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**FIELD EVALUATION OF EFFECTIVENESS OF VSA (VOICE STRESS ANALYSIS)  
TECHNOLOGY IN A US CRIMINAL JUSTICE SETTING**

This research paper represents 18-years of data evaluating the use of the VSA technology for the detection of stress associated with possible deception. Using a combinatorial approach of VSA and a standardized questioning process, an expert obtained the results of stress detection associated with criminal activities, which are proven in 95% of cases. On the other hand, there were no cases when a confession was obtained in the absence of stress. In particular, the most considerable stress levels were detected during the investigation of murder cases, grand larceny and sexual crimes. When the VSA technology was used for diagnostic purposes to predict deception, positive results were obtained in approximately 95% of the cases. Additionally, a strong, indirect relationship (approximately 94%) was discerned between jeopardy (crime consequences) and confession rates among guilty suspects.

The implications of the findings for the suitability of VSA as a deception detection tool in the field are discussed.

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**1. Introduction**

This retrospective analysis assesses 18-years of actual criminal cases, all of which involved Voice Stress Analysis (VSA) examinations conducted by an experienced criminologist. The purpose of this analysis is to evaluate the efficacy and accuracy of VSA technology as a decision support tool

for the detection of stress associated with deception during criminal investigations.

It is known that the encoding of physical stress in the human voice is highly influenced by an increase in respiration, which heightens the sub-glottal pressure during phonation. The distance of speech between breaths is diminished, while the articulation rate is affected. Stress changes the larynx muscle activity and vocal folds, which subsequently modifies the air velocity through glottis and sound frequency (i.e., as vocal folds increase in tension, the frequency increases). Stress also affects the activity of other muscles like tongue, jaw and lips, which shape the resonant cavities and alter speech production [7].

Olaf Lippold's mid-20th century discovery of the 8-12 Hz range physiological tremor in human muscles led to additional research concerning the relationship between psychological stress and the human voice, for the purpose of developing a technology capable of accurately detecting vocal stress levels [6], [12].

The first commercially available VSA system was developed through experimentation by Allan D. Bell, Jr., who discerned which voice characteristics were most likely to show stressed responses. Bell's early studies focused on Frequency-Modulated infrasonic modulations ( $< 20\text{Hz}$ ), which are below the level of human audibility. According to Bell, the unstressed muscle allows a greater variation in the Frequency-Modulated intonation, which becomes flatter as stress increases. This flattening effect could be graphically displayed as VSA output. In fact, VSA output charts show that the normal unstressed voice started with a gradual buildup from initial low energy to full force. Conversely, the stressed utterance usually started with an initial burst of energy and diminished without displaying the Frequency Modulation that characterizes the unstressed pattern. Thus, the stressed utterance resulted in a much flatter line in the graphic output. Based on his findings, Bell produced a VSA device that could detect, measure, and graph the infrasonic wave forms produced by the human voice [1 - 2].

In theory and practice, VSA is designed to identify the phases in speech where the voice displays discernible signs of being under constraining influence. Once the affected utterances are isolated, trained VSA examiners investigate the source for such stress, and question the subject (i.e. the speaker) with a goal of establishing the truth concerning a specific matter. Thus, VSA is categorized as a truth verification technology.

VSA examinations are conducted using established questioning protocols to determine the stress or lack thereof in the human voice. Stress, or the lack thereof, can be identified by a trained VSA examiner to assist in determining truthfulness or deception of the examinee's responses to direct questions. This is accomplished by analyzing and quantifying the characteristic shapes of the voice graphs (e.g., amplitude, cyclic changes, leading edge slopes, and square waveform shapes or blocking) produced by the examinee.

Critics of VSA have debated this technology's accuracy and dependence upon output in coding data is reflective of the algorithms used and the effectiveness of the examiners. Some researchers have claimed that vocal changes cannot be detected as a result of stress, while others have asserted that VSA and its competitors are insensitive to stress and deception, both in the laboratory and field [8].

Advocates of VSA understand its limitations, but they also recognize its promise, as the technology has improved considerably over time. VSA mathematical models are continually being developed and optimized. For instance, Adaptive Empirical Mode Decomposition (AEMD) differentiates between low to medium stress levels in the human voice by decomposing nonlinear, non-stationary signals into the sum of a series of stationary signals, which allows specific fluctuations in frequency and amplitude to be detected in real-time [18].

Additionally, proponents state that even with the use of well-established "staple" algorithms (e.g., Fast Fourier Transform; the McQuiston-Ford Algorithm) VSA is an effective technology for the investigation and detection of human stress associated with deception [9]. As a result of the McQuiston-Ford Algorithm used in several modern VSA systems, the recorded changes of the human voice can be converted into easy-to-interpret voice patterns (i.e., graphical displays), which can be

analyzed and quantified by trained VSA examiners. Further, today, such analyses can be accomplished automatically, by allocating percentages of stress for each voice pattern using standardized scoring processes [16 -17].

Gaining valid and verifiable information has long been a challenge for criminal investigators striving to separate the guilty from the innocent. Many stress-detection technologies have proven to be cumbersome and time-consuming, culminating in questionable results [14]. On the other hand, technology-free investigative interviews and interrogations conducted by police have generally not attained confession rates exceeding 50% [11]. To date, researchers have overlooked a valuable benefit of VSA technology: in the hands of skilled professionals, VSA processes can support investigative assessments, which dramatically increase the rate of valid and legally acceptable confessions and admissions from suspects and other persons of interest to the criminal justice system.

The goal of this retrospective study was neither to disprove nor discredit older stress and deception detection technologies currently in use. Rather, analyses of the cases, conducted over an 18-year period, aimed to test the hypotheses relevant only to this particular technology: during criminal justice investigations, VSA can serve as a reliable decision support tool to help discriminate between deception and no deception; stress and confession rates are interdependent; and the level of jeopardy associated with specific crimes can affect the confession rates obtained from guilty individuals under investigation.

## **2. Method**

### **2.1 Case and Subject Representation**

The original group of total case subjects ( $n > 3,000$ ) tested over an 18-year period was culled for those that could be retrospectively studied, such that they met the following requirements: a confession had been a potential outcome (i.e., a crime had been committed in which the individual was implicated); there was no involvement with non-criminal statement veracity testing; no employment

clearance was involved; the case was not used as confirmation of witness testimony; and controlled testing had occurred (i.e., responses could be verified by the VSA process by means of structured re-questioning).

Following the excluded group, the cases that remained were (n=2,109). After these cases were numbered in consecutive order, the numbers were separated and pooled. The concealed, individual numbers were then randomly selected in single-blind fashion, before being disclosed to the primary researcher for analysis and review. From this final set of cases (n=236), there were (n=329) possible confession outcomes. Not included in the confession rate were those confessions in which suspects admitted their guilt to a wrongdoing other than the crime(s) specifically addressed during the examination.

The subjects (n=279) within this study ranged in age, from 5 to 74, 84% (n=234) were male, and 16% (n=45) were female. Their representation included criminals, defendants, suspects, persons of interest, and court-ordered mandates (e.g., child protective situations), in total n=259, and alleged victims n=20. Within the former group, organized/contract criminals were also included (n=6). A wide spectrum of people was examined from those with no criminal history, to those with previous arrest and/or conviction records, as well as professional criminals; wealthy individuals; well-educated professionals; public officials; indigents; and those found to be below normal intelligence. The number of crimes represented per case ranged from (n=1-3).

Among the different crime types (n=29) in this study: murder 18.2% (n=60), rape 15.8% (n=52), grand larceny 14.9% (n=49), burglary 9.1% (n=30), sexual abuse 8.8% (n=29), larceny 4.6% (n=15), arson 5.8% (n=19), assault 4.9% (n=16), and robbery 3.3% (n=11) were the crimes mostly heavily represented. The crimes that were moderately represented included sodomy 1.5% (n=5), child abuse 1.5% (n=5), armed robbery 1.5% (n=5), misconduct 1.2% (n=4), criminal mischief 0.9% (n=3), weapons violations 0.9% (n=3), narcotics 0.9% (n=3), fraud 0.9% (n=3), indecent assault 0.9% (n=3),

bomb threats 0.6% (n=2), sexual contact 0.6% (n=2), and kidnapping 0.6% (n=2). The crimes that were of low representation (n=1) included manslaughter, coercion, attempted murder, attempted rape, missing person, felony DWI, buying testimony, and perjury.

## 2.2 Interview Formatting and Modus Operandi

Ninety-one percent (91%) of the cases under study represented criminal investigations in which authorities had reached an impasse. In each case, the procedure used by the VSA examiner consisted of the following steps: receiving a briefing from the requesting agency, interview of the subject, questioning, re-questioning, final evaluation by VSA, and post-examination interview if required.

Each subject within the Confession Possibility List had been individually interviewed by the VSA examiner, who had two goals in mind: to exonerate the innocent/identify the guilty and to obtain legally valid and independently verifiable confessions from those individuals who were unable to clear the VSA process. Each interview had been conducted according to a standard protocol in which the wording of the interview, but not the method, was adapted on-site to each specific case. This procedure consisted of six steps, which are outlined in Table 1.

If a confession was made by the subject, the examiner asked the subject to further support his/her confession by verifying specific details of the events under investigation or by providing additional details concerning the events under investigation. False confessions are by no means unknown in law enforcement and legal circles, and it was imperative that the confessions be independently verified and validated [5]. This was accomplished by asking the subject to confirm evidence which had not been made public, and to provide a narration of the event. Any newly obtained information or case specific facts provided during a confession would be checked closely against all available evidence. Additionally, if a confession occurred, a written statement was also taken from the subject. A subsequent VSA examination was then conducted to validate the veracity of the written statement. At the conclusion of the VSA examination process, all findings and work product were turned over to the requesting agency for their use as appropriate.

**Table1: Six Steps of the Standard Procedure used for Interviews**

Step	Process
1.	VSA examiner briefed by requesting authority
2.	Pretest interview with subject conducted (audio recorder used)
3.	Initial VSA questions asked (9-31 questions, yes/no answers)
4.	Processing of answers with VSA and discernment of stress patterns
5.	Retest, as required, using reformulated questions for those issues where stress was observed until no stress was observed or stress could not be eliminated
6.	Outcome (A): "No Stress Indicated" Conclusion = cleared subject
	Outcome (B): "Stress Indicated" Conclusion = post-exam interview of subject to determine reason for stress

**NOTE: The only variability was the wording which was adapted to each case**

### 2.3 Vocal Stress Detection System

The two commercially available VSA systems used for the cases under study employed proprietary versions of the McQuiston-Ford VSA Algorithm, which had been found to be accurate in previous research [13], [16]. These systems detect involuntary and inaudible frequency modulations in the 8-14 Hz range. By use of proprietary signal filtering and discrimination techniques, the systems display the results as VSA graphs.

## 3. Results

### 3.1 Overall Stress and Confession Rates

Each crime category was analyzed for its indicated rates of stress/no stress and confession/no confession. In each of the cases reviewed here (n=236), inclusive of (n=329) confession possibilities, stress was indicated in 92% of the examinations (n=303), leaving 8% of the exams with a no-stress result (n=26). Confessions were obtained from 89% of the interviewees (n=292), leaving an overall 11% no-confession rate (n=37). Most notably, among all interviews conducted, where stress was indicated, 96.4% resulted in suspects making self-incriminating confessions (Table 2).

**Table 2: Breakdown of 329 Interview Rates of Stress and Confession**

	Stress Indicated			No Stress Indicated			Confession			No Confession		
	n	Category (%)	Total (%)	n	Category (%)	Total (%)	n	Category (%)	Total (%)	n	Category (%)	Total (%)
<b>Murder</b>	<b>56</b>	93.3	17.0	<b>4</b>	6.7	1.2	<b>48</b>	80.0	14.6	<b>12</b>	20.0	3.6
<b>Rape</b>	<b>52</b>	100.0	15.8	<b>0</b>	0.0	0.0	<b>51</b>	98.1	15.5	<b>1</b>	1.9	0.3
<b>Grand Larceny</b>	<b>30</b>	61.2	9.1	<b>19</b>	38.8	5.8	<b>30</b>	61.2	9.1	<b>19</b>	38.8	5.8
<b>Burglary</b>	<b>30</b>	100.0	9.1	<b>0</b>	0.0	0.0	<b>30</b>	100.0	9.1	<b>0</b>	0.0	0.0
<b>Sexual Abuse</b>	<b>28</b>	96.6	8.5	<b>1</b>	3.4	0.3	<b>28</b>	96.6	8.5	<b>1</b>	3.4	0.3
<b>Larceny</b>	<b>15</b>	100.0	4.6	<b>0</b>	0.0	0.0	<b>15</b>	100.0	4.6	<b>0</b>	0.0	0.0
<b>Arson</b>	<b>19</b>	100.0	5.8	<b>0</b>	0.0	0.0	<b>18</b>	94.7	5.5	<b>1</b>	5.3	0.3
<b>Assault</b>	<b>16</b>	100.0	4.9	<b>0</b>	0.0	0.0	<b>16</b>	100.0	4.9	<b>0</b>	0.0	0.0
<b>Robbery</b>	<b>10</b>	90.9	3.0	<b>1</b>	0.3	0.3	<b>10</b>	90.9	3.0	<b>1</b>	9.1	0.3
<b>Sodomy</b>	<b>5</b>	100.0	1.5	<b>0</b>	0.0	0.0	<b>5</b>	100.0	1.5	<b>0</b>	0.0	0.0
<b>Child Abuse</b>	<b>5</b>	100.0	1.5	<b>0</b>	0.0	0.0	<b>5</b>	100.0	1.5	<b>0</b>	0.0	0.0
<b>Armed Robbery</b>	<b>5</b>	100.0	1.5	<b>0</b>	0.0	0.0	<b>5</b>	100.0	1.5	<b>0</b>	0.0	0.0
<b>Misconduct</b>	<b>4</b>	100.0	1.2	<b>0</b>	0.0	0.0	<b>4</b>	100.0	1.2	<b>0</b>	0.0	0.0
<b>Criminal Mischief</b>	<b>3</b>	100.0	0.9	<b>0</b>	0.0	0.0	<b>3</b>	100.0	0.9	<b>0</b>	0.0	0.0
<b>Weapons</b>	<b>3</b>	100.0	0.9	<b>0</b>	0.0	0.0	<b>3</b>	100.0	0.9	<b>0</b>	0.0	0.0
<b>Narcotics</b>	<b>3</b>	100.0	0.9	<b>0</b>	0.0	0.0	<b>3</b>	100.0	0.9	<b>0</b>	0.0	0.0
<b>Fraud</b>	<b>3</b>	100.0	0.9	<b>0</b>	0.0	0.0	<b>3</b>	100.0	0.9	<b>0</b>	0.0	0.0



<b>Indecent Assault</b>	<b>3</b>	<b>100.0</b>	<b>0.9</b>	<b>0</b>	<b>0.0</b>	<b>0.0</b>	<b>3</b>	<b>100.0</b>	<b>0.9</b>	<b>0</b>	<b>0.0</b>	<b>0.0</b>
<b>Bomb Threats</b>	<b>2</b>	<b>100.0</b>	<b>0.6</b>	<b>0</b>	<b>0.0</b>	<b>0.0</b>	<b>2</b>	<b>100.0</b>	<b>0.6</b>	<b>0</b>	<b>0.0</b>	<b>0.0</b>
<b>Sexual Contact</b>	<b>2</b>	<b>100.0</b>	<b>0.6</b>	<b>0</b>	<b>0.0</b>	<b>0.0</b>	<b>2</b>	<b>100.0</b>	<b>0.6</b>	<b>0</b>	<b>0.0</b>	<b>0.0</b>
<b>Kidnapping</b>	<b>2</b>	<b>100.0</b>	<b>0.6</b>	<b>0</b>	<b>0.0</b>	<b>0.0</b>	<b>1</b>	<b>50.0</b>	<b>0.3</b>	<b>1</b>	<b>50.0</b>	<b>0.3</b>
<b>Manslaughter</b>	<b>1</b>	<b>100.0</b>	<b>0.3</b>	<b>0</b>	<b>0.0</b>	<b>0.0</b>	<b>1</b>	<b>100.0</b>	<b>0.3</b>	<b>0</b>	<b>0.0</b>	<b>0.0</b>
<b>Coercion</b>	<b>1</b>	<b>100.0</b>	<b>0.3</b>	<b>0</b>	<b>0.0</b>	<b>0.0</b>	<b>1</b>	<b>100.0</b>	<b>0.3</b>	<b>0</b>	<b>0.0</b>	<b>0.0</b>
<b>Attempted murder</b>	<b>1</b>	<b>100.0</b>	<b>0.3</b>	<b>0</b>	<b>0.0</b>	<b>0.0</b>	<b>1</b>	<b>100.0</b>	<b>0.3</b>	<b>0</b>	<b>0.0</b>	<b>0.0</b>
<b>Attempted Rape</b>	<b>1</b>	<b>100.0</b>	<b>0.3</b>	<b>0</b>	<b>0.0</b>	<b>0.0</b>	<b>1</b>	<b>100.0</b>	<b>0.3</b>	<b>0</b>	<b>0.0</b>	<b>0.0</b>
<b>Missing Person</b>	<b>0</b>	<b>0.0</b>	<b>0.0</b>	<b>1</b>	<b>0.3</b>	<b>0.3</b>	<b>0</b>	<b>0.0</b>	<b>0.0</b>	<b>1</b>	<b>100.0</b>	<b>0.3</b>
<b>Felony DWI</b>	<b>1</b>	<b>100.0</b>	<b>0.3</b>	<b>0</b>	<b>0.0</b>	<b>0.0</b>	<b>1</b>	<b>100.0</b>	<b>0.3</b>	<b>0</b>	<b>0.0</b>	<b>0.0</b>
<b>Buying Testimony</b>	<b>1</b>	<b>100.0</b>	<b>0.3</b>	<b>0</b>	<b>0.0</b>	<b>0.0</b>	<b>1</b>	<b>100.0</b>	<b>0.3</b>	<b>0</b>	<b>0.0</b>	<b>0.0</b>
<b>Perjury</b>	<b>1</b>	<b>100.0</b>	<b>0.3</b>	<b>0</b>	<b>0.0</b>	<b>0.0</b>	<b>1</b>	<b>100.0</b>	<b>0.3</b>	<b>0</b>	<b>0.0</b>	<b>0.0</b>
<b>TOTAL</b>	<b>303</b>			<b>26</b>			<b>292</b>			<b>37</b>		
<b>% of total</b>	<b>92</b>			<b>8</b>			<b>88.8</b>			<b>11</b>		

**NOTE: Confessions Obtained when Stress Indicated = 292/303 = 96.4%**

### 3.2 The Link between Stress and Confession in Crime Categories

To determine the one-tailed probabilities of this study's hypo-geometric distributions between stress/no stress and confession/no confession rates, the Fisher's Exact Test was carried out within each crime category and among pooled data. The analysis revealed significant deviations from the null hypothesis in the crime categories of murder ( $p=0.001$ , FET), grand larceny ( $p=0.0001$ , FET), sexual abuse ( $p=0.0345$ , FET), and for pooled data in other crime categories ( $p=0.0001$ , FET).

Within the crime category of grand larceny, one particular case involved  $n=20$  suspects. Of the latter,  $n=19$  were cleared by VSA testing (i.e., no stress indicated), whereas  $n=1$  resulted in a stress indicated determination. A confession was obtained from the one subject who displayed stress. The Binomial Probability of having 20 successful evaluations in this case alone was found to be:  $b(x; n, P) = 9.537e^{-7}$  (20; 20, 0.5), with the mean of the distribution  $\mu_x=10$ , the variance  $\sigma_x^2=5$  and the standard deviation  $\sigma_x=2.236$ .

Therefore, among the categories of murder, grand larceny, and sexual abuse, and for the study as a whole, the results revealed the probability was significantly superior to chance, and the variables were interdependent.

### 3.3 Accuracy and Efficacy of the VSA Test in the Field

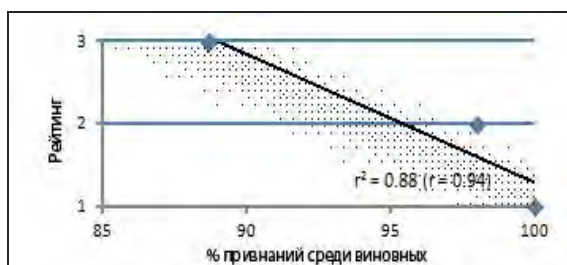
As a decision support tool, based on the data extracted ( $n=329$ ) from this field study, the accuracy and efficacy of the VSA were evaluated. Calculations were based on: Prior Odds (11.048), Likelihood Ratio (27.027), Posterior Odds (298.6), and Posterior Probability (0.9967). The results revealed that a population was tested where 91.7% ( $n=302$ ) of the participants were deceptive. Of those tested who were deceptive, 100% had a positive result. When a positive result was obtained, there was a  $PPV = 99.67\%$  chance that the participant was deceptive, leaving a 0.33% chance of a false positive result. When a negative result was obtained, there was a  $NPV = 100\%$  chance that the participant was not deceptive, leaving no chance of a false negative result.

### 3.4 Correlating Confessions of the Guilty With Consequences of Crime

Confessions among the guilty were grouped in one of three categories, according to the severity of typical sentencing for the crime committed (Table 3). The number of guilty found for each crime was pooled according to rating category, such that the total for each category was as follows: n=53 (Rating 3), n=62 (Rating 2) and n=64 (Rating 1). The number of confessions that ensued in each crime category was also pooled, such that the number (and % among guilty) in each category was as follows: n=47 (88.68%) in Rating 3, n= 61 (98.4%) in Rating 2, and n=64 (100%) in Rating 1. When correlating crime consequence ratings with percent of confessions among the guilty, the Pearson’s Coefficient was found to be  $r = -0.94$  ( $r^2 = 0.88$ ), indicating a very strong, indirect relationship (Table 3). Only categories were considered and analyzed where the sourcing guidelines were well-

**Table 3: Confessions of Guilty Correlated with Crime Consequences**

Typical Sentence	Severity	Rating	Guilty “n”	Confession “n” (%)	Crime Types
20 years to life	high	3	53	47 (88.68%)	murder
5-20 years	medium	2	62	61 (98.4%)	kidnapping, sex abuse, arson, manslaughter, weapon, robbery
< 5 years	low	1	64	64 (100.0%)	burglary, assault, fraud, larceny



*NOTE:* All categories in this particular analysis excluded alleged victims and contract criminals (see Results section). Crime Consequences (average sentencing) were extracted from reputable federal sourcing guidelines [3, 4, 15].

documented and regulated [3, 4, 15]. Contract criminals were excluded from this particular analysis, as this special type of offender is known to reject confessions, due to organized crime affiliations, etc., regardless of what their VSA results or the evidence indicate.

#### **4. Discussion of Results**

This study's confession rate of 96.4% (when stress was indicated), is laudable in being much greater than the confession rates (50% or less), typically obtained as a result of traditional interview and interrogation procedures, and also notably exceeds the results achieved by other widely available truth verification technologies which, according to the US National Academy of Sciences, are prone to high false positive rates and significant inconclusive results [10, 14].

The 100% sensitivity and 96.3% specificity rates of this study imply that the VSA process can precisely and accurately discriminate stress from no stress in real life crime situations involving consequence and jeopardy, thus enabling the exoneration of the innocent. For 100% of the VSA examinations which resulted in No Stress Indicated (n=26, 7.9% of total examination pool), the individuals represented were exonerated from any wrongdoing based upon confessions obtained from other suspects, evidence developed after the VSA examination, or acquittals at trials. Also, the accurate rates of successful evaluations defied chance probabilities. As a key example, in the Grand Larceny case with 20 suspects, 19 of the examinations resulted in No Stress Indicated, and only one resulted in Stress Indicated – which in turn resulted in a confession. The Bernoulli Probability of having had 20 successful evaluations out of 20 examinations was less than 1 in 1,000,000. If VSA were simply a prop to obtain confessions, it would have been virtually impossible to achieve such specific and unerring results.

Interestingly, a relevant portion of this retrospective analysis implies that there appears to be a strong, indirect relationship between crime consequence/jeopardy and confession rates. The correlation found ( $r^2 = 0.88$ ,  $r = -.94$ ) implies that guilty examinees were less likely to confess when the penal

ramifications (i.e., typical prison sentence) for the crime committed became more severe. This finding further demonstrates the efficacy VSA has when used in an experimentally realistic paradigm and underscores the ability of field researchers to discern trends and associations among “real-life” factors.

## 5. Implications and Conclusions

This retrospective study provides compelling evidence that when VSA is utilized as an investigative decision support tool in accordance with required operating procedures, and standard VSA interviewing techniques are employed, elicited confessions from criminal suspects can strongly be predicted based upon results of their VSA examinations. Further, VSA can be used by trained professionals to support the acquisition of court admissible criminal confessions at a rate superior to other legal interrogation methods currently employed by the criminal justice system. Ultimately, however, human skill is required to make VSA technology perform its most valuable investigative functions, to exonerate the innocent or to elicit valid and verifiable confessions from the guilty in real-world criminal investigations.

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### **Summary**

The use of Voice Stress Analysis (VSA) technology in Criminal Justice Setting is considered. Practical evidence of the effectiveness of this technology for the investigation of various criminal offenses is provided.