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The Current Status of Research in Forensic Psychophysiology and Its Application in the Psychophysiological Detection of Deception

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ABSTRACT: Since 1986 there have been unparalleled advances in the psychophysiological detection of deception (PDD) processes and procedures. This paper traces the emergence of a new emphasis in PDD research; the development of forensic psychophysiology as an academic discipline; provides an overview of computerized polygraphs now in use for collecting physiological data; introduces statistical algorithms for analyzing physiological data; identifies new sensors and transducers currently under study; and describes a new instrument now under development.

KEYWORDS: forensic science, psychophysiological detection of deception (PDD), forensic psychophysiology, computerized polygraphs, algorithms

The period between 1986 and the present has been one of unparalleled advances in the psychophysiological detection of deception testing procedures and processes. "Contrary to the general assumption that technology is an offshoot of science, the primacy is really the other way around. Great advances in science tend to occur after technological innovation has given the mind access to a broader range of information" [*1*]. And so it is with the psychophysiological detection of deception (PDD). More sensitive sensors; more efficient transducers; improved means of digitizing and recording physiological data; digitizing analog data at increasingly high sample rates; and algorithms to evaluate physiological data in an unlimited fashion, all represent technical innovations that will enhance the advancement of the new and evolving science of forensic psychophysiology.

This same period has seen a sharp increase in attention to research and to the education and training of the examiner. This focus was brought about by the Defense Authorization Act of 1986 in which the Secretary of Defense was directed to carry out research in PDD testing; and by DoD Directive 5210.78, which established the Department of Defense Polygraph Institute as a higher education and research facility [*2*]. The mission to conduct the Congressionally mandated research was assigned to the Department of Defense Polygraph Institute.

The focus of attention on the professional development of the examiner is clearly illustrated in the knowledge content of a Master's Degree level curriculum in Forensic Psychophysiology, which has been implemented at the Institute [*3*]. All students are required to complete the first semester and the internship portion of this curriculum before they can be certified by their agencies to become unsupervised examiners. This academic curriculum provides a basis for a thorough understanding of the scientific psychological, physiological, and psychophysiological concepts, systems, processes, and applications involved; as well as the scientific bases for test development, standardized test administration, research methodology, statistics and ethics. This curriculum has been reviewed and recommended for implementation by the DoDPI's Advisory Committee [*4*]; by the Deputy Under Secretary of Defense for Security Policy [DUSD(SP)] [*5*]; the Deputy Assistant Secretary of Defense for Counterintelligence and Security Countermeasures [DASD(CI&SCM)] [*6*]; and the Curriculum and Research Guidance Committee [*7*].

The focus on research is expected to produce significant changes in PDD test formats, physiological data collection processes, physiological data analysis, diagnostic procedures, and the recognition and identification of countermeasures. The use of computer algorithms, which will be discussed later, to analyze physiological data collected during PDD tests appears to be a promising method of determining the validity and reliability of a variety of PDD tests, and will enhance the accuracy of PDD testing.

Forensic Psychophysiology and PDD Tests

Psychophysiology is a science involving the presentation of stimuli to one or more of the human senses to determine the effects of those stimuli, when psychologically processed and evaluated, on selected physiological activities [*8*]. Psychophysiological detection of deception tests[2] also involve the presentation of stimuli to one or more of the human senses, normally in the form of verbal questions, to determine the effect of the questions, when psychologically processed and evaluated, on selected physiological activities. Since most PDD tests are conducted to provide information to assist in the resolution of crimes, whether the crime be murder or espionage, the process falls, like other forensic tests, within the criminal justice system. As such, PDD tests can be called forensic tests.

Since the preponderance of principles, concepts, systems, and processes applied in PDD testing are drawn from the discipline

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[2]For years the word "psychophysiology" and the term "psychophysiological detection of deception" have been associated with the detection of deception by scientists and others.

of psychophysiology; and since nearly all PDD tests can be categorized as forensic tests, it is logical and appropriate to define "forensic psychophysiology" as a science that deals with the relationship and applications of PDD tests to the legal system [9].

The use of the modifier "forensic" in forensic psychophysiology delineates and delimits the scope of the broader science of psychophysiology to legal system applications. These include those systems, processes and applications that are an integral and functional part of the psychophysiological detection of deception. Similarly, the modifier "forensic" delineates and delimits the discipline forensic psychology from the broader discipline of psychology; the discipline forensic psychiatry from the broader discipline of psychiatry; the discipline forensic odontology from the broader discipline of dentistry [9]. Forensic psychophysiology is the discipline that provides the student, the practitioner and the researcher, with the theoretical and applied psychological, physiological and psychophysiological fundamentals for understanding and conducting PDD examinations.

Computers and PDD Tests—Exploratory Phase

The use of computers in the process of conducting PDD tests has been in the developmental stages since 1962 and have progressed through several phases. During the first phase, Kubis [10], Yankee [11], and Burch [12] studied and assessed various potential computer applications and feasibility considerations. In the second phase, investigators McGuigan [13], Podlesny [14], James [15], Kircher and Raskin [16,17], Honts [18], Giles and Yankee [19] and Timm [20] used a variety of means to collect, quantify and evaluate physiological data collected with laboratory or traditional polygraphs. It was during this phase that Kircher and Raskin [21] produced the first computer assisted polygraph system (CAPS) and, of major significance, developed the first algorithm to be used for diagnostic purposes.

The current phase has provided three American computerized polygraphs that stand alone and need not be interfaced with traditional or laboratory polygraphs. The three systems are: the Axciton [22], the Computerized Polygraph System (CPS) [23], and the Lafayette (LX-2000-101 and 105) [24]. Each system has its own hardware and software to sample physiological data at higher rates than ever before; and, each can be provided with algorithms to evaluate the physiological data for diagnostic purposes. The first two systems use IBM or compatible computers while the latter uses MacIntosh computers.

Computerized polygraphs have several advantages over traditional polygraphs. Traditional polygraphs require more time to learn how to operate and collect good interpretable physiological data; will distort or lose data when pens enter mechanical pen stops; and they require frequent calibration. Computerized polygraphs, on the other hand, are easy to learn how to use; are not subject to pen stop distortions of the data; allow for editing data for easier and more objective visual analysis without altering the original information; provide word processing and data base functions for more efficient test administration processing; and can store data on disks and simultaneously (or later) print out hard copies of the data. The major advantage, however, is that the computerized polygraph can convert the analog physiological signals into digital signals which are necessary for algorithm developments.

All polygraphs used in PDD testing, traditional and computerized, continue, with minor exceptions, to collect cardiovascular, electrodermal and respiratory information with the same sensors and transducers that have been used for over fifty years. However, the CPS and the Lafayette LX-2000-101 and 105 have provided input devices for increasing the number of recordings that can be collected. The Axciton is being modified to do the same. These modifications may allow the collection of physiological data using one or more of the sensors or transducers now under study. These will be discussed later.

Computers and PDD Tests—Data Analysis Developments

The initial steps in computerizing the PDD process have progressed rather slowly over the years. As mentioned earlier, Kircher and Raskin were the first to produce an algorithm that could process and analyze physiological responses to test questions and assess the probability that the questions were answered truthfully. Although developed later, the Axciton and the Lafayette LX-2000-101 and 105 computerized polygraphs have similar capabilities.

The CPS

The data base for the CPS algorithm was collected from 40 subjects, who had participated in a mock theft scenario, to create a standardization sample [16]. Test data were used to develop a discriminate function for electrodermal, cardiovascular and respiration measures. The distribution of discriminate scores were used to derive Bayesian assessments of the probability of truthfulness. Dichotomous computer classification of subjects in the standardization sample were 93% correct, while blind numerical evaluations of the same data by a human interpreter were 89% correct. On cross validation with data from another group of 48 subjects, computer outcomes were 94% correct and human interpretations were 92% correct.

In a similar study, using physiological data collected during tests involving field criminal cases, Raskin et al. [17] reported that decisions made by the original examiners on individual relevant questions ranged from 91 to 95% correct on confirmed truthful answers and 85 to 95% correct on confirmed deceptive answers. The computer interpretations of the data were higher and ranged from 95 to 96% on confirmed truthful subjects and 83 to 96% on confirmed deceptive subjects.

The Kircher and Raskin algorithm is proprietary and functional with the CAPS and the CPS. Its diagnostic capability is limited to "control question" type tests. The CAPS and the CPS have been used by field PDD examiners, particularly the U.S. Secret Service, for over a decade. There are no recent studies regarding the effectiveness of the algorithm, as a diagnostic tool, from laboratories or from field applications.

The Axciton

This was the first totally computerized polygraph, and has been used for laboratory and field applications for several years. Although the Axciton has an algorithm for rank order scoring of physiological data associated with responses to questions, it is rather rudimentary, and cannot be recommended for diagnostic decision making.

In 1993 the Applied Physics Laboratory, Johns Hopkins University, completed an algorithm to score zone comparison control question PDD tests from PDD field test data collected on Axciton computerized polygraphs. The Polygraph Automated Scoring System (PASS), Version 2.1 [25] software was in service for a very brief period and was replaced by Polyscore, Version 2.3. The Polyscore 2.3 software uses a sophisticated mathematical algorithm to analyze the data, then displays a probability to indicate deception, no deception, or inconclusive. Polyscore 3.0 is expected to be out in the fall of 1994.

The Polyscore 2.3 data base was established by using 539 PDD field criminal examinations. Of the 539 PDD examinations, 162 were confirmed cases. The other 377 were included in the data base if the decisions made by the field examiners were agreed upon by two different examiners or if verified by independent means. Of the 162 confirmed cases, 142 were called correctly and 20 were called inconclusive by the original examiners. The algorithm diagnosed 150 of the 162 correctly, identified 11 as inconclusive, and produced one error [26]. Thus, the algorithm reduced the inconclusives by nine and increased the number of correct calls from 142 to 150.

Lafayette LX-2000-101 and 105

This computerized polygraph can perform many of the same functions as the CPS and the Axciton as regards data collection, storage, editing and printing functions. This Lafayette system does not have an algorithm for data analysis but is expected to use Polyscore, Version 2.3, after the algorithm is converted to a MacIntosh compatible language [27].

Computers and PDD Tests—Assessment

Although there are three computer polygraph systems on the market and in field use, there are only two algorithms—the CPS and the Polyscore 2.3. These algorithms are designed to analyze data collected from one type of test—the Control Question Test. Physiological data can be collected for other types of tests by all three computer polygraphs, however, data from those tests must be analyzed by traditional human interpretation. Currently, algorithms for the Modified General Question Test (MGQT) and the Test for Espionage and Sabotage (TES) are being developed by the Applied Physics Laboratory at the Johns Hopkins University.

Since the difference between the accuracy rates for examiners using traditional scoring systems and the algorithms is not statistically significant, most field examiners are using the algorithm as a "back-up" and as a "second opinion." This will probably continue to be the value of the algorithm until more sophisticated systems, capitalizing on broader data bases and including a broader range of test formats, can be developed that will significantly surpass human evaluation capabilities. In addition, when new means for collecting physiological data that are not amenable to human interpretation, such as systolic time intervals, are developed, the algorithm approach will be the only method capable of making a diagnosis.

There is no danger in overestimating the importance of computers in the advancement of PDD testing and procedures. However, all aspects of computerized PDD operations are still in the developmental stages. Consequently, cautious, intelligent scrutiny, and careful evaluation of new advances must be a constant guide in determining the degree of reliance one can place on these systems.

The Electroencephalography (EEG) and PDD Tests

One of the new approaches to PDD testing involves the use of Event Related Brain Potentials (ERP) recorded with an electroencephalograph (EEG) polygraph. The application of ERP to lie detection is novel in two ways: (1) recorded cortical activity is the sole physiological indicator; and (2) the electroencephalographic signal examined is hypothesized to represent the cognitive (versus emotional) process of recognition [28]. The wave form used to identify a reaction to an "oddball" stimulus among other stimuli (for example, a particular gun used in a crime among other guns), is the P-300 wave, a positive inflection in the EEG signal that occurs 300 or so milliseconds after the stimulus is presented.

Laboratory studies report accuracy rates for identifying guilty knowledge or concealed information in a range from 87% to 100%. Rosenfeld et al. [28] used a GKT paradigm and correctly identified nine of ten subjects (90%). In another study Rosenfeld et al. [29] used a modified CQT and reported 89% accuracy. Farwell et al. [30] used a GKT paradigm with 40 subjects and reported five as inconclusive and 35 decisions as accurate. Johnson et al. [31] using a pre-employment type test paradigm of 31 subjects reported an accuracy rate of 87%.

One field study [32] using the ERP procedure in conjunction with a traditional polygraph and a GKT test format reported a 44% overall accuracy rate with the ERP as compared to 100% accuracy with the traditional polygraph.

There are two serious limitations to this approach to lie detection: (1) there are a limited number of forensic investigation cases where ERP tests using a GKT format could be used [33], consequently the value of forensic PDD tests in resolving cases would be diminished as compared to the robust utility of CQT's and (2) the results of the one field study was not very promising as compared to the higher accuracy rates obtained in the laboratory studies. It should be noted, nonetheless, that the use of ERPs to detect deception is relatively new and may become more practical and useful as different test formats are studied.

New Physiological Equipment—Sensors and Transducers

One of the three dependent measures in PDD testing is the cardiovascular response recorded from a blood pressure cuff placed on the arm. The cuff, when properly attached and inflated, will partially occlude the blood flow in the brachial artery, and retard the return of veinal blood. After a few minutes, this will become uncomfortable for some individuals and painful for others. Research is currently underway to test noninvasive sensors and transducers to replace the blood pressure cuff, eliminate discomfort, and provide cardiovascular data that is easier to quantify. Instruments and techniques being investigated include the Finapres, the Cortronic, the Impedance Cardiograph, one type of Systolic Time Interval (STI), Pulse Wave Velocity (PWV), Thumb Cuff, Plethysmograph, and the Cardio Activity Monitor (CAM).

The Finapres is a transducer that is applied to a finger and responds to changes in blood volume in the arterioles and capillaries. As these changes are monitored and processed through an algorithm, the information serves as the basis for inferring systolic pressure, diastolic pressure, and heart rate [34]. The Finapres can be used to monitor cardiovascular activity, for hours or days, without discomfort to the individual.

The Cortronic transducer, unlike the Finapres, uses a standard, occlusive blood pressure cuff technique. The traditional cuff requires more pressure than the Cortronic. Like the Finapres, the Cortronic device uses less pressure and can be applied for longer periods of time than the traditional blood pressure cuff, without discomfort to the individual.

The Impedance Cardiograph (ZCG) provides a noninvasive but relatively uncomfortable means for recording cardiovascular activity. Application of a high frequency (20 to 200 kHz) constant-current electrical signal across the thoracic cavity causes a surface impedance which can be measured between the two electrodes. This will vary as a function of the volume of the contained region

[35]. ZCG can be used to estimate many of the whole body cardiovascular parameters such as heart rate [36].

Systolic Time Intervals (STI) are derived from standard ECG recordings. Systolic and diastolic blood pressure can be evaluated as a series of selected intervals within the cardiac cycle. Because these intervals are precise time measures, quantification is relatively straight forward. There are various STI's but the one currently under investigation is the R Wave Peak Carotid Incisura (RWPCI) [37].

The Pulse Wave Velocity (PWV) is obtained by placing strain gauge transducers at the brachial and radial arteries of the arm and measuring the time it takes for the pressure pulse to pass through the two locations [38]. These time measures will be converted to voltages and plotted as an amplitude wave form which has been shown to be highly correlated with mean arterial pressure [39].

While PDD research has been completed using the plethysmograph, the thumb cuff and the CAM, the results have not been definitive. Further work needs to be done, with these sensors as well as those mentioned earlier, before a decision can be made regarding the most effective way to record cardiovascular activity for PDD purposes.

All of these devices have advantages and disadvantages; however, if the results of any one of these studies clearly demonstrate that a particular device is superior to the others and to the traditional blood pressure cuff, it will undoubtedly be adapted.

Another development in sensors and transducers, unrelated to cardiovascular recordings, is the use of a Shure 570S lavaliere microphone to record oral, 'yes' or 'no' responses to questions asked during a mock PDD examination. The voice responses will be digitized and analyzed using Canadian Speech Research Environment (CSRE) spectrum analysis software, and customized spectrum analysis software written by Dr. Victor Cestaro [40]. This approach to voice spectrum analysis for PDD testing should not be confused with vocal stress analysis systems which examine traces recorded from laryngeal microtremors and thought to be associated with stress, and the stress in turn, with lying [41]. The latter has been a stand-alone method for detecting deception, while the former is far more complex in its analytical approach and is intended to supplement traditional recordings obtained during a PDD examination rather than supplant them.

Algorithms/Statistical Approaches

As reported earlier in this paper, there are only two diagnostic algorithms currently being used in the field: the CPS and the Polyscore, Version 2.3. Both are designed to evaluate physiological data collected during Zone Comparison Control Question tests. Algorithms that are compatible with other types of test formats are needed.

Several research projects using different statistical approaches to improve diagnostic decisions are under way. Angus and Castelaz [42] of Claremont Graduate School investigated the use of artificial neural networks (ANN) to classify physiological data from field PDD examinations as indicating deception or non-deception. They designed and trained an ANN and coupled that with a cellular automaton (CA) feature extractor to classify the data. The CA classifier could classify 87% of the deceptive and 95% of the nondeceptive subjects correctly with no inconclusive results. Coupled with an ANN classifier, the combined algorithm correctly classified 100% of the deceptive and non-deceptive subjects with no inconclusives. The database was small (41 confirmed deceptive and 15 confirmed nondeceptive); therefore, no cross validation was possible. Consequently, caution is needed regarding interpretation of these findings, and cross validation with a larger database is essential. Currently, Angus and Castelaz are evaluating data from a new test procedure that uses event related control questions (ERC). The data is being collected in an analog study [43] involving a mock espionage scenario and 160 subjects. One hundred of the 160 will be used to train an ANN and 60 will be used for cross validation.

Using MGQT data sets from field examinations, Knapp, at San Jose State University, San Jose, California, is applying "fuzzy logic" as a statistical tool to develop a diagnostic algorithm. Fuzzy Logic purports that "... signals can be generally classified into three categories: deterministic, probabilistic and possibilistic (fuzzy events). In the case of biological data, the patterns are probabilistic or possibilistic because they generally contain a large random component ..." Computer scoring of physiological data from PDD tests relies on probabilistic discrimination functions and an arbitrary threshold to classify the data [44]. Using a fuzzy logic algorithm, the investigator analyzed the physiological data from 200 confirmed MGQT field tests of which 150 were guilty and 50 innocent. They divided the guilty cases into three sets of data and combined each set with the 50 innocent. The algorithm was able to accurately diagnose one set at 85%, another set at 88% and the third set at 91%.

Honts [45], at the University of North Dakota, compared the accuracy of conventional human numerical evaluations of PDD data with two statistical approaches to decision making: discrimination analysis and bootstrapping. The results of analyses, using a data base of 100 innocent and 100 guilty subjects from a mock crime, were statistically equivalent (bootstrapping, 78%; human evaluation, 82%; and discriminant analysis, 84%) for the three approaches. Honts reports that, as compared to discriminant analysis, the bootstrap may be more useful since it avoids retroactive, non-theoretical assumptions and is likely to be widely generalizable.

Which of these statistical systems—discriminant analysis; artificial neural networks; fuzzy logic; or bootstrapping,—if any, will eventually provide a flexible, generalizable and highly accurate diagnostic algorithms for a variety of test formats should be determined within the next year or two.

Other work underway is the development of an algorithm to detect mental countermeasures. Countermeasures are deliberate attempts by the examinee to distort or interfere with test procedures by using physical (for example, biting lip); mental (for example, disassociation); and/or pharmacological (for example, drug use) techniques to suppress or augment physiological activity. Preliminary results indicate that countermeasures, or forced responses, can be discriminated from real responses [46]. This work will continue since finding methods for detecting countermeasures is critical to the validity and reliability of PDD tests.

A New Polygraph: Autonomic Response Indicator System (ARIS)

The ARIS is a new concept in polygraph design. The physiological and neural processes to be extracted and recorded will be based on knowledge derived in recent years from academic disciplines within the neurosciences. It is expected that the first phase of instrumentation will be used in PDD studies during 1994. To date, no PDD research has been conducted that incorporates the current knowledge of the homeostatic communication between brain structures and peripheral physiology. ARIS will extract measures of neural control from measures of peripheral physiology based on patented procedures developed by Dr. Stephen Porges [47]. It is his position that the central nervous system (CNS) regulates the peripheral physiology and that neural control regulates homeostatic processes. Thus, he hypothesizes that deception will result in a transient disruption of these homeostatic processes. ARIS will be designed to measure, quantify and detect these disruptions.

Upon completion of the other phases of ARIS, the algorithm will consist of five input systems: ECG, respiration, blood pressure, movement, and electrodermal activity. It will derive more than twenty variables from the five physiological measures.

Summary

The emergence of forensic psychophysiology as an academic discipline and the application of computer technology to PDD testing procedures has essentially ushered out an era that began with Lombroso in the late 1800s [48] and has stimulated an avalanche of change for current and future research.

The current thrust of research is now directed toward the evaluation of new sensors and transducers; new means of digitizing physiological data, while it is being recorded; means of analyzing data on-line; new diagnostic approaches with specifically designed algorithms for various test formats; and algorithms to identify the presence of countermeasure tactics during PDD tests. This research will enhance the scientific evaluation of existing PDD tests and will facilitate the introduction of totally new PDD test types and formats.

The increase in PDD research activity will not only provide new and better PDD tests and diagnostic procedures, but will provide new knowledge that will enhance the evolution of forensic psychophysiology as an academic discipline.

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[3] Department of Defense Polygraph Institute Catalog, 1992–93.
[4] The Advisory Committee is a requirement of DoD Directive 5210.78, dated September 18, 1991, and consists of the Program Managers for PDD Operations within the Department of Defense. Members of this Committee include: Mr. Gale Ahern, Air Force Office of Special Investigations; Mr. Jim Morrison/Mr. Bruce Thomson, Office of the Secretary of the Air Force; Mr. Wilbur Hardy, Army Crime Records Center; Mr. Roger Thurber, Army Intelligence and Security Command; Mr. Timothy Schroeder, Defense Criminal Investigative Service; Mr. Thomas Ewald, Defense Investigative Service; Mr. Jerry Craig, Defense Intelligence Agency; MSgt Earl Jones, Headquarters, U.S. Marine Corps; Mr. Jim Lucas, National Security Agency; Mr. Al Billington, Naval Criminal Investigative Service. Program Managers from the Federal Agencies such as the FBI, Secret Service, etc. are invited and participate in all Advisory Meetings. This Committee's purpose is to advise the DoDPI Director on curriculum and research matters.
[5] Deputy Under Secretary of Defense for Security Policy [DUSD(SP)], Mr. Craig Alderman, was responsible for the DoDPI development from 1986 to 1991.
[6] Deputy Assistant Secretary of Defense for Counterintelligence and Security Countermeasures [DASD(CI&SCM)], Ms. Nina Stewart, was responsible for DoDPI development from 1991 to 1993. Deputy Assistant Secretary of Defense for Intelligence and Security [DASD(I&S)], Mr. Keith Hall is now responsible for DoDPI's operations and fully supports the Institute's direction in research and curriculum development.
[7] The DoDPI Curriculum and Research Guidance committee is represented by: Dr. William Iacono, University of Minnesota; Dr. Edward Katkin, University of New York at Stoneybrook; Dr. Christopher Patrick, Florida State University; Dr. Stephen Porges, University of Maryland; and Dr. John Furedy, University of Toronto. All are reputable psychophysiologists.
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