The Finapres (Volume Clamp) Recording Method in Psychophysiological Detection of Deception Examinations: Experimental Comparison with the Cardiograph Method

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Summary

The cardiograph instrument that is commonly used in polygraphic detection of deception examinations occludes circulation in the arm and causes discomfort and other adverse effects to examinees. The Finapres instrument is based on a newer technology that allows similar recordings to be obtained without discomfort. This study evaluated the Finapres as a potential replacement for the cardiograph.

The Finapres method was evaluated and compared with the cardiograph method in simulated detection of deception examinations. Subjects participated in a simulated theft in either innocent or guilty roles. Guilty subjects took and kept two $5 bills. A $100 bonus was offered and paid to all subjects whose examinations produced nondeceptive results regardless of their actual roles. Of 120 subjects, 40 subjects (20 innocent and 20 guilty) were assigned to each of three recording methods: Finapres, cardiograph, and Finapres/cardiograph. The examinations were conducted without knowledge of the subjects' individual roles in the simulated crimes. The polygraph records were studied using computerized physiological measurements, blind independent evaluations by experienced polygraph examiners, and evaluations by a computer algorithm.

Examinations using the Finapres and those using the

cardiograph discriminated significantly between innocent and guilty conditions, and examinations with the Finapres were at least as accurate as those with the cardiograph. The accuracy of computer decisions (correct divided by total decisions, excluding inconclusives) for the examinations using the Finapres was 84% for innocent subjects and 88% for guilty subjects, and the inconclusive rates were 5% and 20%, respectively. However, the results did not indicate that the discomfort caused by the cardiograph pressure cuff significantly affects the validity of examinations. Analysis of Finapres and cardiograph recordings obtained simultaneously showed strong correlations, indicating that Finapres and cardiograph outputs reflect essentially the same physiological activity. Based on previous reports of strong correlations between Finapres and intra-arterial recordings of blood pressure, the results indicate that the cardiograph probably also records changes in blood pressure. This study provides a scientific basis for the introduction of the Finapres method in actual control-question criminal examinations. This would dramatically reduce discomfort to examinees and would make it possible to present larger numbers of control and relevant questions during examinations, possibly resulting in improved reliability and validity of the examinations.

Project Description

Polygraphic detection of deception examinations commonly employ a cardiograph instrument for recording cardiovascular responses. The cardiograph is based on a modification of Ehrlanger's oscillometric method for measuring blood pressure. The cardiograph was introduced to polygraphy at the Berkeley, California Police Department in the early 1920s.[2] A cardiograph instrument consists of a pneumatic pressure cuff connected by tubing to a pressure transducer, an inflation pump, and a pressure gauge. The cuff is wrapped firmly around the examinee's upper arm and inflated, usually to about 70 mmHg during examinations. Cardiovascular activity is detected by the pressure transducer, amplified, recorded, and evaluated along with respiration and electrodermal activity to determine the results of examinations.

Polygraph practitioners generally believe that cardiograph information is valid based on their experience. Several experiments using simulated crimes and typical control-question techniques demonstrated that amplitude measures of increases in the cardiograph diastolic, systolic, or average tracing level were valid.[3] Other results suggest some uncertainty regarding validity. Podlesny and Raskin[4] found significant results for innocent but not guilty subjects and suggested that the cause was

weak cuff-arm pressure coupling due to the use of a low cuff-inflation pressure (50 mmHg). Dawson[5] used a cuff pressure of 60 mmHg and found significant results only for guilty subjects. Honts, Raskin, and Kircher[6] used a cuff pressure of 70 mmHg and found no significant difference between innocent and guilty control subjects.

In addition to issues of validity, the cardiograph method is physically intrusive. During the course of a polygraph examination, the cardiograph cuff must remain pressurized on the examinee's arm during the presentations of the questions. There are typically three or more repetitions of the questions ranging from 2.5 to 5 minutes per repetition. During these recording intervals, the pressure in the cuff exceeds the pressure in the venous system of the arm. This impedes the normal return of blood to the heart and causes vasocongestion (swelling and discoloration) in the arm. Examinees commonly report discomfort, pain, stiffness, and broken capillaries in the skin distal to the cuff. In a recent study,[7] 29 of 96 subjects (30%) spontaneously reported discomfort from the pressure cuff.

There have been some attempts to modify or replace the cardiograph in order to reduce discomfort to examinees. These include the use of a low-pressure cuff and two versions of a device known as the "cardio activity monitor (CAM)."[8] Research

with these methods failed to show evidence of validity with control-question tests.[9] An arterial tonometric method proved unreliable in extensive pilot studies by the first author at the FBI Academy, Quantico, Virginia.

The Finapres (FINger Arterial PRESsure) instrument is a promising potential alternative to the cardiograph. The Finapres is based on a volume clamp principle described by Peñáz.[10] This method was realized in instruments developed at TNO Institute of Applied Physics, Amsterdam, The Netherlands, and Datex-Ohmeda, Tewksbury, Massachusetts (formerly Ohmeda Division, BOC Group). A servo system controls the pressure in a finger cuff, continuously counterbalancing the pressure in the arteries of the finger. This physically clamps volume oscillations of the arterial walls, canceling pulsations. The Finapres derives calibrated, continuous blood pressure output from the instantaneous cuff pressure required to clamp the volume of the arteries. Studies with medical patients showed that the Finapres tracks changes in intra-arterial blood pressure.[11] The Finapres method has been used to monitor patients continuously for as long as 7.5 hours, and a study of circulation in the fingertip revealed no dangerous effects.[12] In addition, the Finapres was found resistant to changes in vasomotor activity.[13]

Pilot studies with concurrent Finapres and cardiograph

recordings at the University of Utah, Salt Lake City, Utah,[14] and the FBI Academy, Quantico, Virginia, revealed strong correlations between Finapres and cardiograph output and confirmed that the Finapres finger cuff can be operated for extended periods without causing discomfort. Unlike the cardiograph, the Finapres is resistant to movement artifacts, and it produced high-quality recordings for all subjects. However, prior to the present study, there had been no systematic efforts to evaluate relationships between Finapres and cardiograph output during detection of deception examinations nor to assess the validity of measures derived from the Finapres.

Pressure in the cardiograph cuff is, itself, a source of stimulation to examinees. Discomfort caused by the pressure cuff could affect the validity of examinations either positively or negatively. Informal discussions with examiners and scientists suggested that two views were generally held regarding the effects of cuff pressure. One view is that the discomfort caused by the cuff is a distraction that may reduce examinees' attention to test questions and may reduce the overall validity of examinations. Another view is that the discomfort of the cuff helps to convince examinees that the examinations are serious, and may, therefore, improve the validity of examinations. It should also be added that cuff pressure may have no effect or

could act through other mechanisms than those suggested. Since the Finapres finger cuff produces little or no discomfort to subjects, examinations conducted with the Finapres provide a relatively neutral condition against which the effects of cuff-pressure discomfort on other physiological measures can be evaluated. This study compared the validity of skin conductance, respiratory, and heart-period measurements in the presence of the Finapres versus the cardiograph.

The physiological source of cardiograph output has been debated but not resolved.[15] It has been suggested that cardiograph recordings reflect relative changes in blood volume in the upper arm. The rationale for this view is that the sympathetic nervous sustem, believed to be stimulated during polygraph examinations, could cause vasodilation in the muscle tissues of the arm. Alternatively, it has been suggested that cardiograph recordings reflect relative changes in blood pressure in the arteries of the upper arm. To evaluate the latter possibility, within-subjects cardiograph and Finapres recordings were compared in a separate treatment condition.

The objective of the present study was to evaluate the Finapres method as a possible replacement for the cardiograph method in control-question detection of deception examinations. The specific goals were to:

1) Evaluate the validity of examinations using the Finapres as a replacement for the cardiograph,

2) Compare the validity of examinations using the Finapres with those using the cardiograph,

3) Compare the validity of Finapres and cardiograph measurements,

4) Test for possible effects of cardiograph discomfort on the validity of other physiological measurements, and

5) Compare simultaneous Finapres and cardiograph recordings.

Scope and Methodology

Research Design

The research design contrasted examinations using the Finapres with examinations using the cardiograph and, additionally, provided data on similarities between Finapres and cardiograph recordings and measures. The contrast was provided by a full-factorial Recording Method X Role design. There were two recording methods: examinations using the Finapres and examinations using the cardiograph. There were two roles: innocent and guilty. There were 20 subjects within each of the four Recording Method X Role cells. The Finapres and cardiograph were recorded simultaneously in two additional groups of 20 innocent and 20 guilty subjects to obtain data on similarities. Equal numbers of male and female subjects were

assigned to each cell, and the location of the Finapres and cardiograph transducers (left or right arm/hand) was counterbalanced within each recording method and role. All 120 subjects were assigned in random order to a recording method (Finapres, cardiograph, or Finapres/cardiograph) and a role (innocent or guilty) in order of their arrival.

Subjects

The subjects were recruited by a temporary employer. They were paid and offered a possible bonus. Data for 29 of the 149 subjects who reported for the study were either unavailable or eliminated.[16] Of the 120 subjects whose data were retained, 60 were male and 60 female (by selection). The racial makeup of the sample was 20% black, 74% white, and 6% other. Subjects' ages ranged from 18 to 43 years (MD = 25 years), and they reported 8 to 19 years of education (MD = 14 years). None reported any serious illness (4% reported hypertension). Thirteen percent reported one or more previous polygraph examinations.

Apparatus

The examinations were conducted in a quiet, well-lit, 10' by 12' room within a comfortable temperature range. The subjects sat in an armchair. The instruments were located behind them in the same room. Physiological activity was recorded using a Beckman Dynograph Model R611. Cardiograms were recorded with a

Lafayette Model 76442-G cardiograph and a 9806A Beckman coupler from a cuff placed on the upper arm. The armrests were adjusted to position the cardiograph cuff away from the subject's torso. The cuff pressure was adjusted to give strong oscillations, and the pressure was released upon completion of each repetition of the questions. The mean cuff pressure was 76 mmHg, and there were no significant group differences in mean cuff pressures. The Finapres recordings were obtained from the middle phalanx of the second finger using an Ohmeda 2300 Finapres Blood Pressure Monitor and a 9806A A-C Beckman coupler. Respiration was recorded from a mercury strain gauge using a 9875B Beckman coupler. The gauge was fastened around the torso at the level of the diaphragm. Skin conductance was recorded from UFI 8-mm Ag/AgCl electrodes with a .05 molar NaCl electrolyte using a 9844 Beckman coupler. The electrodes were attached to the palmar surfaces of the second and third fingertips of the hand on the same arm as the Finapres transducer.[17] The digitization rate for each channel was 200 samples/second.

Procedure

A temporary employer recruited the subjects and scheduled appointments. Subjects performed their roles without personal coaching by following tape-recorded and written instructions. Each subject participated in two sessions that were three days to

two weeks apart. The crime simulations were conducted during Session I and the polygraph examinations during Session II. All subjects were instructed that, if they could pass the examination, they would receive a $100 bonus in addition to their pay.

An assistant assigned the subjects to recording methods and roles in order of arrival using a randomized list. Sufficient crime simulations and examinations were conducted to fill all cells of the research design.

Upon arrival for Session I, each subject was escorted to a lounge area and directed to listen to tape-recorded instructions. Each subject performed a role that was fully described by the instructions. The simulations were monitored by television to assure conformance with the instructions.

After listening to the tape, each subject in the guilty role walked to a second lounge and found a purse. The subject took two $5 bills from the purse and concealed them on his/her person. The subjects were instructed to do this in a way that would not arouse suspicion, to avoid leaving fingerprints, and to prepare an alibi in case they were caught. They were instructed to keep and spend the $10 and that they would be disqualified if they attempted to return it. After taking the money, each subject returned to the first lounge. Subjects in the innocent role were

instructed that there had been a theft of money and that they were innocent suspects. They were told to remain in the lounge.

After each subject had carried out those instructions, an FBI Special Agent entered the lounge and questioned the subject regarding the theft. In accordance with the instructions, all subjects stated that they had come for a polygraph study and listened to a tape recording that told them they were innocent. All subjects denied the theft and signed a statement to that effect. The Agent then obtained each subject's agreement to take a polygraph examination.

Upon returning for Session II, each subject was given an envelope containing written instructions. The subjects in the guilty role were reminded to lie about the theft, and those in the innocent role were reminded to tell the truth. Subjects in both roles were instructed to tell the examiner the same story: they had come for a polygraph study, listened to tape-recorded instructions, the tape recording said they were innocent, and they knew nothing about the theft. Each subject was instructed that he/she would receive a $100 bonus by passing the examination, and the bonus would be paid before the end of the session.

The examiner (the first author) was a graduate of the polygraph training courses at the Backster School of Lie

Detection, San Diego, California, and the U.S. Army Military Police School, Fort McClellan, Alabama. The examiner designed the study but did not know the assigned roles of individual subjects and was not informed of the correct roles of individual subjects until he had completed all the examinations.

The examination procedure conformed to the method known as the "Zone Comparison Technique" among practitioners. After obtaining consent and background information, the examiner asked the subject to describe his/her family and rearing. The examiner asked the subject if he/she had been taught that lying and stealing are wrong and if it was correct that "you are not the kind of person who would lie or steal." The subjects all responded affirmatively. This procedure committed each subject to presenting as a person who did not lie or steal and was intended to predispose subjects to answer "no" to the control questions (see below). The examiner told the subject there had been a theft during the subject's first visit, asked the subject to explain what had happened, and listened to the subject's explanation. The examiner then stated that the purpose of the examination was "to find out if you are telling the truth." Then he introduced the test questions to the subject in the following order: (the questions are numbered for reference)

Relevant Questions

5. Did you take that money from the purse?

7. Did you take that money from the purse on [date]?

10. Did you take that money from the purse in the lounge?

Control Questions

4. Before 1994, did you ever steal anything?

6. While you were [in high school], did you ever steal anything?

9. Between the ages of [18] and [24], did you ever steal anything?

Irrelevant Questions

1. Is your name [William]?

8. Do you live in [Alexandria]?

"Sacrifice Relevant" question

3. Regarding the theft of that money, do you intend to tell the truth about that?

"Outside Issue" question

2. Are you convinced I will ask only the questions we have discussed?

To introduce the control questions, the examiner explained that he needed to find out if the subject was the "type of person who would steal and lie about it." He stated that the subject had already told him he/she was "not that kind of person," and there would be some questions on the test to verify that. He

introduced the control questions and solicited the subject's answers to them. The control questions clearly excluded the date of the subject's first session and conformed to the individual's background. When the subjects answered "yes" to control questions, the examiner feigned surprise, asked about the circumstances, made some notes, and then asked, "You haven't done anything else, have you?" This procedure was repeated until the subject stated that he/she had not done anything else. Typically, subjects initially answered "no" or made one or two minor admissions. The examiner reworded the control questions to exclude the admissions; e.g., "Besides what you told me about..." All of the subjects answered "no" to the original or reworded versions of the control questions and to the relevant questions during the tests.

The examiner placed the sensors on the subject and conducted a practice test during which the subject truthfully answered a list of questions about his/her choice of a number.[18] After the practice test, he told the subject that the instruments were working properly. The examiner reviewed the list of questions with the subject and then presented four repetitions of the questions while recording the subject's physiological activity. There were five-minute rest periods between the repetitions of the questions. The repetitions were presented in the following

orders: Repetition I, 1 2 3 4 5 6 7 8 9 10; Repetition II, 8 2 3 9 5 4 7 1 6 10; Repetition III, 1 2 3 6 5 9 7 8 4 10; and Repetition IV, 8 2 3 4 5 6 7 1 9 10. The minimum interval between question onsets was 20 seconds. Longer intervals were used as required to allow physiological recovery and to avoid artifacts. After Repetition I, the examiner asked, "Did any of the questions bother you?" After Repetition II, the examiner asked, "Did any of the questions bother you that time? Are you still convinced that you are telling me the truth?" This procedure was intended to enhance subjects' concern about the examination outcome without directing their attention to particular questions. Some subjects made admissions to the control questions, and the examiner made adjustments as described above. After the examination, an assistant debriefed the subject while the examiner evaluated the recordings. When the examiner's decision was "no deception," the assistant paid the subject $100.

Data Reduction and Analysis

Objective Measurements. Selected physiological features were measured from the digitized physiological data using computer algorithms. An algorithm located the pulse-by-pulse diastolic low points and systolic high points in the Finapres and cardiograph recordings and stored the level and time for each point that occurred between -4 and +19 seconds relative to each

question onset. Diastolic amplitude and pulse amplitude changes were measured using the method of Kircher and Raskin.[19] Analysis showed that increases in pulse amplitude were more strongly correlated with Role than were decreases in pulse amplitude (Finapres; r = .45 versus r = .36; cardiograph, r = .36 versus r = .27). Therefore, further analyses were conducted using increases in pulse amplitude. Skin conductance amplitudes were measured using the method of Kircher and Raskin.[20] Respiration excursions were measured using the method of Podlesny and Truslow.[21] Heart periods were computed from the diastolic timing data. Heart period amplitudes were measured by subtracting the mean period for the last two beats prior to question onset from the longest period between four and 15 seconds after question onset. Negative values were replaced with 0.

Standardization of Objective Measures. Within each subject, each objective measure was expressed as a standardized mean difference score. The mean for relevant questions was subtracted from the mean for the control questions, and the difference was divided by the pooled standard deviation. The sign of the difference scores for respiration excursion was reversed to establish a common direction for predicted effects. Thus, for all measures, larger responses to control questions resulted in positive values and larger responses to relevant

questions resulted in negative values.

Independent Examiner Evaluations. The polygraph recordings were evaluated independently by four instructors of the Department of Defense Polygraph Institute (DoDPI), Fort McClellan, Alabama. The evaluators were graduates of examiner training at DoDPI, had 4 to 16 years (MD = 8.5 years) experience in polygraph positions, and were experienced in scoring control-question examinations. The evaluators had no contact with any of the subjects and were given no information about the Role assignments. To mask the recording method, Finapres and cardiograph recordings were labeled "A" and "B" and preprocessed to show only a series of connected diastolic points. Each examiner evaluated a randomly selected partition of 30 examination recordings.[22] The examiners were cautioned not to make any assumptions about the base rate of guilt, since it could vary depending on the particular set of records assigned. They scored the response to each relevant question by comparison with the response to the adjacent control question and provided separate scores for the respiration, skin conductance, and Finapres or cardiograph recordings using a seven-point integer scale (-3 to +3).[23] Larger responses to the relevant questions were assigned negative scores, and larger responses to the control questions were assigned positive scores. The scores were

totaled for each examination. The decision was "no deception" when the total score was +6 or more positive; "deception" when the total was -6 or more negative; and "inconclusive" when the score was between +5 and -5, inclusive.

Independent Automated Evaluations. The polygraph recordings were evaluated independently using a commercial version of a computer algorithm introduced by Kircher and Raskin[24] ("Computer Polygraph System, CPS"). The CPS algorithm is based on a discriminant analysis of combined data from a laboratory study of 100 subjects and a field study of 76 criminal polygraph examinations.[25] The resulting standardized discriminant coefficients for skin conductance, respiration, and cardiograph measures were .77, .44, and .31, respectively. To apply the CPS algorithm to the present Finapres group, Finapres amplitudes were substituted for cardiograph amplitudes.

Detailed Findings[26]

Cardiovascular Recording Method and Role Discrimination

Descriptive statistics for each physiological measure and treatment condition are shown in Exhibit 1. Full-factorial analyses of variance (ANOVAs) of the standardized difference scores for each measure provided tests for Role discrimination and compared examinations conducted with the Finapres versus the cardiograph. As predicted, all of the main effects for Role were

significant: skin conductance amplitude, $F(1,72) = 44.53$, $MS_e = 0.44$; respiration excursion, $F(1,72) = 20.89$, $MS_e = 0.37$; heart period amplitude, $F(1,72) = 10.90$, $MS_e = 0.48$; Finapres/cardiograph amplitude, $F(1,72) = 26.56$, $MS_e = 0.45$; and pulse amplitude increase, $F(1,72) = 19.24$, $MS_e = 0.61$. However, there were no significant interactions of Recording Method X Role. Thus, there was no evidence from the ANOVAs that any of the measures were more or less diagnostic with the Finapres than with the cardiograph.[27]

Exhibit 1. Descriptive Statistics and Point-Biserial Correlations with Role for the Objective Measurements.

	Standardized Difference Scores				
	Innocent		Guilty		
Measure	Mean	SD	Mean	SD	r_{pb}
Finapres Group					
Skin Conductance Amplitude	.67*	(.80)	-.46*	(.49)	.66*
Respiration Excursion	.45*	(.75)	-.26*	(.39)	.52*
Finapres Amplitude	.49*	(.92)	-.31*	(.50)	.49*
Finapres Pulse Amplitude	.66*	(1.17)	-.37*	(.67)	.48*
Heart Period Amplitude	.34	(.86)	-.11	(.63)	.30
n	20		20		
Cardiograph Group					
Skin Conductance Amplitude	.34*	(.70)	-.49*	(.71)	.51*
Respiration Excursion	.08	(.58)	-.46*	(.61)	.42*
Cardiograph Amplitude	.44*	(.52)	-.30*	(.63)	.55*
Cardiograph Pulse Amplitude	.42*	(.45)	-.09	(.59)	.44*
Heart Period Amplitude	.30*	(.59)	-.27	(.61)	.43*
n	20		20		

* $p < .05$.[28] (Exhibit continued on next page)

Exhibit 1 (continued)

Measure	Standardized Difference Scores: Innocent Mean	Innocent SD	Guilty Mean	Guilty SD	r_{pb}
Finapres/Cardiograph Group					
Skin Conductance Amplitude	.51*	(1.01)	-.44*	(.48)	.53*
Respiration Excursion	.51*	(.69)	-.33*	(.52)	.58*
Finapres Amplitude	.28	(.84)	-.32*	(.61)	.39*
Cardiograph Amplitude	.25	(.94)	-.22	(.60)	.29
Finapres Pulse Amplitude	.30	(1.16)	-.53*	(.64)	.41*
Cardiograph Pulse Amplitude	.26	(1.07)	-.30*	(.54)	.31*
Heart Period Amplitude	.35*	(.56)	-.38	(.92)	.44*
n	20		20		

In Exhibit 1, a mean value of 0.00 would indicate no difference between the mean of responses to relevant and control questions. Each of the difference score means was compared with 0.00 to provide a conservative test of the basic assumptions underlying the control-question technique.[29] Specifically, these tests determined if subjects in the innocent role produced larger mean reactions to control questions than to relevant questions

(positive difference scores) and if guilty subjects produced the reverse (negative difference scores). As shown in Exhibit 1, these assumptions were jointly supported for all of the measures except heart period amplitude in the Finapres group, for only skin conductance amplitude and cardiograph amplitude in the cardiograph group, and for only skin conductance amplitude and respiration excursion in the Finapres/cardiograph group.

Point-biserial correlations (r_{pb}) between the subjects' roles and the standardized difference scores for each of the measures evaluated relationships between the roles and the measurements obtained. As shown in Exhibit 1, all the r_{pb}s were significant except heart period amplitude in the Finapres group and cardiograph amplitude in the Finapres/cardiograph group. The size of r_{pb} indicates the ability of each of the measures to discriminate innocent and guilty roles in these data.

Since there were no significant Recording Method X Role interactions, the likely ranges for differences between the Finapres and cardiograph groups were estimated. Exhibit 2 shows the 95% confidence intervals for differences between the Finapres and cardiograph group means for each role and measure. The width of these confidence intervals ranged from 0.66 to 1.14 pooled

within-group standard units, and all of the intervals included the value 0.0.

Exhibit 2. Confidence Intervals for Mean Finapres Group Minus Cardiograph Group Differences in the Objective Measurements.

	Boundaries of 95% Confidence Intervals for Differences in Mean Standardized Difference Scores			
	Innocent		Guilty	
Measure	lower	upper	lower	upper
Skin Conductance Amplitude	-0.15	0.81	-0.36	0.42
Respiration Excursion	-0.06	0.80	-0.13	0.53
Finapres/Cardiograph[1] Amplitude	-0.43	0.53	-0.37	0.35
Finapres/Cardiograph[1] Pulse Amplitude	-0.33	0.81	-0.68	0.12
Heart Period Amplitude	-0.43	0.51	-0.24	0.56
n	40		40	

[1] These differences were obtained by subtracting measures of cardiograph recordings (cardiograph group) from measures of Finapres recordings (Finapres group).

To determine the likely ranges for differences between Finapres and cardiograph measures recorded simultaneously, 95% confidence intervals were computed for differences between the Finapres and cardiograph measures in the Finapres/cardiograph group. The limits of these confidence intervals are shown in Exhibit 3. The confidence interval for pulse amplitude excluded 0.0 in the guilty group, indicating that Finapres pulse amplitude was significantly more diagnostic than cardiograph pulse amplitude in that group.

Exhibit 3. Confidence Intervals for Differences Between Objective Finapres minus Cardiograph Measures Recorded Simultaneously in the Finapres/Cardiograph Group.

	Boundaries of 95% Confidence Intervals for Differences in Mean Standardized Difference Scores			
	Innocent		Guilty	
Measure	lower	upper	lower	upper
Diastolic Amplitude	-0.18	0.24	-0.24	0.04
Pulse Amplitude	-0.42	0.47	-0.42	-0.06
n	20		20	

Cardiovascular Recording Method and Validity of Decisions

Exhibit 4 shows the outcomes of blind evaluations by the DoDPI instructors and the CPS computer algorithm. Correct decisions were significantly more frequent (by χ^2 tests) than incorrect decisions for all combinations of Evaluation Method, Role, and Recording Method, except for examiner evaluations of the innocent group tested with the cardiograph. All the χ^2 tests for the Finapres were significant. Examination of Exhibit 4 suggests a trend toward less frequent errors and inconclusives with the Finapres. The average accuracy[30] of examiner decisions was 70.0% for the Finapres group and 52.5% for the cardiograph group. The average accuracy of automated evaluations was 75.0% for the Finapres group and 65.0% for the cardiograph group. The average accuracies for the Finapres/cardiograph group, in which Finapres and cardiograph were recorded simultaneously and decisions were based in part on cardiograph data, were 52.5% and 67.5%, respectively, for examiner and automated evaluations. These findings are similar to those obtained for the cardiograph group.

Exhibit 4. Outcomes of Independent Examiner Evaluations and Automated Computer Evaluations.

Group	Frequency (Percent)			
	Correct	Error	Inconclusive	Correct Decisions
	Decisions using Examiner Evaluations			
Innocent				
Finapres	14 (70)	3 (15)	3 (15)	$^{14}/_{17}$ (82)*
Cardiograph	10 (50)	5 (25)	5 (25)	$^{10}/_{15}$ (67)
Finapres/Cardiograph	10 (50)	2 (10)	8 (40)	$^{10}/_{12}$ (83)*
Guilty				
Finapres	14 (70)	1 (5)	5 (25)	$^{14}/_{15}$ (93)*
Cardiograph	11 (55)	3 (15)	6 (30)	$^{11}/_{14}$ (79)*
Finapres/Cardiograph	11 (55)	3 (15)	6 (30)	$^{11}/_{14}$ (79)*
	Decisions using Automated Evaluations			
Innocent				
Finapres	16 (80)	3 (15)	1 (5)	$^{16}/_{19}$ (84)*
Cardiograph	15 (75)	3 (15)	2 (10)	$^{15}/_{18}$ (83)*
Finapres/Cardiograph	14 (70)	0 (0)	6 (30)	$^{14}/_{14}$ (100)*
Guilty				
Finapres	14 (70)	2 (10)	4 (20)	$^{14}/_{16}$ (88)*
Cardiograph	11 (55)	3 (15)	6 (30)	$^{11}/_{14}$ (79)*
Finapres/Cardiograph	13 (65)	4 (20)	3 (15)	$^{13}/_{17}$ (76)*

* $p < .05$.[31]

Relationships Between Finapres and Cardiograph Recordings

A linear regression analysis was computed for each subject in the Finapres/cardiograph group to evaluate the pulse-by-pulse relationships between the Finapres and cardiograph recordings obtained simultaneously from the same individuals. Changes in diastolic and systolic levels were computed for each question by subtracting the last value prior to each question onset from each value that occurred during the 19 seconds following question onset. The resulting time series represented changes from baseline for each question. The time series for the individual questions were concatenated within each subject. The Finapres values were regressed onto the cardiograph values separately for relevant questions, control questions, and pooled questions within each subject. A standardized regression coefficient and a constant offset were obtained from each of these analyses.

Exhibit 5 shows the lower and upper bounds of the 95% confidence intervals for the coefficients and offsets. The relationships between the Finapres and the cardiograph were consistent across roles and question types. The results for diastolic levels indicate a strong relationship between recorded changes in the Finapres and cardiograph (mean $r = .84$), with a mean constant offset of less than 1 mmHg and narrow limits for the regression coefficients. The regression coefficients for

systolic levels were also strong but somewhat smaller (mean r = .74) and more variable. The confidence intervals for systolic offsets were all within a few mmHg, but the confidence interval for combined roles and pooled questions was entirely in the positive range, indicating that small changes occurred in Finapres systolic levels in the absence of changes in cardiograph systolic levels.

To evaluate the relationship between objective measurements obtained from the Finapres and the cardiograph, the corresponding standardized difference scores for the Finapres and the cardiograph were correlated in the Finapres/cardiograph group. Both increases in diastolic amplitude and increases in pulse amplitude were strongly correlated (r = .88 and r = .72, respectively).

Exhibit 5. Relationships Between the Finapres and Cardiograph Diastolic and Systolic Levels Recorded Simultaneously from Subjects in the Finapres/Cardiograph Group. Shown are Confidence Intervals for Subject-by-Subject Linear Regression Statistics. Finapres Levels Were Treated as the Dependent Variable in the Regression Analyses.

	Boundaries of 95% Confidence Intervals							
	Diastolic Levels				Systolic Levels			
	Standardized Regression Coefficient		Constant (mmHg)		Standardized Regression Coefficient		Constant (mmHg)	
Role/Question Type	lower	upper	lower	upper	lower	upper	lower	upper
Innocent (n = 20)								
Control Questions	.82	.89	-0.4	0.5	.63	.80	-0.6	1.6
Relevant Questions	.81	.89	-0.2	0.9	.63	.79	-0.9	1.9
Pooled Questions	.82	.89	-0.2	0.7	.64	.80	-0.5	1.6
Guilty (n = 20)								
Control Questions	.81	.89	-0.5	0.6	.68	.81	-0.9	2.4
Relevant Questions	.80	.88	0.1	1.1	.68	.82	0.7	3.7
Pooled Questions	.80	.88	-0.1	0.8	.67	.81	0.0	2.9
Combined Roles (n = 40)								
Control Questions	.83	.88	-0.3	0.4	.68	.79	-0.3	1.6
Relevant Questions	.82	.88	0.1	0.8	.69	.78	0.3	2.3
Pooled Questions	.82	.87	0.0	0.6	.69	.79	0.1	1.9

Analysis and Discussion

Validity of Examinations with the Finapres and the Cardiograph

The objective of this study was to provide an empirical evaluation of the Finapres (volume clamp) method as a potential replacement for the cardiograph in control-question detection of deception examinations. There has not been any previous empirical study comparing the Finapres method with the cardiograph method in control-question tests. The present study employed simulated crimes and examinations as a means to provide the required data. In general, examinations conducted using the Finapres were at least as valid as examinations using the cardiograph. This was true for analyses of objective physiological measurements, decisions based on evaluations by experienced polygraph examiners, and decisions based on a computer algorithm. All of the physiological measures in the Finapres group, except heart period amplitude, were significantly correlated with Role, and their means departed significantly from 0.00 in opposite directions for innocent and guilty subjects, in accordance with the predictions for a control-question test. It is noteworthy that increases in Finapres diastolic amplitude and pulse amplitude were among the valid measures, since this is the first such demonstration. The lowest error and inconclusive rates were obtained with examinations using the Finapres.

Hypothetical Effects of Cuff Discomfort

This study provided an empirical test of hypothetical favorable or unfavorable effects on the validity of control-question examinations due to discomfort from the pressurized cardiograph arm cuff. Analyses of skin conductance amplitude, respiration excursion, and heart period amplitude measures produced no evidence that results obtained in the presence of the cardiograph cuff were either more or less valid than those obtained in its absence. This conclusion is based on the lack of significant interactions between Recording Method and Role. Therefore, this study did not provide any support for the hypothesis, favored by some practitioners, that the discomfort produced by the cuff improves validity of examinations.

Implications Regarding the Source of Cardiograph Activity

The physiological source of cardiograph activity has been a matter of some controversy. This study provided a systematic evaluation of relationships between cardiograph recordings and Finapres recordings in simulated control-question examinations. In combination with previous reports that the Finapres is correlated with intra-arterial blood pressure recordings, the results support the conclusion that the cardiograph likely reflects variations in blood pressure.

Linear regression analyses of pulse-by-pulse simultaneous

recordings in the same subjects showed that diastolic and systolic variations in Finapres and cardiograph output were strongly related. These results were consistent for guilty and innocent subjects and for control and relevant questions. Similarly, discrete Finapres and cardiograph diastolic amplitude and pulse amplitude responses also were strongly correlated.

Medical researchers have evaluated the Finapres as a possible substitute for intra-arterial or other standard blood pressure measurements. Typically those studies were concerned with the precision of blood pressure measurements with the Finapres. However, a handful of studies provided information on the covariation between Finapres recordings and intra-arterial blood pressure recordings. Those studies consistently showed strong linear correlations between Finapres output and intra-arterial blood pressure for rest, cold pressor, head-up tilt, surgery, normal individuals, and patients.[32] The available evidence indicates that the Finapres closely tracks variations in intra-arterial blood pressure. Since cardiograph recordings were strongly related to Finapres recordings in the present study, it appears that the cardiograph probably also reflects changes in intra-arterial blood pressure. The Finapres (volume clamp) method was designed specifically to provide continuous recordings of blood pressure,[33] and the cardiograph was originally adapted

from the Ehrlanger method for measuring of blood pressure.[34] Therefore, it is not surprising that the output of both instruments varies with arterial blood pressure.

Limitations of This Research

This study employed simulations of crimes and examinations rather than actual examinations. Therefore, caution should be used in generalizing the results of this research to actual examinations. Some authors[35] suggested that actual control-question tests of criminal suspects may have higher false positive rates than laboratory simulations since real criminal examinations involve the threat of punishment, and this possibility should be considered.

Lykken[36] generally discounts the value of experiments on the detection of deception. However, it is a common scientific practice to conduct laboratory simulations of phenomena that are difficult to study directly. A notable example is the massive effort currently underway at The European Laboratory for Particle Physics and Fermi National Accelerator Laboratory to simulate physical conditions that occurred billions of years in the past, within a few milliseconds of the Big Bang. Likewise, the recent spectacular advances in biochemistry and biotechnology would not have been achieved if scientists were compelled to conduct all their experiments *in vivo* and were unable to employ simulations

in vitro. Psychologists, of course, frequently attempt to generalize results from animal models or laboratory studies of college students. Many such examples of laboratory simulations may be found throughout various scientific disciplines.

Rather than to discount results obtained in the laboratory indiscriminately, it is common scientific practice to employ simulations and interpret the results carefully. Laboratory simulations of polygraph examinations provide an experimental means for evaluating existing methods and testing new methods, such as the Finapres, without the risk of introducing errors in tests of criminal suspects. Podlesny and Raskin[37] discussed the relative advantages and disadvantages of laboratory research and concluded that laboratory studies of polygraph methods should employ realistic simulations, strong motivation of subjects, and field techniques, in order to maximize the generality of results to field conditions. They considered laboratory and field research to be complementary means for the study of polygraph examinations, each with relative advantages and disadvantages.

This study adhered to those criteria for laboratory studies. Features included were a realistic crime simulation in which guilty subjects actually kept the $10 they had taken, a simulated investigative interview prior to the examination, an interval of at least three days between the crime simulation and the

examination, a typical control-question examination method, and a highly-motivating $100 bonus given to both guilty and innocent subjects who passed the test. Nevertheless, the results should be interpreted with awareness of the need for field validation.

It should not be concluded from the general lack of significant differences between the Finapres and cardiograph groups that examinations with Finapres and cardiograph instruments are equivalent in validity. There were practical considerations limiting the number of crime simulations and examinations that could be conducted in this study, and this affected the power of our statistical tests. For example, the present sample size provides only moderate statistical power for a medium effect size in tests for interaction between Recording Method and Role. Therefore, there is a moderate probability that a small or medium effect may not have been detected. Our results suggest that replacement of the cardiograph with the Finapres might enhance the validity of examinations. However, this was not demonstrated with our statistical analysis of the available data.

It should also be noted that this study did not provide any direct comparisons of Finapres or cardiograph recordings with any independent data for arterial blood pressure. Our conclusion that the cardiograph reflects variations in arterial blood

pressure is an inference based on the present results and those in previous reports.

Further Research and Development

During the course of the present research, the manufacturer of our Finapres instrument discontinued its production. At present, it appears that suppliers of instrumentation based on the Finapres (volume clamp) method are scarce. One supplier is TNO-TPD Biomedical Instrumentation, The Netherlands Organization for Applied Scientific Research, Amsterdam, The Netherlands. TNO-TPD offers a compact portable instrument known as the Portapres that is designed for ambulatory continuous monitoring of blood pressure. This instrument appears readily adaptable to portable polygraph instrumentation. However, the Portapres is much more costly than was the Ohmeda instrument used in this research. TNO markets the Portapres only as a limited-production research instrument. The polygraph community could explore price reductions for larger scale production and/or seek another manufacturer.

Examinations conducted with the cardiograph must be interrupted by rest periods during which the cuff is deflated to reestablish normal circulation in the examinee's arm. Thus, examinations are conducted by presenting several repetitions of the questions. The rest periods reduce the number of control and

relevant questions that may be presented during the course of an examination. The use of the Finapres to replace the cardiograph would create the possibility of conducting examinations with fewer rest periods or no rest periods at all, allowing for more presentations of the questions. This could improve the reliability and the validity of examinations. The ability to present questions as a single extended series would also allow the evaluation of the Dichotomization Hypothesis[38] that posits innocent and guilty subjects should produce opposite patterns in the habituation rates of control and relevant questions. Habituation rates could potentially provide a new source of diagnostic information in examinations conducted using the Finapres.

Conclusions and Implications of Findings

The present experiment showed that simulated detection of deception examinations with the Finapres were at least as valid as those with the cardiograph. Therefore, this study provides an empirical basis for replacing the cardiograph with the Finapres for recording blood pressure. Use of the Finapres would allow examinations to be conducted with dramatically reduced physical discomfort to the examinees. The introduction of the Finapres method should be accompanied by systematic scientific evaluations of its validity in the field. Since the manufacturer has

discontinued production of the Finapres instrument used in this study, a new source for instruments would be needed. The Netherlands Organization for Applied Research (TNO-TPD) is a limited supplier of portable Finapres (Portapres) instruments.

The use of the Finapres in examinations would create opportunities for potential improvements in examination formats through the elimination of rest periods and the inclusion of new diagnostic indicators such as Finapres pulse amplitude and measures of habituation to the different kinds of examination questions.

Notes

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16. Data for 29 subjects were either unavailable or eliminated for the following reasons: Eight failed to attend both sessions. Two were unavailable for session II within 14 days after session I. Three reported outside discussions about the study with previous subjects. Two refused to take the $10 during the simulated thefts. Three did not follow other instructions. One reported a serious illness during the examination. One refused to tolerate the cardiograph cuff. In addition, there were three methodological errors, four equipment failures, and two interferences with the crime simulations.

17. Electrocardiograms were also recorded from electrodes on both arms, and the subject's vocalizations were recorded from a microphone on a boom at the subject's right side. Those data are not included in this report.

18. Podlesny and Truslow, "Validity of an Expanded-Issue (Modified General Question) Polygraph Technique in a Simulated Distributed-Crime-Roles Context."

19. Kircher and Raskin, "Human versus Computerized Evaluations of Polygraph Data in a Laboratory Setting," 294-295. Pulse amplitude changes were measured from the time series of pulse-by-pulse differences between systolic and diastolic levels.

20. Ibid., 294-295.

21. Podlesny and Truslow, "Validity of an Expanded-Issue (Modified General Question) Polygraph Technique in a Simulated Distributed-Crime-Roles Context," 791.

22. Fixed and random effects analyses of variance (ANOVAs) were conducted to determine whether the random assignment of different partitions of the examination records to different examiners resulted in any confounding effects due to differences among the examiners. These tests used a conservative α of .30. There were no significant effects due to examiners or interactions of examiners with Recording Method or Role.

23. The examiners were asked to base their scoring exclusively on respiration suppression/apnea, slowing, and baseline increases; skin conductance amplitude and duration; and Finapres or cardiograph amplitude and duration of increases in diastolic levels.

24. Kircher and Raskin, "Human versus Computerized Evaluations of Polygraph Data in a Laboratory Setting."

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26. All statistical significance tests were two-tailed with α = .05.

27. There were only two other significant effects among the ANOVAs of the standardized difference scores. One of these was a significant main effect of Recording Method for respiration excursion, $F(1,72) = 4.18$, $MSE = 0.37$. The mean for the cardiograph group was more negative than the mean for the Finapres group. The other was a Role X Sex interaction for skin conductance amplitude, $F(1,72) = 4.88$, $MSE = 0.44$. The mean difference between innocent and guilty roles was larger for females than for males. Both of these effects were marginally significant, and neither had been predicted.

28. The r_{pb}s in Exhibit 1 are Pearson product moment correlations of the measures with Role. The difference score means were compared with 0.00 using two-tailed *t* tests. The value of 0.00 represents a difference of 0.00 between the mean relevant and control-question responses. Significant negative means indicate that the relevant-question responses were larger than the

control-question responses; significant positive means indicate the reverse.

29. Podlesny and Raskin, "Effectiveness of Techniques and Physiological Measures in the Detection of Deception," 345; Podlesny and Truslow, "Validity of an Expanded-Issue (Modified General Question) Polygraph Technique in a Simulated Distributed-Crime-Roles Context," 789; Podlesny and Raskin, "Physiological Measures and the Detection of Deception," 786.

30. See Lykken, D. T., *A Tremor in the Blood: Uses and Abuses of the Lie Detector*. New York: McGraw-Hill, 1981. Lykken defined the average accuracy as the average of the percentages correct for innocent and guilty subjects. See also, McCauley, C. and Forman, R. F., "A Review of the Office of Technology Assessment Report on Polygraph Validity," *Basic and Applied Social Psychology*, 9(1988):73-84.

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