

Beyond the Polygraph: Deception Detection and the Autonomic Nervous System

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The polygraph and other emerging technologies are used to aid in the interrogation and screening of employees, but examiners and physicians should be aware that results are vulnerable to inaccuracies in subjects with autonomic disorders and may be confounded by multiple medications.

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The US Department of Defense (DoD) and law enforcement agencies around the country utilize polygraph as an aid in security screenings and interrogation. It is assumed that a person being interviewed will have a visceral response when attempting to deceive the interviewer, and that this response can be detected by measuring the change in vital signs between questions. By using vital signs as an indirect measurement of deception-induced stress, the polygraph machine may provide a false positive or negative result if a patient has an inherited or acquired condition that affects the autonomic nervous system (ANS).

A variety of diseases from alcohol use disorder to rheumatoid arthritis can affect the ANS. In addition, a multitude of commonly prescribed drugs can affect the ANS. Although in their infancy, functional magnetic resonance imaging (fMRI) and EEG (electroencephalogram) deception detection techniques circumvent these issues. Dysautonomias may be an underappreciated cause of error in polygraph interpretation. Polygraph examiners and DoD agencies should be aware of the potential for these disorders to interfere with interpretation of results. In the near future, other modalities that do not measure autonomic variables may be utilized to avoid these pitfalls.

POLYGRAPHY

Throughout history, humans have been interested in techniques and devices that can discern lies from the truth. Even in the ancient era, it was known that the act of lying

had physiologic effects. In ancient Israel, if a woman accused of adultery should develop a swollen abdomen after drinking “waters of bitterness,” she was considered guilty of the crime, as described in Numbers 5:11-31. In Ancient China, those accused of fraud would be forced to hold dry rice in their mouths; if the expectorated rice was dry, the suspect was found guilty.¹ We now know that catecholamines, particularly epinephrine, secreted during times of stress, cause relaxation of smooth muscle, leading to reduced bowel motility and dry mouth.²⁻⁴ However, most methods before the modern era were based more on superstition and chance rather than any sound physiologic premise.

When asked to discern the truth from falsehood based on their own perceptions, people correctly discern lies as false merely 47% of the time and truth as nondeceptive about 61% of the time.⁵ In short, unaided, we are very poor lie detectors. Therefore, a great deal of interest in technology that can aid in lie detection has ensued. With enhanced technology and understanding of human physiology came a renewed interest in lie detection. Since it was known that vital signs such as blood pressure (BP), heart rate, and breathing could be affected by the stressful situation brought on by deception, quantifying and measuring those responses in an effort to detect lying became a goal. In 1881, the Italian criminologist Cesare Lombroso invented a glove that when worn by a suspect, measured their BP.⁶⁻⁸ Changes in BP also were the target variable of the systolic BP deception test invented by William M. Marston,

PhD, in 1915.⁸ Marston also experimented with measurements of other variables, such as muscle tension.⁹ In 1921, John Larson invented the first modern polygraph machine.⁷

Procedures

Today's polygraph builds on these techniques. A standard polygraph measures respiration, heart rate, BP, and sudomotor function (sweating). Respiration is measured via strain gauges strapped around the chest and abdomen that respond to chest expansion during inhalation. BP and pulse can be measured through a variety of means, including finger pulse measurement or sphygmomanometer.⁸

Perspiration is measured by skin electrical conductance. Human sweat contains a variety of cations and anions—mostly sodium and chloride, but also potassium, bicarbonate, and lactate. The presence of these electrolytes alter electrical conduction at the skin surface when sweat is released.¹⁰

The exact questioning procedure used to perform a polygraph examination can vary. The Comparison Question Test is most commonly used. In this format, the interview consists of questions that are relevant to the investigation at hand, interspersed with control questions. The examiner compares the changes in vital signs and skin conduction to the baseline measurements generated during the pretest interview and during control questions.⁸ Using these standardized techniques, some studies have shown accuracy rates between 83% and 95% in controlled settings.⁸ However, studies performed outside of the polygraph community have found very high false positive rates, up to 50% or greater.¹¹

The US Supreme Court has ruled that individual jurisdictions can decide whether or not to admit polygraph evidence in court, and the US Court of Appeals for the Eleventh Circuit has ruled that polygraph results are only admissible if both parties agree to it and are given sufficient notice.^{12,13} Currently, New Mexico is the only state that allows polygraph results to be used as evidence without a pretrial agreement; all other states either require such an agreement or forbid the results to be used as evidence.¹⁴

Although rarely used in federal and state courts as evidence, polygraphy is commonly used during investigations and in the hiring

TABLE 1 Physiologic Measurements Taken by Polygraph

| Physiologic Measures | Related Regulatory Autonomic Components | Effector Neurotransmitters | Conditions Possibly Affecting Results |
|--|---|--|---|
| Blood pressure | Sympathetic noradrenergic system, sympathetic adrenergic system | Norepinephrine, epinephrine | Essential hypertension, heart failure, diabetes mellitus |
| Heart rate | Parasympathetic nervous system, sympathetic noradrenergic system, sympathetic adrenergic system | Acetylcholine, norepinephrine, epinephrine | Heart failure, athletic conditioning, diabetes mellitus, anxiety disorders |
| Perspiration (skin electrical conductance) | Sympathetic cholinergic system | Acetylcholine | Autonomic neuropathies, α synucleopathies (eg, dementia with Lewy bodies, multiple system atrophy) |
| Respiration | Medullary respiratory control center | Acetylcholine | Pulmonary conditions, neuromuscular weakness, neurodegenerative diseases |

process of government agencies. DoD Directive 5210.48 and Instruction 5210.91 enable DoD investigative organizations (eg, Naval Criminal Investigative Service, National Security Agency, US Army Investigational Command) to use polygraph as an aid during investigations into suspected involvement with foreign intelligence, terrorism against the US, mishandling of classified documents, and other serious violations.¹⁵

The Role of the Physician in Polygraph Assessment

It may be rare that the physician is called upon to provide information regarding an individual's medical condition or related medication use and the effect of these on polygraph results. In such cases, however, the physician must remember the primary fiduciary duty to the patient. Disclosure of medical conditions cannot be made without the patient's consent, save in very specific situations (eg, Commanding Officer Inquiry, Tarasoff Duty to Protect, etc). It is the polygraph examiner's responsibility to be aware of potential confounders in a particular examination.¹⁰

Physicians can have a responsibility when in administrative or supervisory positions, to advise security and other officials

TABLE 2 Medications That Affect the ANS

| Medications | Common Examples | Effect on ANS | Physiologic Effect(s) |
|------------------------------|---------------------------------------|---|---|
| β blockers | Propranolol Atenolol Metoprolol | Blocks β -1 and/or β -2 noradrenergic receptors | Reduced heart rate, reduced blood pressure |
| α -1 blockers | Tamsulosin Prazosin | Blocks α -1 and/or α -2 noradrenergic receptors | Reduced blood pressure, may increase heart rate |
| Tricyclic antidepressants | Amitriptyline Nortriptyline | Block acetylcholine receptors | Reduced sweating, increased heart rate |
| Antihistamines | Diphenhydramine | Block acetylcholine receptors | Reduced sweating, increased heart rate |
| Carbonic anhydrase inhibitor | Acetazolamide | Inhibition of carbonic anhydrase | Reduced sweat response |
| α -2 agonists | Clonidine Guanfacine | Binds to and activates α -2 receptors | Reduced blood pressure, may increase heart rate |

Abbreviation: ANS, autonomic nervous system.

regarding the fitness for certain duties of candidates with whom there is no physician-patient relationship. This may include an individual's ability to undergo polygraph examination and the validity of such results. However, when a physician-patient relationship is involved, care must be given to ensure that the patient understands that the relationship is protected both by professional standards and by law and that no information will be shared without the patient's authorization (aside from those rare exceptions provided by law). Often, a straightforward explanation to the patient of the medical condition and any medication's potential effects on polygraph results will be sufficient, allowing the patient to report as much as is deemed necessary to the polygraph examiner.

Polygraphy Pitfalls

Polygraphy presupposes that the subject will have a consistent and measurable physiologic response when he or she attempts to deceive the interviewer. The changes in BP, heart rate, respirations, and perspiration that are detected by polygraphy and interpreted by the examiner are controlled by the ANS (Table 1). There are a variety of diseases that are known to cause autonomic dysfunction (dysautonomia). Small fiber autonomic

neuropathies often result in loss of sweating and altered heart rate and BP variation and can arise from many underlying conditions. Synucleinopathies, such as Parkinson disease, alter cardiovascular reflexes.^{14,16}

Even diseases not commonly recognized as having a predominant clinical impact on ANS function can demonstrate measurable physiologic effect. For example, approximately 60% of patients with rheumatoid arthritis will have blunted cardiovascular baroreceptor responses and heart rate variability.¹⁷ ANS dysfunction is also a common sequela of alcoholism.¹⁸ Patients with diabetes mellitus often have an elevated resting heart rate and low heart rate variability due to dysregulated β -adrenergic activity.¹⁹ The impact of reduced baroreceptor response and reduced heart rate variability could impact the polygraph interpreter's ability to discern responses using heart rate. Individuals with ANS dysfunction that causes blunted physiologic responses could have inconclusive or potentially worse false-negative polygraph results due to lack of variation between control and target questions.

To our knowledge, no study has been performed on the validity of polygraphy in patients with any form of dysautonomia. Additionally, a 2011 process and compliance study of the DoD polygraph program specifically recommended that "adjudicators would benefit from training in polygraph capabilities and limitations."²⁰ Although specific requirements vary from program to program, all programs accredited by the American Polygraph Association provide training in physiology, psychology, and standardization of test results.

Many commonly prescribed medications have effects on the ANS that could affect the results of a polygraph exam (Table 2). For example, β blockers reduce β adrenergic receptor activation in cardiac muscle and blood vessels, reducing heart rate, heart rate variability, cardiac contractility, and BP.²¹ This class of medication is prescribed for a variety of conditions, including congestive heart failure, hypertension, panic disorder, and posttraumatic stress disorder. Thus, a patient taking β blockers will have a blunted physiologic response to stress and have an increased likelihood of an inconclusive or false-negative polygraph exam.

Some over-the-counter medications also have effects on autonomic function. Sympathomimetics such as pseudoephedrine or antihistamines with anticholinergic activity like diphenhydramine can both increase heart rate and BP.^{22,23} Of the 10 most prescribed medications of 2016, 5 have direct effects on the ANS or the variables measured by the polygraph machine.²⁴ An exhaustive list of medication effects on autonomic function is beyond the scope of this article.

A medication that may affect the results of a polygraph study that is of special interest to the DoD and military is mefloquine. Mefloquine is an antimalarial drug that has been used by military personnel deployed to malaria endemic regions.²⁵ In murine models, mefloquine has been shown to disrupt autonomic and respiratory control in the central nervous system.²⁶ The neuropsychiatric adverse effects of mefloquine are well documented and can last for years after exposure to the drug.²⁷ Therefore, mefloquine could affect the results of a polygraph test through both direct toxic effects on the ANS as well as causing anxiety and depression, potentially affecting the subject's response to questioning.

ALTERNATIVE MODALITIES

Given the pitfalls inherent with external physiologic measures for lie detection, additional modalities that bypass measurement of ANS-governed responses have been sought. Indeed, the integration and combination of more comprehensive modalities has come to be named the forensic credibility assessment.

Functional MRI

Beginning in 1991, researchers began using fMRI to see real-time perfusion changes in areas of the cerebral cortex between times of rest and mental stimulation.²⁶ This modality provides a noninvasive technique for viewing which specific parts of the brain are stimulated during activity. When someone is engaged in active deception, the dorsolateral prefrontal cortex has greater perfusion than when the patient is engaged in truth telling.²⁸ Since fMRI involves imaging for evaluation of the central nervous system, it avoids the potential inaccuracies that can be seen in some subjects with autonomic irregularities. In fact, fMRI may have superior sensitivity and

specificity for lie detection compared with that of conventional polygraphy.²⁹

Significant limitations to the use of fMRI include the necessity of expensive specialized equipment and trained personnel to operate the MRI. Agencies that use polygraph examinations may be unwilling to make such an investment. Further, subjects with metallic foreign bodies or noncompatible medical implants cannot undergo the MRI procedure. Finally, there have been bioethical and legal concerns raised that measuring brain activity during interrogation may endanger "cognitive freedom" and may even be considered unreasonable search and seizure under the Fourth Amendment to the US Constitution.³⁰ However, fMRI—like polygraphy—can only measure the difference between brain perfusion in 2 states. The idea of fMRI as "mind reading" is largely a misconception.³¹

Electroencephalography

Various EEG modalities have received increased interest for lie detection. In EEG, electrodes are used to measure the summation of a multitude of postsynaptic action potentials and the local voltage gradient they produce when cortical pyramidal neurons are fired in synchrony.³² These voltage gradients are detectable at the scalp surface. Shortly after the invention of EEG, it was observed that specific stimuli generated unique and predictable changes in EEG morphology. These event-related potentials (ERP) are detectable by scalp EEG shortly after the stimulus is given.³³

ERPs can be elicited by a multitude of sensory stimuli, have a predictable and reproducible morphology, and are believed to be a psychophysiologic correlate of mental processing of stimuli.³⁴ The P300 is an ERP characterized by a positive change in voltage occurring 300 milliseconds after a stimulus. It is associated with stimulus processing and categorization.³⁵ Since deception is a complex cognitive process involving recognizing pertinent stimuli and inventing false responses to them, it was theorized that the detection of a P300 ERP during a patient interview would mean the patient truly recognizes the stimulus and is denying such knowledge. Early studies performed on P300 had variable accuracy for lie

detection, roughly 40% to 80%, depending on the study. Thus, the rate of false negatives would increase if the subjects were coached on countermeasures, such as increasing the significance of distractor data or counting backward by 7s.^{36,37} Later studies have found ways of minimizing these issues, such as detection of a P900 ERP (a cortical potential at 900 milliseconds) that can be seen when subjects are attempting countermeasures.³⁸

Another technique for increasing accuracy in EEG-mediated lie detection is measurement of multifaceted electroencephalographic response (MER), which involves a more detailed analysis of multiple EEG electrode sites and how the signaling changes over time using both visual comparison of multiple trials as well as bootstrap analysis.³⁷ In particular, memory- and encoding-related multifaceted electroencephalographic response (MERMER) using P300 coupled with an electrically negative impulse recorded at the frontal lobe and phasic changes in the global EEG had superior accuracy than P300 alone.³⁷

The benefits of EEG compared with that of fMRI include large reductions in cost, space, and restrictions for use in some individuals (EEG is safe for virtually all patients, including those with metallic foreign bodies). However, like fMRI, EEG still requires trained personnel to operate and interpret. Also, it has yet to be tested outside of the laboratory.

CONCLUSION

The ability to detect deception is an important factor in determining security risk and adjudication of legal proceedings, but untrained persons are surprisingly poor at discerning truth from lies. The polygraph has been used by law enforcement and government agencies for decades to aid in interrogation and the screening of employees for security clearances and other types of access. However, results are vulnerable to inaccuracies in subjects with autonomic disorders and may be confounded by multiple medications. While emerging technologies such as fMRI and EEG may allow superior accuracy by bypassing ANS-based physiologic outputs, the polygraph examiner and the physician must be aware of the effect of autonomic dysfunction and of the medications that affect the

ANS. This is particularly true within military medicine, as many patients within this population are subject to polygraph examination.

Author disclosures

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Disclaimer

The opinions expressed herein are those of the authors and do not necessarily reflect those of *Federal Practitioner*, Frontline Medical Communications Inc., the US Government, or any of its agencies.

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