraph. It should be noted that a T-splitter may confound the measurements of both devices since their mechanisms move according to pressure waves, which affects the mechanism in the other device.

The first author replicated a portion of the above study using a modern polygraph instrument. The first author attached the blood pressure cuff to the upper arms of two healthy adult male subjects and recorded the cardiograph tracing while the subjects held their breath. For the first trial, the cuff pressure was set below maximum oscillation pressure. For the second trial, the cuff pressure was set above maximum oscillation pressure. Figures 4 and 5 display sections of typical charts obtained during this exercise. The first author repeated the experiment several times with similar results for both subjects.

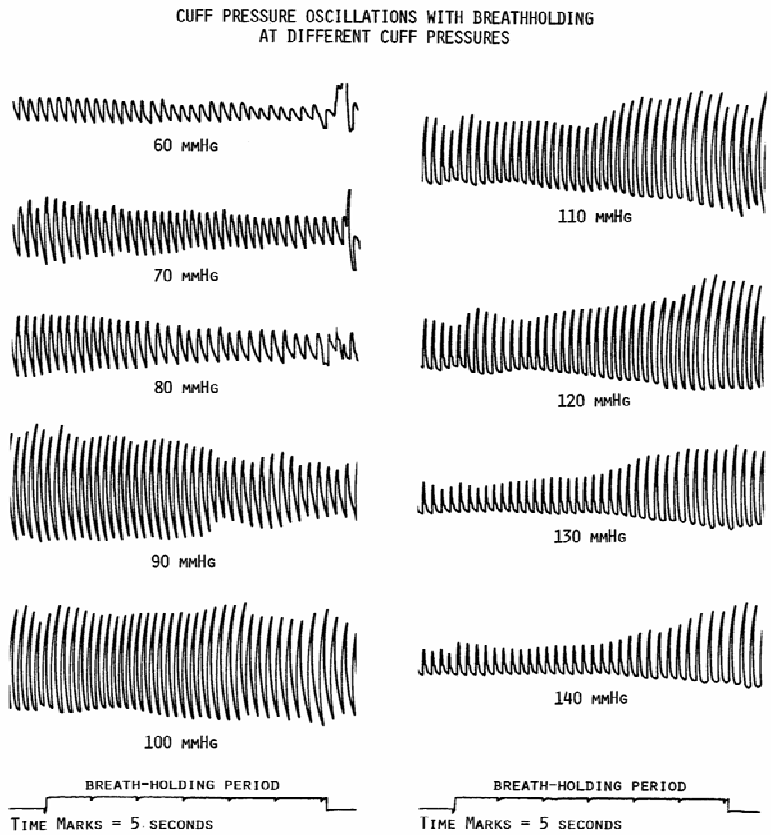


Figure 3. The results of the subject are shown in figure 3. When cuff pressure was initially set at 60-70 mmHg the breath holding caused a barely perceptible decrease in amplitude. As cuff pressure approached 80-90 mmHg the reduction in amplitude became clearly discernable by the human eye. At about 100 mmHg, the breath holding did not alter the tracing amplitude. As cuff pressure was increased, breath holding resulted in marked amplitude increases. The investigators reported all subjects tested displayed similar results. This graph was previously published in *Polygraph* and is reprinted here with the permission of the American Polygraph Association.

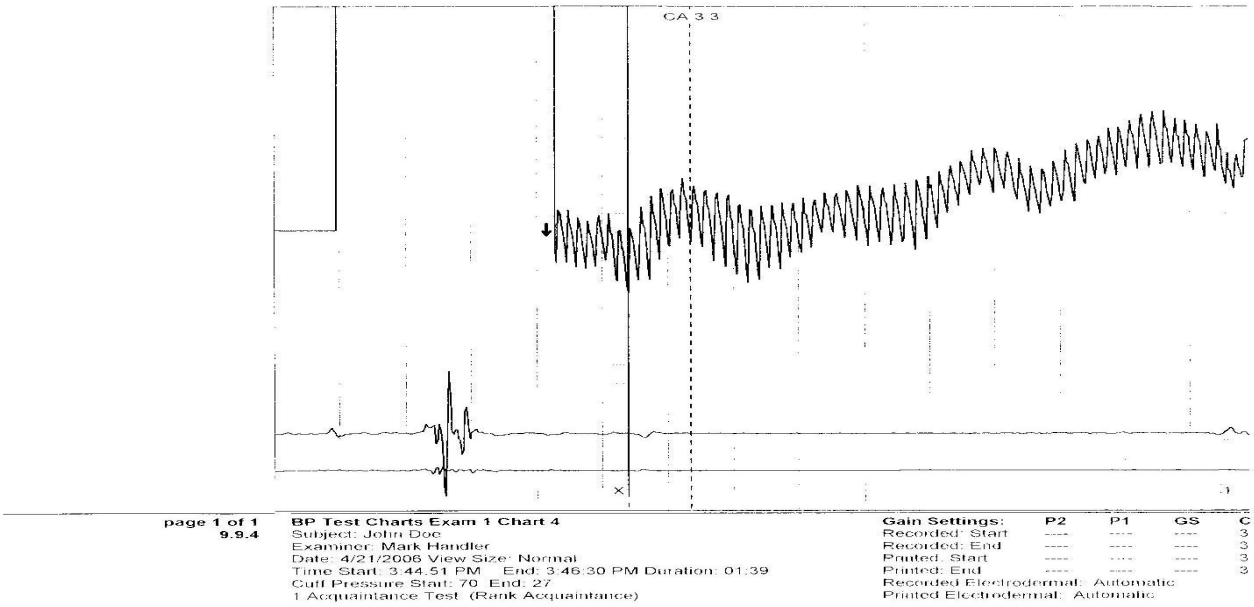


Figure 4. This tracing was obtained using a Lafayette Instrument computerized polygraph (LX-4000). With the cuff pressure set at 70 mmHg, breath holding caused a rise in baseline and a decrease in amplitude.

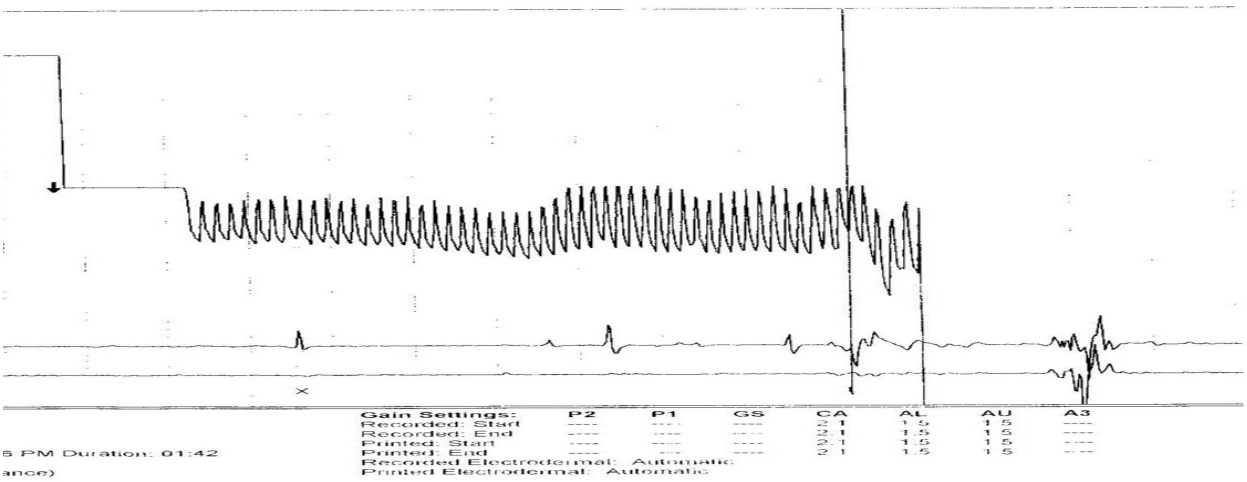


Figure 5. This tracing was obtained using a Lafayette Instrument computerized polygraph (LX-4000). With the cuff pressure set at 113 mmHg, breath holding caused a slight rise in baseline and an increase in amplitude.

What is important to note is that there is a cuff pressure-arterial pressure relationship where amplitude oscillations are maximized. As these two pressures move further away from one another the pulse amplitude will decrease. Matte (1996) and DACA (Anatomy and Physiology) have published the amplitude of the cardiograph tracing represents Mean Arterial Blood Pressure. This appears to be supported by our experiments with modern polygraph equipment and those of earlier investigators.

Baseline Changes

Cardiograph baseline changes typically present as either a tonic (long term) rise or a

phasic (short term) rise and fall. Phasic changes are generally associated with SNS arousal. They rise quickly and generally fall to the pre-stimulus level or a new level. Both Matte (1996) and DACA (Anatomy and Physiology) have published that baseline changes are manifested by changes in blood volume at the site where it is being recorded. Matte states the cardio cuff is measuring net volumetric changes in the arteries, arterioles, capillaries, venules and veins.

A counter-pressure in excess of 40 mmHg can cause the collapse of the underlying tissue capillary beds (Marieb, 1999). Since polygraph examiners typically inflate the cuff to a level above 40 mmHg, the capillary beds below the cuff may be compressed and no swelling could occur below the cuff due to an increase in blood volume. This means that the rise in cardiograph baseline may be due to something other than blood volume changes in the tissue below the monitoring site. Since the capillary beds are compressed under the cuff during a polygraph examination, this would lead one to question how much baseline arousal in the cardiograph tracing results primarily from increased blood volume changes.

Theoretical Considerations

To test how changes in arterial pressure affect polygraph tracing amplitude and baseline, it is necessary to manipulate the *measured* arterial pressure of a subject while recording the cardiograph channel on a polygraph instrument without actually changing the subject's blood pressure. This is done so that we have presumably not altered any volume change at the monitoring point because of a change in the subject's blood pressure. If we can falsely change the measured relative blood pressure without causing any volume change, we can isolate the blood pressure effect on the cardiograph tracing. We were able to conduct a simple experiment to show the effect a change in measured relative blood pressure has on our two tracings of concern.

Geddes (1970) has demonstrated a simple method to modify the blood pressure recorded at the cuff. This is done by simply manipulating the level of the cuffed arm of the subject by raising it above the level of the subject's heart. This is best accomplished by having someone grasp the subjects arm and raise and lower the arm while monitoring the cardiograph channel. *It is important to ensure the subject does not raise or lower their own arm.* If the subject moves their own arm, the compression of their muscle against the brachial artery causes a rise in baseline. See the below Figure 6 for an explanation of this procedure.

Methods

Participants

The participants were three healthy adult males age 35, 42 and 44. None reported any significant health problems and none were currently taking any prescription medications.

Apparatus

For the arm-cuff testing, a standard 12-cm blood-pressure cuff was wrapped around the upper arm of three healthy adult male subjects while seated in a plastic portable polygraph chair. For the finger-cuff trials, a "finger-cuff" sold by the Lafayette Instrument Company was wrapped around the subject's thumb. We used a Lafayette Instrument Company computerized polygraph instrument (LX-4000) to record the cardiograph channel.

Procedure

The arm-cuff method consisted of comfortably seating the subject in the polygraph chair in a quiet polygraph suite and wrapping the cuff around the left upper arm. The chart recording function was started and the cuff inflated. After the cuff was inflated, the cuff was "massaged" to equalize pressure and then the cuff pressure was adjusted again to the target pressure. The subject was instructed not to attempt to raise or lower their arm. They were told to allow the assistant to move their arm for the test. Once the tracing was stabilized, an assistant slowly raised the subject's right arm from the chair rest to above the subject's head as shown in figure 6. The assistant grasped the subject's wrist with one hand and placed their other hand under the subject's elbow. While the assistant watched the polygraph chart, they slowly raised or lowered the subject's left arm while maintaining support under the elbow and

Situation **a** Situation **b**

Figure 6. The importance of cuff location during the arm-cuff experiment. In situation **a**, blood pressure is measured at the heart level. In situation **b**, the first author demonstrates a correct way to support the subjects arm during height manipulation. When blood pressure is measured with the arm elevated, it is reduced by 22.4 mmHg per foot of vertical distance from the heart.

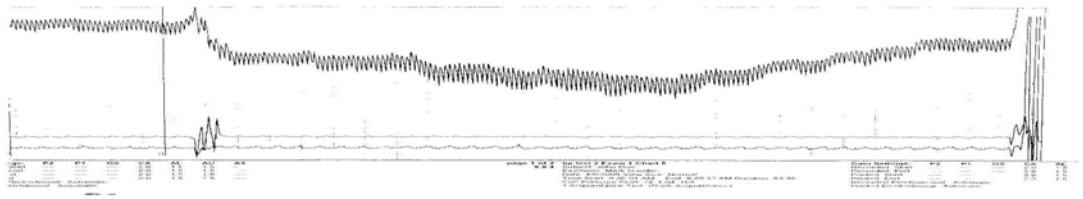
using the wrist to lift or lower the subject's arm.

The finger-cuff method consisted of comfortably seating the subject in the polygraph chair in a quiet polygraph suite and wrapping the cuff around the left thumb. The cuff was inflated and the chart recording function started. After the cuff was inflated, the cuff was "massaged" to equalize pressure and then the cuff pressure was adjusted again to the target pressure. The subject was instructed not to attempt to raise or lower their arm. They were told to allow the assistant to move their arm for the test. Once the tracing was stabilized, an assistant slowly raised the subject's left arm from the chair rest to above the subject's heart using the assisted method described earlier.

In the first trial, the target cuff pressures were set at approximately 60 - 70 mmHg. In the second trial, the target pressure was approximately 110-115 mmHg.

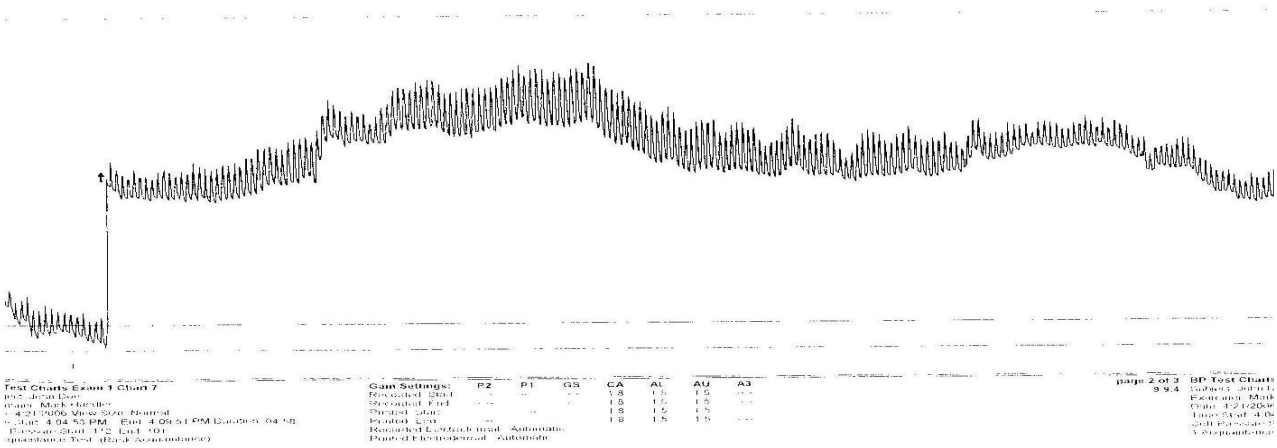
Results

Figure 7 displays the typical results of a subject with the arm-cuff pressure set below mean arterial pressure. In this trial the experiment began with the subject's arm at heart level. The assistant raised and then lowered the subject's arm. Raising the subject's arm caused a lowering of the blood pressure monitored at the cuff. The tracing amplitude increases and the baseline decreases as the monitored blood pressure is lowered. Lowering the subject's arm causes a rise in blood pressure monitored at the cuff. The pulse amplitude decreases as the baseline increases. This tracing is typical for all subjects tested at this lower target pressure.



X Begin raising arm. XX Begin lowering arm.

Figure 7. An example of the cardiograph tracing obtained by manipulating the subjects arm with the arm-cuff pressure set below mean arterial pressure. The X marks the point at which the assistant began raising the subject's arm. The XX marks the point where the assistant began lowering the subject's arm.



X Begin lowering arm. XX Begin raising arm.

*Figure 8***.** An example of the cardiograph tracing obtained by manipulating the subjects arm with the arm-cuff pressure set above mean arterial. The X marks the point at which the assistant began lowering the subject's arm. The XX marks the point where the assistant began raising the subject's arm.

Situation **a** Situation **b**

Figure 9 The importance of cuff location during the finger-cuff experiment. In situation **a**, blood pressure is measured at the heart level. In situation **b**, the first author demonstrates a correct way to support the subjects arm during height manipulation. When blood pressure is measured with the arm elevated, it is reduced by 22.4 mmHg per foot of vertical distance from the heart.

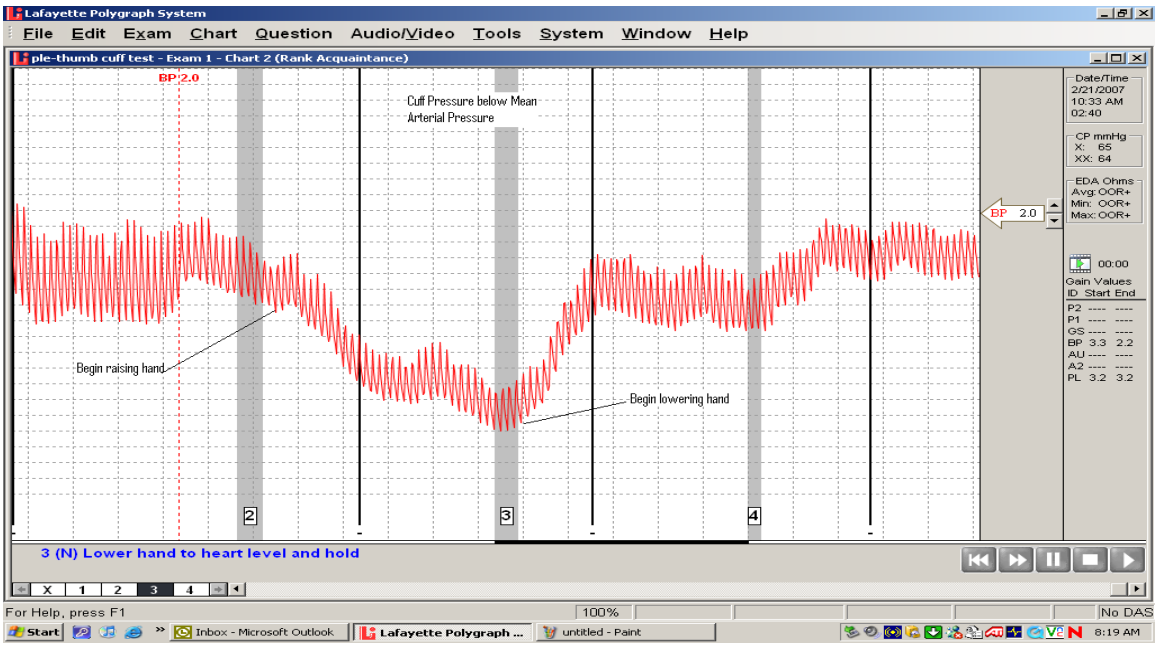


Figure 10. An example of the cardiograph tracing obtained by manipulating the subjects arm with the finger-cuff pressure set below mean arterial pressure. The chart is noted at the point where the assistant began raising and lowering the subject's arm.

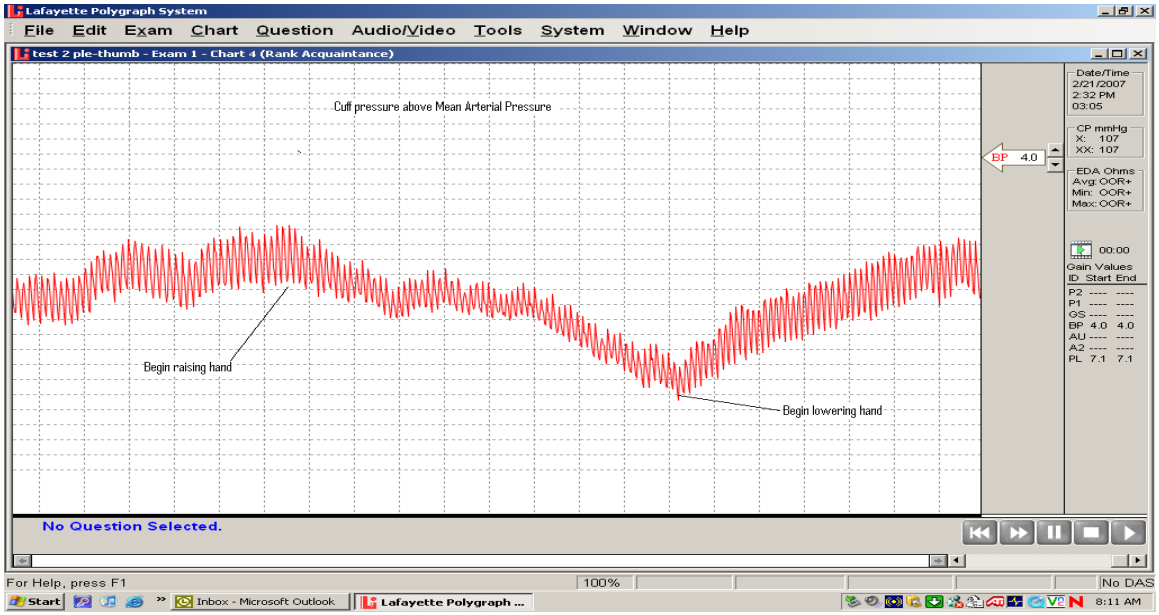


Figure 11. An example of the cardiograph tracing obtained by manipulating the subjects arm with the finger-cuff pressure set above mean arterial. The X marks the point at which the assistant began lowering the subject's arm. The chart is noted at the point where the assistant began raising and lowering the subject's arm.

Figure 8 displays the typical results of a subject with arm-cuff pressure set above mean arterial pressure. In this trial the experiment began with the subject's arm held above the head. The assistant lowered the subject's arm which caused a rise in blood pressure monitored at the cuff. The tracing baseline increased as the pulse amplitude increased. The assistant then slowly raised the subject's arm which caused the blood pressure monitored at the cuff to fall. The tracing baseline decreased and the amplitude decreased. This tracing is typical for all subjects tested at this higher target pressure.

Figure 10 displays the typical results of a subject with a finger-cuff pressure set below mean arterial pressure. In this trial the experiment began with the subject's arm at heart level. The assistant raised and then lowered the subject's arm. Raising the subject's arm caused a lowering of the blood pressure monitored at the cuff. The cardio tracing baseline decreases and as the blood pressure lowers at the monitoring point. Lowering the subject's arm causes a rise in blood pressure and the baseline to increase. Note: Comparatively smaller amplitude changes were noted during these trials. This tracing is typical for all subjects tested at this lower target pressure.

Figure 11 displays the typical results of a subject with a finger-cuff pressure set above mean arterial pressure. In this trial the experiment began with the subject's arm at heart level. The assistant raised and then lowered the subject's arm. Raising the subject's arm caused a lowering of the blood pressure monitored at the cuff. The cardio tracing baseline decreases and the cardio pulse amplitude decreases as the monitored blood pressure lowers at the cuff. Lowering the subject's arm causes a rise in blood pressure measured at the thumb and causes the baseline and cardio pulse amplitude to increase. This tracing is typical for all subjects tested at this lower target pressure.

This simple experiment demonstrates the changes observed in the cardiograph tracings when measured blood pressure is changed without SNS arousal. By raising and lowering the subject's arm, we manipulated the blood pressure recorded at the cuff site without attempting to raise the subject's

arterial pressure. Since we presumably did not alter the subject's arterial pressure, we did not cause any swelling of the underlying tissue. These experiments tend to support the earlier work of Geddes and Newberg (Geddes and Newberg, 1977). If the cuff pressure is set below maximum oscillation pressure, as typically done in modern polygraphy, a rise in arterial pressure will result in a baseline rise and a decrease in pulse amplitude

Discussion

An inference can be drawn that the cardiograph changes are manifested from arterial pressure changes based on the tracings obtained via the Finapres and the experiments conducted in this paper. We have demonstrated that pulse amplitude is a function of the relationship between arterial pressure and cuff pressure. The changes that occur in pulse amplitude size are dependent on a number of factors that include systolic and diastolic changes throughout the examination and the cuff pressure. This can be confounded by the starting points of each in relation to one another. Since cuff pressure remains relatively constant throughout the chart collection phase, the primary variable is a change in blood pressure at the monitoring site.

Since mean arterial pressure is a function of systolic and diastolic pressures then it could be inferred that they are the primary cause for change in pulse-amplitude. Increases in systolic and diastolic pressures caused by SNS arousal will result in a rise in arterial pressure. As shown earlier this will result in a mean arterial pressure that is further from cuff pressure and the cause of a decrease in pulse amplitude.

It would seem impossible to have a baseline arousal without a decrease in pulse-amplitude, but this is not uncommon in polygraph. One possible explanation is the lowered cuff pressure in modern polygraph recordings. Computerized polygraph allows us to operate with lower cuff pressures and accommodate through the use of amplification.

The physiological source of the cardiograph tracing has been a point of contention. Prior studies, including the one done by Podlesney and Kircher (1999) provided data from which inferences may be drawn. These researchers reached the same inference as we did, that the cardiograph reflects variations in arterial blood pressure.

The results of the experiments discussed in this paper provide a possible physiological basis for the changes observed in the cardiograph tracing. Our results replicated the earlier work of Geddes and Newberg using modern polygraph equipment and we reached the same conclusions.

As professionals we should strive to learn as much as we can about what we actually record. With the many different disciplines studying the human body and human behavior, we owe it to our profession to seek guidance from experts in these different fields of study. Many psychophysiology and anatomy researchers have conducted studies that can be applied to polygraph. If these experts can help shed more light in an area of polygraph, we should take advantage of their work. Inter-discipline cooperation will assist us to gain and maintain the respect of our fellow professionals.

Limitations and Further Research and Development

Since actual arterial blood pressure was not monitored during these experiments, we cannot say with certainty the source of baseline arousal is strictly due to arterial blood pressure change. During the Finapres experiments conducted by Podlesney and Kircher (1999) they too did not directly measure arterial blood pressure. Also we cannot say with absolute certainty we did not raise the subject's blood pressure during the arm raising experiment.

It is suggested that polygraph instrument manufacturers collaborate with other medical instrument manufacturers to provide alternative instrumentation capable of measuring mean arterial blood pressure dynamics without the use of a cardio cuff. The current cuff used to obtain data for the cardiograph channel, partially occludes circulation distal to the applied location. This occlusion has been the source of discomfort to

polygraph examinees and may limit the number of questions asked during a polygraph chart. An alternative method of recording arterial pressure that does not cause discomfort may allow examiners to ask more questions during a single polygraph chart.

The Finapres may provide an attractive alternative to cardiovascular recordings. During Probable Lie Testing the validity coefficients between the Finapres and cardiograph were statistically indistinguishable (Kircher, Packard, Bell & Bernhardt, 2001). Unfortunately the Finapres may be cost-prohibitive to most end users of polygraph.

Routine inclusion of blood volume or pulse volume measurements needs to be explored as well. Polygraph examiners should contact their instrument manufacturer regarding photoplethysmograph components. Since the cardio cuff acts as a tourniquet, over the duration of a polygraph recording, any digital blood volume recording must be done on a non-restricted arm.

Acknowledgements

The authors are grateful to Mr. Don Krapohl, Dr. Tim Weber, Mr. Charles Slupski and Dr. Robert F. Simons for their thoughtful reviews and comments to an earlier draft of this paper and to Sgt. Jerry Thomas for his physiological contributions to the chart productions and photographic contribution to the demonstration in figure 6. The views expressed in this article are solely those of the authors, and do not necessarily represent those of the Purdue University, SUNY, the Montgomery County Texas Sheriff's Office, or the APA. Questions and comments are welcome at polygraphmark@sbcglobal.net.

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