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A NEUROPHYSIOLOGICAL REVIEW AND A PROPOSED RATIONALE FOR INTERPRETING ELECTRODERMAL POLYGRAPH RECORDS

By

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Foreword

I have several goals in this article. One of them is briefly to review selected neurophysiological phenomena and to promote how understanding them is relevant to the polygraph examination. I will try to do this in Part I. Also, I want to propose a model for interpreting electrodermal polygraph records. I will try to do this in Part II. The model I will describe is developed on the basis of current physiological and biophysical concepts which relate the skin's structure and function to its water and salt contents which, in turn, depend heavily on local sweat gland activity. I will try to show how the tonic and phasic secretion of these glands has a second-order effect on skin electrical phenomena, even though there is no liquid sweat to be seen on the skin surface. Changes in skin hydration due to low-level sweat gland activity is known to affect also many of the skin's other physical and physiological properties, and I will review those interactions which it seems to me are important for polygraphers to know about.

Polygraph examiners face several challenges in doing their jobs. Not only is there an obligation for them to understand the biological bases for their complex polygraph tracings, but they must also be able to spot inconsistencies among these data and relate them interpretively to the psychological environment they have constructed in the examination itself. As the first step in this process, the examiner needs to function as a well-informed and sharply perceptive applied physiologist who must make correlations among the examinee's cardiovascular, respiratory and electrodermal records to judge changes in conscious, affective and autonomic neural states. Finally, the examiner must be able to describe and communicate his conclusions to others using nomenclature which not only is appropriate and accurate, but which also is standard within the biomedical community. This article is designed to help the polygrapher with such an extraordinarily difficult task.

I am a physiologist, not a polygraph examiner, therefore I am not qualified by training or experience to comment with authority on issues such as the reliability of different types of polygraph examination techniques, the relative merits of differently structured questions for the polygraph examination, or the importance of social, personality or pharmacological factors that may influence attempts to detect deception

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using physiological records. On the other hand, because records of electrodermal activity are considered by many (see reference No. 1) to have special significance in polygraphy, it seems valuable to understand in detail the anatomical, physical and physiological principles on which these measurements depend. Those are the topics I wish to address. I have not constructed this article to be a comprehensive literature review. Rather, I intend it to be a statement primarily of only one view of how electrical and hydration characteristics of the skin are related to functions of the nervous system. My hope is that you will find this article informative and interesting enough to read all of it, and that it will be a stimulus for both thought and future discussion.

Part I. Organization and Function of the Nervous System

Introduction

The nervous system is a complex organization of millions of microscopically small, individual, specialized cells. Its primary role is to coordinate an animal's activities so that it successfully adapts to a specific environment and is able not only to survive, but also to function effectively in it. Nerve cells coordinate body functions by gathering information about the animal's internal and external environments, communicating this information among themselves with both electrical and chemical signals, and then reflexly controlling muscle and gland activities. Virtually all body processes are either under the direct control of, or are influenced indirectly by neural activity.

Central and Peripheral Parts of the Nervous System

The nervous system has two major anatomical divisions, the central nervous system and the peripheral nervous system. The central nervous system contains most of the body's nerve cells which form the brain, midbrain, medulla, spinal cord and many other anatomical subdivisions. A distinguishing characteristic of the central nervous system is that it is surrounded by the protective, boney envelopes of the skull and the vertebral column. It is suspended within these structures and floats in a constantly circulating bath of cerebrospinal fluid which is normally replaced about every 4 hours. The clear, watery cerebrospinal fluid (about 3.5 oz) not only provides mechanical protection for the delicate cells and blood vessels of the central nervous system, but also its chemical composition influences neural function. Cerebrospinal fluid is constantly secreted at one site in the brain and reabsorbed at another. In this way, the central nervous system is exposed to a perpetually renewing fluid environment at a near-constant pressure which not only cushions it and protects it from mechanical injury, but which also is involved in chemically regulating its many functions.

In contrast, the peripheral nervous system consists of nerve fibers which lie outside of the skull and the vertebral column. These fibers are bound in connective tissue sheaths and are not exposed to cerebrospinal fluid. The primary function of the peripheral nervous system is to communicate information to and from the central nervous system to support the animal's coordinated and integrated responses. The peripheral nervous system transmits electrical signals from peripheral receptors (for example, the eyes, ears, touch, pain, temperature and many other sensory

organs in the skin and throughout the body) to the central nervous system along sensory nerve fibers. It also transmits signals from the central nervous system to peripheral muscles and glands (for example, the voluntarily controlled muscles of the skeleton, muscles in blood vessels, body viscera, adrenal glands and many other sites) along motor nerve fibers. The coordinated response of an animal to any environment and to any stimulus requires a complex interaction of central nerve cells and peripheral (both sensory and motor) nerve fibers. The basic pattern of such interaction is called a reflex.

The peripheral nervous system functions primarily as a communication link which connects the animal's sensory and motor organs to the central nervous system. The central nervous system functions primarily as an integrating site for the neural information delivered to it and as a generating source of motor signals. All decisions related to behavior and response are made within the central nervous system fundamentally on the basis of reflex action. The central nervous system can be accurately imagined to be an extremely complex computer which has been programmed by genetic and environmental factors as well as by learning, experience, personality and volition to produce the response patterns which are characteristic for each individual animal or person. The central nervous system of even the most primitive and comparatively simple life form, though, is many times more complex than even the largest and most sophisticated computer currently available.

An animal's nervous system is its most rapidly reponding organ to stimuli. The rapid transmission of electrical signals into and out of the central nervous system provides a mechanism by which an animal can respond quickly and appropriately to environmental stimulation. Electrical signals are transmitted at speeds up to 120 meters per second (over 250 miles per hour) in the human peripheral nervous system. The most rapid, coordinated, reflex response in humans is completed within 25/1,000ths of a second. This is the total time, from the beginning of the environmental stimulus to the completion of the response, including all of the electrical and chemical events that occur in the central and peripheral nervous systems. One's final response to stimulation (movement of a limb, secretion of a hormone, change in cardiovascular function, etc.) is usually longer than this, though, because organs other than the central and peripheral nervous systems are involved in the response, too. The nervous system, however, has done its part of the job with lightning-like speed.

Somatic and Autonomic Divisions of the Central Nervous System

Based on both anatomical and physiological criteria, the central nervous system is described as having two major components--the somatic and the autonomic divisions. The somatic nervous system is that part of the central nervous system which is involved in the coordination and use of sensors and muscles which orient the body in space. Standing, walking, looking at and reaching for an object, and the maintenance of body posture all involve the somatic nervous system, as does, of course, driving a car or operating other machinery.

Although the somatic nervous system can be activated by voluntary control (as in speaking, walking, running, writing, the use of tools, etc.) it can also be triggered reflexly; that is, without voluntary action

and without conscious control. Jerking one's hand away from a site at which it was painfully stimulated (by a burn or a cut, for example) does not require voluntary control. The extremity is moved rapidly, reflexly and effectively away from the damaging environment due to information transmitted from pain receptors in the skin (of the hand in this example) into the somatic division of the central nervous system and then re-transmitted along nerve fibers to the muscles that control hand position. The integration of incoming (sensory) information to coordinate purposeful (motor) movements in response to even such a simple stimulus as pain takes place among hundreds of thousands of nerve cells in the central nervous system which are involved in positioning the hand and arm. This requires precise coordination in both time and space of the contractions of the many muscles that move the upper and lower arm, wrist and fingers, for extension, withdrawal and rotation of the extremity. Most of this is done not only reflexly quick but also without conscious control.

Reflex limb movements (for example, the unconscious pulling away of the hand in response to pain), however, are simple and stereotyped in comparison to the wide range of patterns for finger, hand and arm movements that are voluntarily controlled. The reflex movement of the hand in response to pain only grossly represents the precision and dexterity of coordinated movements required to play a piano, for example.

The execution of basic somatic reflexes requires only nerve cells in the spinal cord; higher nerve centers or the person's voluntary control are not needed. If the brain or other higher central neural tissue has been either destroyed, or separated from the spinal cord (as in paraplegic persons, for example), basic somatic reflexes can still be activated below the level of the injury. Such reflexes are generally purposeful, but they are involuntary and they lack precision and fine coordination. Voluntary control of somatic responses, of course, requires intact, undamaged central and peripheral nervous systems. The precision of well-directed and finely controlled body movements requires input from the higher nervous system.

Autonomic Division

The autonomic division of the central nervous system is that part which is involved in the regulation of involuntary body functions. Heart rate, breathing rates and patterns, intestinal motility, blood pressure, body temperature and other body maintenance functions are under the direct control of the autonomic nervous system. The suggestion that this part of the central nervous system might be called "automatic," rather than autonomic, underlines its general freedom from voluntary control and emphasizes its regulatory functions in the body.

Some body functions which are normally under autonomic control, however, can be temporarily placed under voluntary control. For example, speaking or singing requires the voluntary, complex activation and orchestration of many respiratory muscles, but once the voluntary control is removed, as in sleep, respiratory movements are again autonomically (automatically) regulated to maintain blood gases within ranges compatible with life.

The autonomic nervous system plays an essential role in regulating

organ, gland and muscle functions throughout the body to maintain life sustaining processes. The prime responsibility of the autonomic nervous system is to hold body processes within the narrow range of function demanded for the preservation of life, regardless of the stresses placed on the animal. For example, it automatically regulates body heat gain and losses to hold body temperature constant within a few tenths of a degree Fahrenheit, despite periodic thermal loads due to exercise, fevers, and environmental heat and cold exposures. An analogous challenge would be for a person to attempt to maintain a near-constant room temperature while windows and doors are being opened and closed, and air conditioners and furnaces are being turned on and off.

The autonomic nervous system also normally modulates the distribution of blood flow to the exercising muscles, brain, nutrient absorbing surfaces of the gastrointestinal tract, heat dissipating skin surfaces and many other body organs while keeping blood pressure within a narrow, normal range. An analogous challenge would be for a person to attempt to maintain a constant water pressure in a house while toilets are being flushed, showers turned on and off, and dishwashers and washing machines being periodically operated.

The autonomic nervous system operates so automatically that most of us are totally unaware of the many, many life-dependent adjustments it makes for us every second of our lives. It operates with such precision that despite the severe loads of exercise, thermal exposure, food and water ingestion, respiratory alterations due to talking and other environmentally imposed stresses, our blood pressure, body temperature, arterial pH and blood gas concentrations and other vital functions are all autonomically regulated to within narrow limits, even when neural function is impaired by fatigue, disease, or by alcohol or other drug intoxications.

Although they are different parts of the central nervous system, the functions of the autonomic and somatic nervous systems are intimately related. When a pain stimulus activates a somatic reflex to jerk the hand away from the site of stimulation, many autonomic reflexes are also produced. Less apparent than the movement of the extremity, there are triggered at the same time, changes in heart rate, blood flow distribution, respiratory movements, pupillary diameter and a wide range of other effects. There are many autonomic responses which follow a painful stimulus and which are predictable correlates of somatic reflexes.

An increasing amount of evidence indicates that the interplay between the somatic and the autonomic nervous systems is much greater than previously suspected. Some of this evidence predicts functional relationships between psychic states and dysfunction of normal autonomic regulation for many body organs. The neurophysiological relationships between emotion and heart disease, hypertension, atherosclerosis, ulcers and many other pathologies are now topics of focus in many research laboratories. It seems quite reasonable to expect that future research will reveal many links between chronic autonomic activity and illness.

Sympathetic and Parasympathetic Parts of the Autonomic Division of the Nervous System

The autonomic nervous system maintains a complex, but nonetheless

finely tuned regulation of organ function due in large part to a unique arrangement of its motor nerve fibers. Virtually all body organs, including the heart, gastrointestinal tract, skin, voluntary and involuntary muscles and most glands receive two kinds of autonomic nerve fibers. One type arises from the sympathetic division and the other type from the parasympathetic division of the autonomic nervous system. Each organ is said to receive a "dual innervation."

In the simplest analysis, the general activity of the parasympathetic nerve supply is to regulate an organ's function compatible with basic body maintenance. For a relaxed, non-stressed person or animal, the effects of the parasympathetic nervous system are predominant. Also in the simplest analysis, the general activity of the sympathetic nerve supply is to regulate an organ's function to support the organism in time of stress. for a frightened animal or for one in pain, the whole body effects of sympathetic nerve activity are predominant. In the moment-to-moment experiences of everyday life, the ebb and flow of sympathetic and parasympathetic activity is tuned to the physical environment we perceive and to the psychological environment we construct, and defines in net balance our autonomic reaction to them.

Neural Responses to Stress

It is easy to understand how the effects of sympathetic nerve control prepare the organism to counter stress, physical attack or danger, if the associated change in function is reviewed for different organs. Through sympathetic reflexes triggered by perceived danger, stress or experienced pain, the coronary blood vessels dilate to increase the flow of blood to the heart muscle. The heart itself increases the volume flow rate of blood it propels by increasing heart rate and/or the amount of blood pumped with each contraction. Blood flow to the body's voluntary muscles increases, as does their level of contraction, while that to the skin and viscera decreases. The pupil of the eye increases its diameter (more light enters the eye), the eye lid automatically elevates and the lens of the eye is adjusted for distant vision. In furred animals, the body fur becomes more erect. In humans, the hair shafts become more erect. The diameter of the bronchial airways in the lungs becomes larger which reduces the respiratory work required to bring air into and out of them.

Even gross evaluation of an animal which has become sympathetically activated in response to pain or perceived danger yields the impression of an organism which is ready for confrontation or defense. The body muscles are more rigid and are perfused with blood at a higher rate, heart and breathing rates are elevated, the eyes are wide and fixed on the expected source of danger and the fur is raised. Reflex drawing back of the lips, showing of the teeth and snarling also convey the impression that this animal is ready for action and poised for battle.

If the source of the anticipated danger is removed, or if the pain stimulus is terminated, the activity of the sympathetic nervous system slowly subsides and each organ returns to a more relaxed and vegetative level of function. Each organ returns to the control of the parasympathetic nervous system. In contrast to somatic reflexes which are rapidly completed (for example, the jerking away of the hand in reflex response to pain) the effects of autonomic reflexes require longer periods to

disappear. This is in part due to the more elaborate and complex connections among the multitude of nerve cells which comprise the autonomic nervous system. It is also due to the fact that there is a reflex release of a chemical into the body's circulation subsequent to sympathetic activation, as described in the next section of the article.

Long Term

Coincident with the whole body pattern of increased sympathetic nervous system activity which is precipitated by stress, electrical signals are transmitted from the central nervous system to the adrenal glands which results in the release of adrenalin (epinephrine) into the circulating blood. This chemical is carried throughout the body within seconds of its release where it begins to exert specific effects on different organs. Its general effect is to produce responses similar to those elicited by the sympathetic nervous system itself. It functions as a chemical reinforcement to the effects produced by sympathetic nerves in the organ, and as a back-up system for organs that may have had their nerves damaged or destroyed.

Whereas the effects of somatic reflexes are rapidly initiated and quickly terminated, the effects of sympathetic reflexes throughout the body are much longer lasting. Not only do the neural effects of sympathetic nervous system activity need to abate as the animal relaxes, but also the concentration of secreted adrenalin circulating in the blood needs to be reduced by its being detoxified and excreted. The time required to return to a relaxed physiological state after sympathetic activation may be a few minutes, many minutes or even hours, depending on the nature and time course of the presented danger, as well as on the animal's or person's psychic response to the stress. The long-lasting effects of sympathetic stimulation are apparent to anyone who has tried to quiet a child awakened by a nightmare. They are also apparent at a more personal level to any driver who is aware of his or her own heart rate (if nothing else) after a near-miss collision or after executing an emergency stopping procedure to avoid hitting an animal or a person.

Stress and Memory: The Limbic System

The characteristically long term effects of sympathetic activation, and especially their emotional counterparts, are also due to the reflex involvement of a special brain area, the limbic system. The limbic system is a communications network among several aggregates of major nerve cell groups within the brain which developed early in the evolution of the nervous system. It is that part of the brain which is fundamentally involved in behaviors associated with feelings of pain and pleasure and many other emotions, including fear.

One of the unique functions of the limbic system is shown in the coordinated behaviors related to emotion described as the "affective-defensive" pattern of response. Electrical stimulation of a small segment of the limbic system in experimental animals immediately produces a fully developed and coordinated "rage response." This includes baring of the teeth, the assumption of a defensive body posture, snarling, growling and extension of the claws. The least provocation of an animal in such a state precipitates an immediate and a savage attack. In humans, threatening

environmental stimuli (real or imagined) will produce sympathetic responses which undoubtedly wil involve the limbic system in coordinating defense behaviors and associated emotions.

Defense reactions, including autonomic and limbic system involvement, are initiated by stimuli other than direct pain and direct threat. An important aspect of such a response reside in the learning and experience base of the person or animal. For example, for someone who has never been to a dentist or who has never had extensive or painful dental work, the odors, sounds and general environment of the dental waiting room present an innocuous, non-threatening setting. For others, however, even scheduling an appointment, seeing or hearing dental tools and drills in action on other people, or even mentioning the phrase "dental drill" can produce responses of the sympathetic nervous system which are not only intense but may also be long-lasting. These might include grimacing, increases in body muscle tone, flushing or paling of the face, sweating, feelings of nausea and anxiety, fidgeting and increased body movements, inability to concentrate and a wide range of other responses.

Although there may be no direct threat to the individual himself, the resurrection of painful memories is adequate to produce sympathetic nervous system responses and initiate defensive reactions. Many people can recall when they have reacted in such a way themselves either in response to remembering a painful experience, or to seeing someone else in danger or in pain. Many times, however, these autonomic reflexes develop without our being consciously aware of them. Anyone monitoring the reactive states of either our cardiovascular, respiratory, gastrointestinal or other body systems, or the secretory state of our atrichial sweat glands, though, would have little trouble accurately documenting the fact that we are undergoing autonomic reflexes, whether or not we divulge our state of consciousness or awareness.

At any specified time, an animal's or a person's body and emotions are reflecting the net effects of simultaneously produced somatic and autonomic responses. This is the general result of their gathering information in great complexity and detail from their internal and external environments, evaluating it in the light of past experience, and acting on that information to produce appropriate (for them) reactions. Only a very small part of this total information processing occurs at a conscious level. Intimately interwoven into these patterns of response are the effects of learning, personality, prior experience and volitional drives.

I hope that readers will want more information about the central and peripheral nervous system than is presented in this article. The references listed at the end of this article are recommended from the many available based not only on their being authoritative, but also because they are easily read, well-organized, reasonably inexpensive and (with the exception of reference no. 2) available in paperback editions. Reference no. 2 is an outstandingly well-illustrated neuroanatomical and neurophysiological summary. Reference no. 3 is suggested for more neuroanatomical detail, and references no. 4 and no. 5 provide succinct correlations between neuroanatomical and neurophysiological principles with a clinical focus. Reference no. 6 is a useful review of neuropathology.

Thomas Adams

Part II. Electrodermal Activity Related to the Structure and Function of the Skin

Introduction

Many different skin electrical properties have been measured which presumably reflect either a person's emotional state or a level of autonomic nervous system function. The purpose of the second part of this article is to provide distinctions among these measurements and show how they can be examined in view of the anatomy and physiology of the skin to provide a rationale for their interpretation.

Terminology

The history of measuring the electrical properties of the skin is long. Many of the terms once used to describe these phenomena have lost their original meanings over the years. Continuing to use nomenclature which has different definitions for different people is costly in attempting accurate and precise communication. For this reason, the use of the acronym "GSR" is discouraged because it has become only a vague and imprecise designation. For some people, for example, it means, "Galvanic Skin Response," with no clarification as to which of the many complex features of the electrodermal record it specifically refers. For others, it means, "Galvanic Skin Resistance," even though electrical resistance may not have been the recorded phenomenon. Obviously, such imprecision can lead not only to confusion, but also to fruitless controversy. It seems more useful to refer to whatever electrical measurement is made from the skin in terms of the physical property actually being recorded. These fall into two general categories.

When electrical measurements are made from the skin without applying an external voltage source to it, they are called "endosomatic." This implies that only energies arising from the skin itself are being recorded. The measurement of "skin electrical potential" is an example. When electrical measurements are made from the skin while an external voltage source is applied to it, they are called "exosomatic." This implies that whatever is being recorded is seen when an electrical power source external to the skin is applied to it. The measurements of "skin electrical resistance," "skin electrical conductance" or "skin electrical impedence" are examples. Most polygraph measurements of skin electrical phenomena are made using an electrical bridge (or voltage divider) circuit which applies a small DC voltage current. For this reason, these are exosomatic measurements and usually provide information about either the DC electrical resistance or electrical conductance of the skin. If an AC voltage is used, information can be deduced about both the electrical resistance and capacitance of the skin from the measurement of skin electrical impedence.

Skin Electrical Phenomena and Emotion

Skin is unique in that few other organs (except the brain itself) have electrical characteristics which respond to a change in a person's emotional state. How the skin does this has been intensely investigated for decades. Even so, complete answers are not available. The concepts presented in the following pages may best be viewed as only one of several

possible explanations. Additional research will have to be conducted and much more detailed information will have to be available before there is complete insight into these phenomena. Nonetheless, I consider that understanding how the electrical properties of the skin are related to central and peripheral neural activity requires knowing something about the structure of the skin and about the sweat glands it contains, even though this may be only part of the total story.

Skin Anatomy

The skin of any animal is an important boundary between its internal and external environments. Especially for animals that live on the land, it is a critical barrier to the loss of body water and salts. Human skin is unique in at least two ways. It does not have the density of fur and hair that is typical for other animals, and it has a rich supply of a specialized secretory organ, the sweat gland.

Figure I is a drawing of a cross-section of human skin that would be typical for the hand, the sole of the foot, or the pads of the fingers or toes. Characteristic of these skin sites, the upper layer of the skin (the epidermis) is a thick tissue mass in which there are no blood vessels and few if any nerve endings, other than perhaps pain receptors. The only organs that penetrate this outer skin layer are the characteristically coiled distal tubules of the atrichial (or eccrine) sweat glands. These will be described in some detail in the next section of this article.

The outer portion of the epidermis is a thick, cornified layer of skin cells called the stratum corneum. Looking at the normal skin surface, one sees the outer layer of the stratum corneum. If one examines the skin of the fingers with a low power microscope or even a magnifying glass, it is easy to see the openings of the sweat glands at the skin surfaces. They are located at precise intervals along the top of the fingerprint ridges and appear as slight depressions in their surfaces. There are normally 300 to 500 sweat glands per cm^2 (about 2,500 per in^2) of skin surface. These glands function in a number of very important ways other than protecting the body from overheating, as I will try to explain in the next few pages.

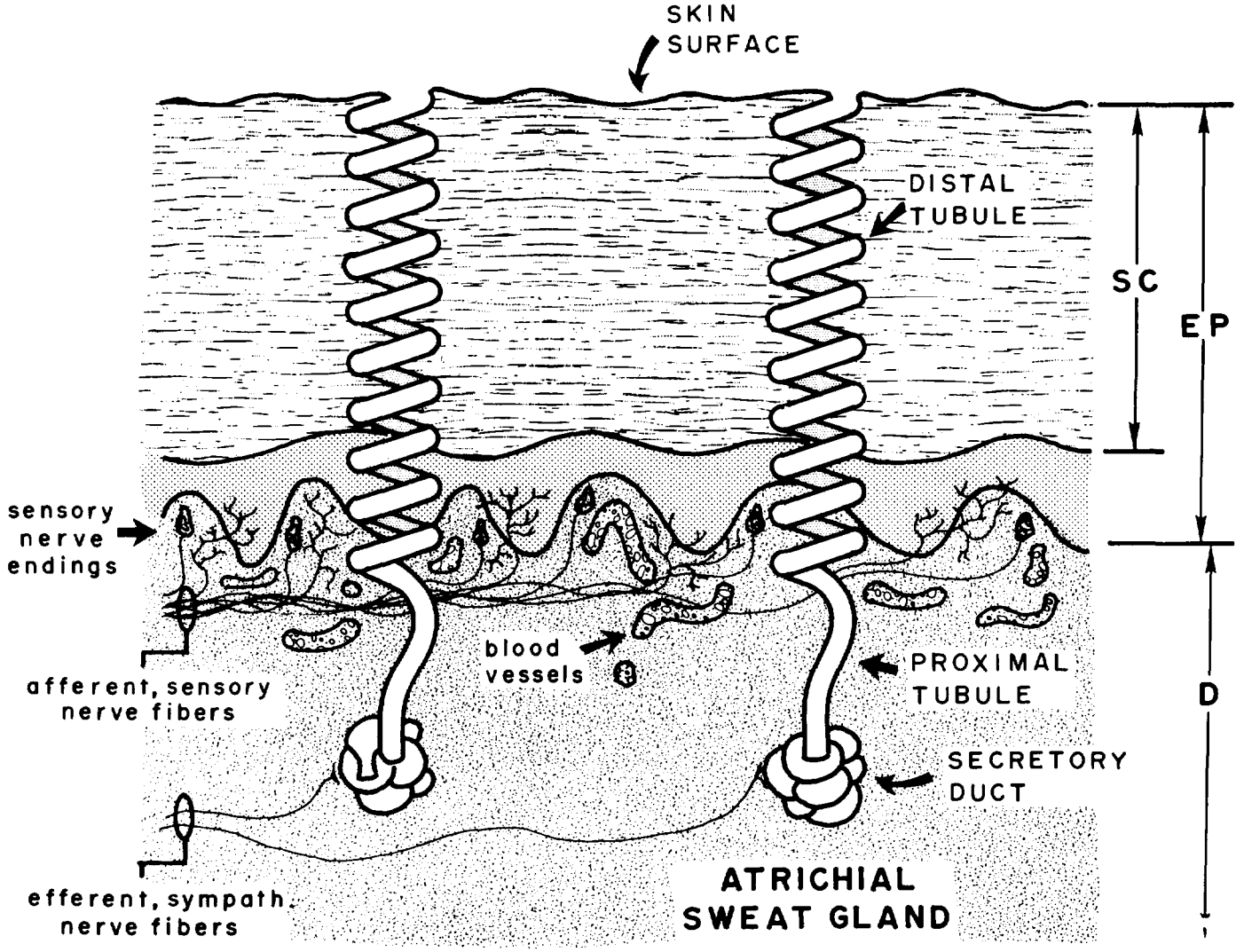
When there is no sweat gland activity, the outer surface of the skin appears to be dry, that is, no liquid water can be seen on it. It actually contains water, however, which it gets from one or both of two sources. It can absorb water vapor from the air surrounding the skin (depending on the relative humidity of the air), and it can retain some of the water that seeps from skin layers below the epidermis in which there are blood vessels. Because the outer surface of the skin appears to be dry, however, does not mean that the sweat glands are inactive. This will be explained in the next few sections.

Locations of Sweat Glands

Humans have two kinds of sweat glands. One has the opening of its duct associated with hair shafts that penetrate the skin. These are called "epitrichial" (epi = near or beside; trichial = hair) sweat glands. In the past, these glands have also been called "apocrine" sweat glands. They are most densely distributed in the groin and in the armpits. The

Figure I

This idealized drawing of a cross section of tactile skin shows the location of atrichial sweat glands, sensory nerve endings and blood vessels in the dermis (D) in relationship to the epidermis (EP) and its upper layer of cells, the stratum corneum (SC), the outer boundary of which is the skin surface (from reference No. 7).



other kind of sweat gland is called "atrichial" (a = without). The openings of these glands are not associated with body hair, as their name implies but have ducts which terminate directly at the skin surface where they can be seen along the fingerprint ridges. In the past, these sweat glands have also been called "eccrine" sweat glands. The information that follows in this article relates primarily to the atrichial (or eccrine) sweat gland. It is this type of gland that has been depicted in Figure I. People normally have atrichial sweat glands in the skin which covers the entire body, as well as in that of the tactile (hand, finger, foot and toe) body surfaces. I will try to show later in this article that the activity of the atrichial sweat gland in tactile skin from which electrodermal records are being made is of special significance in the polygraph examination.

Sweat Gland Functions

One function of the atrichial sweat gland is obvious. During whole body exposure to hot environments and when one is overheated by doing physical exercise or by working, these glands actively secrete a large volume of water which spreads over the skin surface. When this water evaporates, it cools the skin and helps the person retain a normal body temperature. Of course, no matter how intense the sweating is, no heat is lost and body temperature cannot be reduced by sweating if the water in sweat does not evaporate. Water would not evaporate from the skin surface, for example, if the relative humidity of the air were 100%, or if the body surface was covered with a plastic or rubber surfaced coat which is impermeable to water vapor. Under these circumstances the water brought to the skin surface by sweating would run off it in drops, but there would be no water evaporation and no cooling would occur.

Secreted sweat is about 99% water. The remaining 1% is largely composed of body salts (predominently sodium chloride) that are secreted normally with the water in sweat. As anyone knows who has been exposed for a long time in a hot environment, it is necessary to replace not only the water lost in sweat, but also the salts that are secreted with it. Normal people have a built-in physiological mechanism that helps them conserve the salt that is secreted in sweat. When sweat is formed in the body at the secretory duct of the sweat gland (see Figure I), it has about the same concentration of salt as does the blood and body tissues. As the sweat moves through the sweat gland's proximal tubule (see Figure I), most of its salt is removed as long as sweating rates are low. Even at low sweating rates, however, some (about 1%) of the salt normally reaches the skin surface along with the water in which it is dissolved. During work in hot environments, 15 to 20 grams (.5 to .7 oz.) of sodium chloride may be lost along with 10 to 15 liters (2 1/2 to 4 gallons) of water. At high sweating rates, both body water and salt composition are endangered.

People who have cystic fibrosis do not reabsorb salt from secreted sweat as readily as do those who are normal. One of the early diagnostic signs of this serious metabolic disease is that the skin of its victims tastes salty, as parents note when they kiss their affected child. Because this is a fatal disease for which there is currently no cure, this characteristic sweat gland defect is seen only in children and in young adults. The malfunction in cystic fibrosis that alters normal exocrine gland functions throughout the body (lungs, pancreas, gastrointestinal

tract, etc.) with lethal consequences also affects the sweat gland's ability to reabsorb body salts from secreted sweat, and a sweat that is abnormally rich in electrolytes appears at the skin surface.

Mechanisms of Skin Hydration

It has been known for some time that not only does normal skin serve as a barrier to the loss of water and salts from the body, but also it is able to change its own water content. Skin layers below the epidermis (see Figure I) are important sites for storing water related to the whole body hydration needs of the person. Water (and salt) contained in the upper layers of the skin (the epidermis and stratum corneum), though, is important in establishing its electrical and other physical characteristics. The amount of water in the outer skin layer (see Figure II) depends not only on the relative humidity of the air to which it is exposed and the rate at which water comes to it from deeper skin regions by diffusion, but it is also related to sweat gland activity. The role of the sweat gland in keeping the skin moist has only recently been recognized.

Figure II shows that the water content of the skin depends in part on the relative humidity of the air at its surface. Hydration deep in the skin is always high due to blood vessels there which supply water continuously to the tissues below the epidermis. Water moves from the body into the epidermis and into the stratum corneum in two ways. Because the skin is not a perfect barrier to water loss, some water moves into it from deep in the body to be lost eventually to the surrounding environment (large arrow in Figure II). When the upper layers of the epidermis are drier than its deep tissue, water also moves into the stratum corneum from the atrichial sweat gland when its ducts are filled with sweat (Figure III). Because sweat normally contains salts as well as water, they move into the outer skin layers, too.

The upper layers of the skin (the epidermis and the stratum corneum) have a reservoir function for water and salt. They store water to become hydrated either when the skin is exposed to a high humidity environment, or when there is sweat gland activity, and they loose water from storage when the skin becomes dehydrated. These changing states of epidermal water storage are intimately involved in establishing the elctrical characteristics of the skin.

Skin Electrical Phenomena and Skin Hydration

Few people would be surprised to learn that the electrical resistance of a porous material such as paper (or a piece of sugar) is lower when it is saturated with salt water (an electrolyte solution) than when it is free of water and salt. They would not be surprised because they would recognize that a salt water solution is a good conductor of electrical current, and that if a material contains an electrolyte, it would predictably have a low electrical resistance. Using this concept, it was suggested a long time ago that the electrical properties of the outer layers of the skin reflect its water and salt content. Considering that the outer layers of normal skin are able to change the amount of water and salt they contain due to sweat gland activity, it is suggested that electrical properties of the skin are in part related to its sweat gland function which in turn modifies epidermal hydration.

Figure II

For skin in which sweat glands are inactive, water is lost (shaded arrow) along a hydration gradient from near the dermoepidermal junction to the skin surface. The transepidermal hydration gradient (shown on left as hydration density (abscissa) as a function of distance (x; ordinate; mm x 10^{-1}) from the dermoepidermal junction) depends on the hydration state of the dermis and on the water vapor pressure of air at the skin surface. If the air is "dry" (i.e, low relative humidity), this gradient is steep (a). If air is "wet" (i.e., high relative humidity), this gradient is less steep (b). There is no hydration gradient below the level of the dermoepidermal junction because blood flow maintains the vascularized dermis with a high and uniform water content. The shaded area between lines a and b represents the amount of water than can be transiently stored in the epidermis when one goes from a low to a high relative humidity environment, or lost from it when one goes from an area of high to low relative humidity (from reference no. 7).

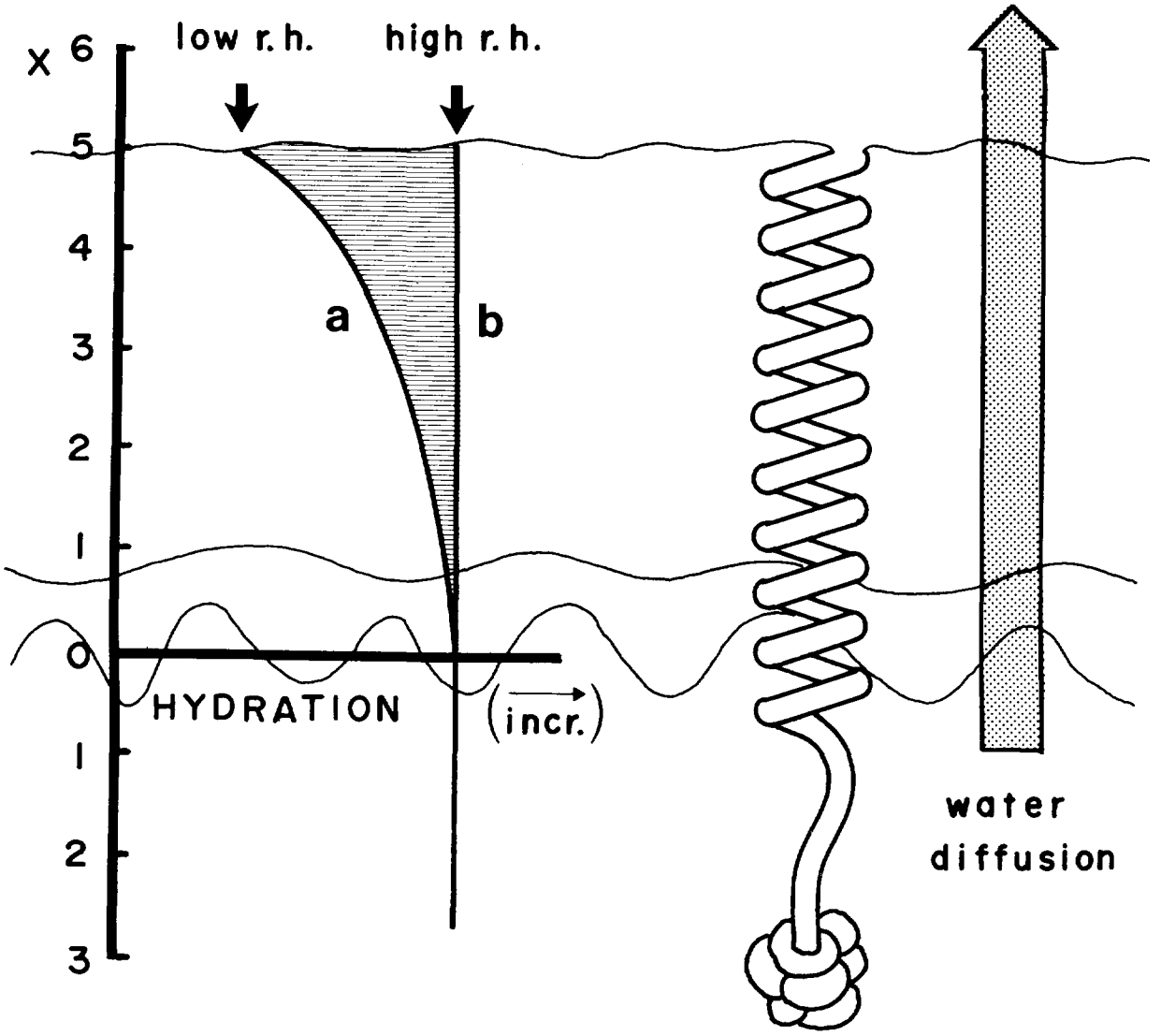
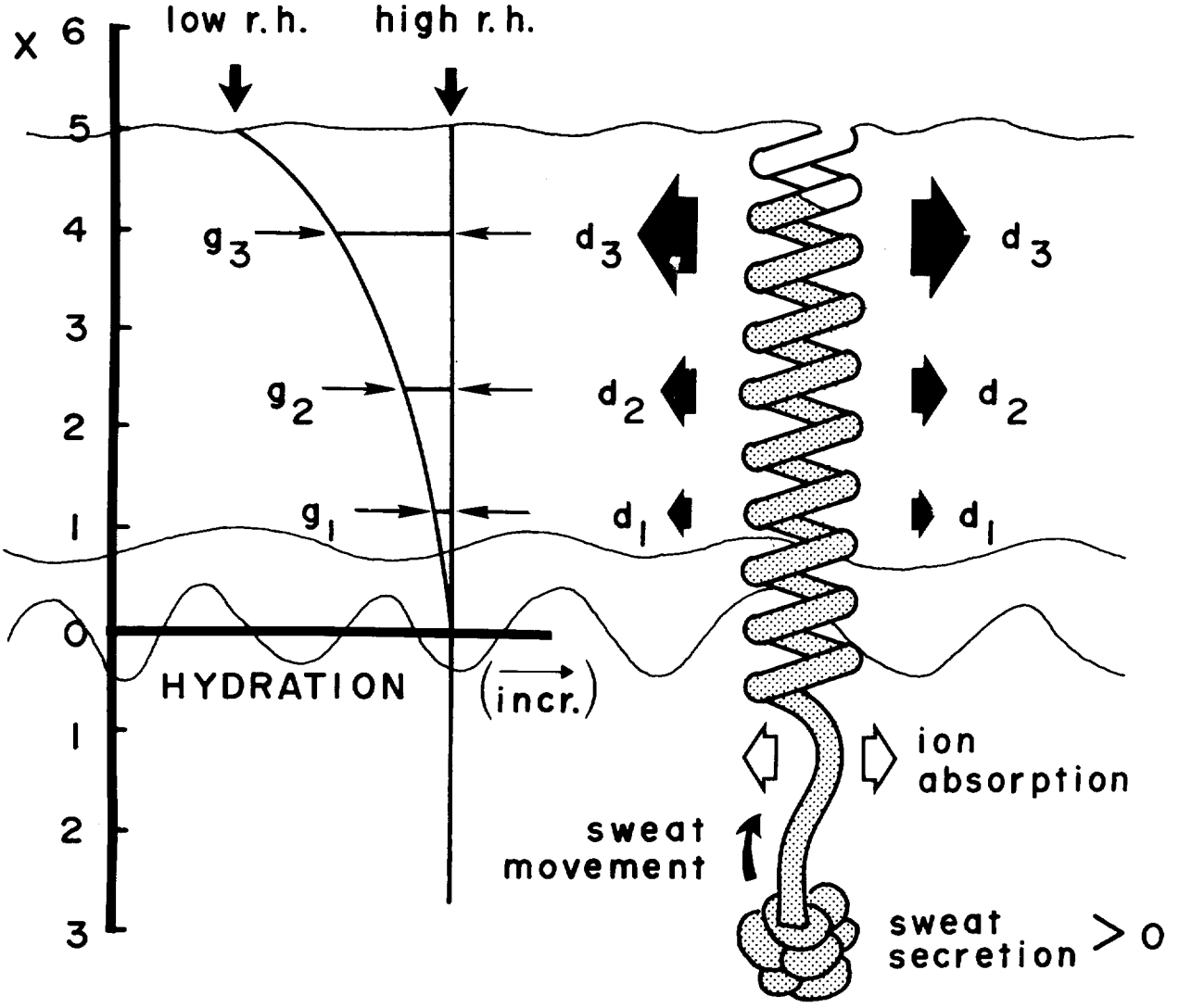


Figure III

During sweating, both water and salts passively diffuse (d_1, d_2, d_3) from the inner lumen of the sweat gland's distal tubule into the relatively drier, peritubular epidermis along hydration and osmotic gradients (g_1, g_2, g_3) parallel to the skin surface. The permeability (or diffusion) coefficients for these diffusion processes are unknown, but are suspected to be different for different places in the epidermis. They are also suspected to be substantially larger than are those perpendicular to the skin surface at any level in the epidermis. In humans, some electrolytes are extracted from secreted sweat by the gland's proximal tubule. If there is no transepidermal hydration gradient (for example, during exposure to air with 100% relative humidity, during intense sweating, or when there is a barrier to water diffusion at the skin surface), all secreted sweat appears at the skin surface as a liquid (from reference no. 7).



Even though it was suggested many years ago that there was a possible relationship between sweat gland activity and skin electrical phenomena, this theory was not quantitatively tested until recently. Figure IV shows the correspondence between skin electrical resistance and sweat gland activity measured simultaneously on normal humans. These data appear to strengthen the argument that sweating on the human palm is related closely to the electrical resistance of the skin at the same site.

Studies on the intact skin of normal humans and laboratory animals reinforce the idea that local sweating and skin electrical resistance (and conductance) are intimately related. There are undoubtedly other factors operating also, but the movement of water and salts into the outer layers of the skin seems clearly to be involved in affecting the skin's electrical properties. But how is this pertinent to the question of the relationships between a person's emotional state and their patterns of skin electrical characteristics?

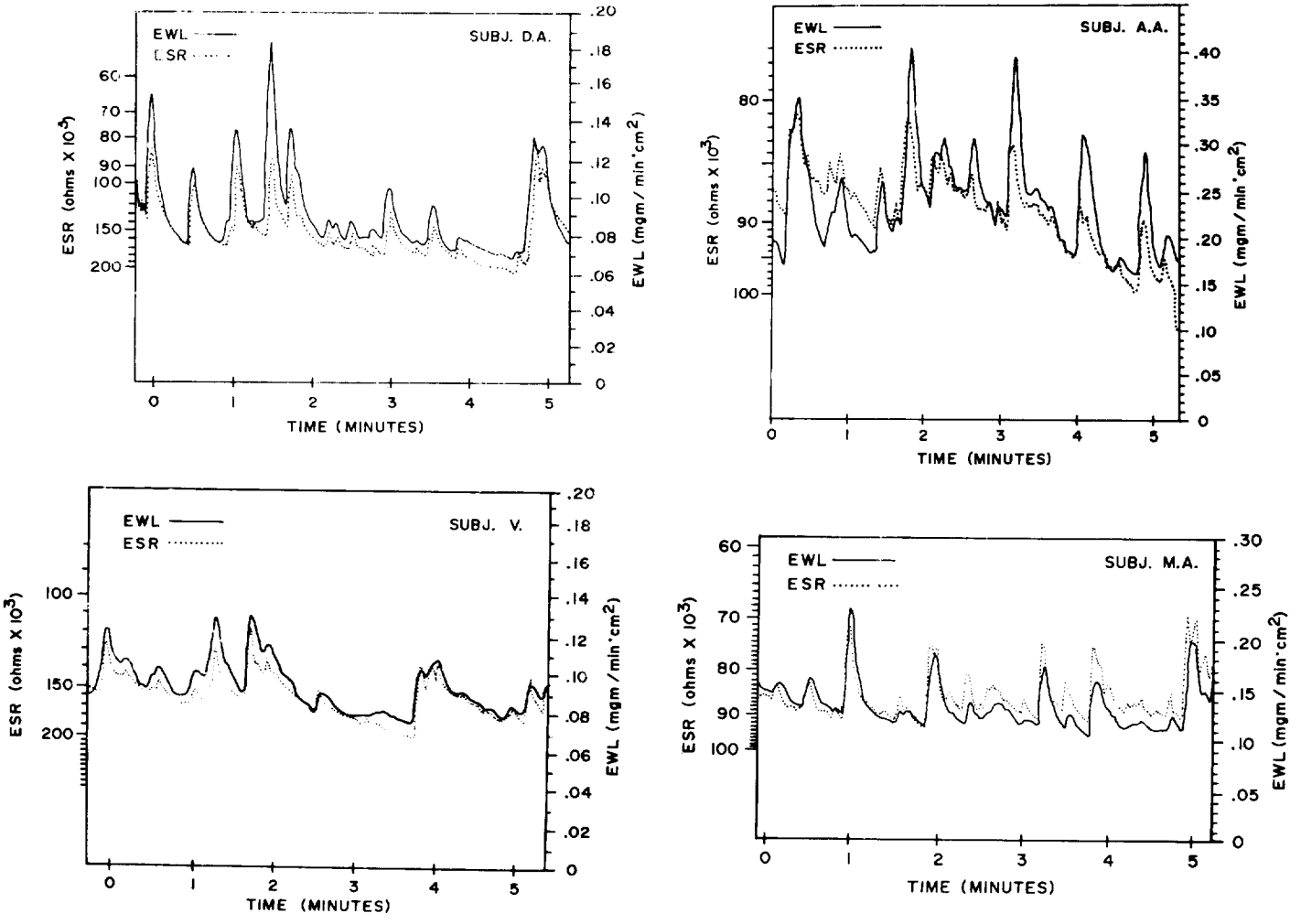
Emotions and Skin Electrical Phenomena

Atrichial (eccrine) sweat glands on the hand and foot surfaces of humans are unique in several ways. One of these features is pertinent to how emotional stress is reflected in sweating. It was described earlier that most body organs are controlled by a "dual innervation" of the autonomic nervous system, that is, most organs receive nerves from both the sympathetic and parasympathetic nervous systems. Atrichial sweat glands are an important exception. As shown in Figure I, they receive nerves only from the sympathetic division of the autonomic nervous system; they have no parasympathetic innervation. This means that atrichial sweat glands secrete only when the sympathetic nerves are activated. That is, they secrete only when a person is frightened, under stress or in pain. Sweat glands on the general body surface secrete also when the person is overheated, but it appears that those on the hand and foot surfaces become active more in response to psychic stimulation than they do to thermoregulatory stress. These responses are not totally isolated from one another, however, and in most situations thermoregulatory and psychogenic sweating are interdependent to some degree.

There is a simple and direct logical sequence that links emotions to the neural and secretory events which lead to changes in the skin's electrical properties. The first step is that physical or emotional stress automatically triggers functions of the sympathetic division of the autonomic nervous system. In addition to the short term and long term changes that occur in body function when the sympathetic nervous system is active (changes in heart rate, blood pressure, blood flow, respiration, etc.), sweat glands on the hands and feet increase their rate of secretion. Sweat not only brings water and salt to the skin surface, but some of it also penetrates the outer layers of the skin where it is temporarily stored. Because a salt water solution is a good conductor of an electrical current, there is a very predictable decrease in the electrical resistance of the skin (and an increase in its electrical conductance) when a person is emotionally aroused. Such a dependency between sweat gland secretion and skin electrical characteristics is seen in the records shown in Figure IV. It is not easy to identify the specific emotion, but it is reasonable to consider that when the sympathetic nervous system is active and the atrichial sweat glands are secreting, skin electrical resistance

Figure IV

Skin surface evaporative water loss (EWL) due to sweat gland activity was measured simultaneously with skin electrical resistance (ESR) in 4, normal subjects while each sat quietly. Even though each person shows differences in both the level and time course of sweating, both skin resistance and sweating are closely related to one another. This is true both for people with high electrical resistance baselines and those who have high conductance levels (from Adams, T. and J.A. Vaughan, "Human Eccrine Sweat Gland Activity and Palmar Electrical Skin Resistance," Journal of Applied Physiology, 20: 980, 1965).



would be low (and vice versa), and skin electrical conductance would be high (and vice versa).

Because the outer layers of the skin serve as a reservoir (see Figure II) for both water and salt, its electrical properties reflect not only the effects of current sweating episodes, but also of those in the immediate past. Sudden deceases in skin electrical resistance (see Figure IV) are attributed to bursts of sweating which fill the sweat gland ducts with an electrolyte solution which has good electrical conducting properties. The maintained, low level of skin resistance (see Figure IV) is related to the high concentration of water and salts in the skin due to sweating bursts in the recent past. Large peaks of rapidly decreasing electrical resistance of the skin are generally correlated with low resistance (high conductance) baselines, and vice versa. Both baselines and response peaks of skin electrical resistance (and conductance) records provide information about epidermal hydration, present and recently past sweat gland activity, and offer indirect information about autonomic (sympathetic) responses to stimuli.

Other Skin Changes Due to Sweating

The penetration of sweat into the outer layers of the skin produces other changes in it besides affecting its electrical characteristics. For example, hydration of the skin alters its frictional properties, as anyone knows who has ever spit on their hands or moistened their fingertips before picking up an object. It is common experience that slight dampening of the skin improves its frictional contact. Skin friction decreases, however, if the amount of water in or on the skin surface is too high. This effect is involved in the slippery feel of a car's steering wheel when a driver is negotiating a difficult traffic situation and his hands are sweating heavily due to the related emotional stress and reflexly increased sympathetic autonomic tone. Hydration of the skin also alters the characteristics of heat transfer across the skin. This is apparent to anyone who feels colder than expected on a "cold-wet" day, compared to a "cold-dry" day, even though the air temperature is the same for both days.

I have recently summarized some of the physical and physiological effects of skin hydration in a review article for physicians which readers of the present article might find interesting (see reference no. 7). Other hypotheses than the one presented here for skin electrical properties are expertly and interestingly reviewed in Chapter 15 of reference no. 8. That book contains several other excellent review articles about the skin's physical properties, as does reference no. 9 which is more recent.

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DETECTING DECEPTION: THE PROMISE AND THE REALITY OF VOICE STRESS ANALYSIS

By

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Abstract

Within the past decade a number of so-called voice stress analyzers have been marketed for law enforcement and forensic science purposes. These devices are said to extract from the vocal spectrum a subaudible microtremor signal that is useful in detecting stress in a speaker's voice; thus, it is claimed these devices have great utility as lie detectors and are as accurate as the traditional polygraph instrument. A review of the evidence now accumulated about these devices shows that the evidence for the existence of a microtremor in the voice is problematic and that the capability of these devices in detecting stress is equally questionable. Without exception, however, the scientific evidence reported to date shows that voice stress analyzers are not effective in detecting deception; none of these devices has yet been shown to yield detection rates above chance levels in controlled situations. A brief comparison of voice stress analysis and polygraphic testing as methods of lie detection is made.

In the lie detection field, the most widely publicized development in the past decade has been the so-called voice stress analyzer. In advertisements in popular magazines and in various trade and professional voice stress analyzers have been marketed as "truth machines" -- devices capable of detecting lies with an accuracy that equals or exceeds that of the more traditional polygraph.

There are now some four or five different voice stress analyzers on the market. The prototypical instrument, and the one most prominently advertised, is the Psychological Stress Evaluator (PSE). The PSE was first marketed in 1971 by two former military intelligence officers who reportedly developed the device for the purpose of carrying out "lie detection" tests in a covert manner, or at least in a manner that did not require attached sensors. According to its manufacturer, Dektor, Inc., the PSE detects and measures subaudible and involuntary frequency modulations (FM) that are superimposed on audible voice frequencies. The frequency modulations, whose strength and pattern are inversely related to the degree of stress in a speaker at the moment of utterance, are said to result from minute oscilliations of the muscles of the voice mechanism. Such oscillations, known as physiological tremors(1), are believed to be

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under control of the central nervous system during nonstressful periods. As stress is imposed, however, the autonomic nervous system gains dominance, resulting in a suppression of the microtremors. This suppression, indicative of emotional stress, is displayed by the PSE as a characteristic blocked or rectangular wave form.

The PSE processes voice frequencies preserved on a normal tape recording, using electronic filtering and frequency discrimination techniques. The stress-related FM patterns, displayed on a moving strip of heat-sensitive paper, can be processed in four different modes of display for either gross or detailed analysis; because the recovery of the FM indicator spontaneously occurs with the removal of the stressing stimulus, stress in either narrative or monosyllabic speech can be evaluated.(2)

Since the development of the PSE a number of other voice stress analyzers have appeared on the market. According to the advertising literature about these devices they also detect a subaudible microtremor in the voice; thus, the theoretical physiological basis for these devices is identical to that claimed for the PSE. Some of them, however, are engineered so as to obviate the need for a graph-recorded display. Instead, they produce a direct, instantaneous analysis of the voice microtremor and signal "stress" by means of a series of flashing lights or a digital readout.(3-5)

Although voice stress analyzers have other obvious applications, they are primarily marketed as a technological breakthrough in the field of lie detection. Because contactual sensors are not necessary and because a subject need be neither present nor even aware that he or she is undergoing a lie detector test, the voice stress devices are reported to be more versatile than, yet as effective as, the traditional polygraph. In fact, it is the purported versatility of those devices and their apparent usefulness in noncontemporary and covert situations that have captured the imagination of the popular media; for example, it has been reported by proponents of voice stress analysis that Lee Oswald was truthful in his denial of shooting President Kennedy(6), that President Carter lied about Bert Lance, and that Ted Kennedy told the truth about Chappaquidick(7).

The purpose of this paper is to discuss and analyze the major empirical evidence pertaining to the claims made about voice stress analysis, in particular, the assertion that voice stress devices are effective in lie detection. Because voice stress devices are usually compared to the polygraph in the research literature (as well as in advertising literature for the voice devices) a limited comparison of results obtained with those two instruments will be made. Before discussing that research, however, it will be useful to discuss briefly some of the other claims made about the voice stress analyzers.

The Microtremor Theory

Voice stress analyzers are said to detect subaudible, low-frequency modulations in the 8 to 12 Hz range in the voice. There have been several acceptable attempts to test that claim. Shipp and McGlone(8) found no electromyographic evidence of low-frequency tremors in the laryngeal muscles in the vocalization of either truthful or deceptive utterances. Similarly, McGlone and Hollien(9) spectrographically analyzed speech samples

of subjects who read a series of electrical shocks; they found no low-frequency energy in the speech samples of either group of subjects. Inbar and Eden(10), however, have reported that their research, in which electromyographic recordings were correlated with frequency changes in the voice spectrum, does suggest the existence of low-frequency voice tremors generated by the central nervous system. Thus, the evidence supporting the premise on which the voice stress analyzers are based is not well developed and is certainly not compelling. Nonetheless, even if the microtremor explanation is incorrect, that would not necessarily imply that the devices do not detect vocal manifestations related to emotional stress.

Detection of Stress

There have been a number of studies carried out to determine the relationship between what the stress analyzers detect and accepted traditional indicators of emotional stress. Many of these studies were well-controlled, reliable assessments; the results, however, have been mixed. VanDercar et al(11), for instance, reported that they were unable to replicate their own findings of a relationship between PSE voice stress measures and heart rate and A-State scores from the State Trait Anxiety Inventory. Similarly, Brenner et al(12) were unable to obtain consistent results with a PSE voice stress analyzer in detecting stress caused by deception and that caused by performance of mental arithmetic tasks; the latter was related to voice stress patterns whereas the former was not. Lynch and Henry(13) found that PSE voice stress patterns were not effective in the identification of either stressful or unstressful words spoken by 43 college students. On the other hand, Borgen and Goodman(14) found systematic changes in PSE voice stress measures with the Stroop color/word conflict task; those changes appeared to accompany changes in other psychophysiological measures. Other investigators have also reported a relationship between voice stress measures and indicators of stress, particularly when self-reports of subjects are the criteria (12, 14-17). Thus, the available literature does not demonstrate that voice stress analyzers clearly and unfailingly detect emotional stress; the research results have been very inconsistent and the issue needs much more research before it will be settled. It is possible, furthermore, that such research may show the voice microtremor to be a voluntarily controlled component of the voice that is related to stress and anxiety in a largely unpredictable way; the reports of Inbar and Eden(10), VanDercar et al(11), and Brenner et al(12) suggest such an outcome.

Detection of Deception: Controlled Studies

Unlike the research reported pertaining to other claims made about voice stress analyzers, the well-controlled studies in which lie detection has been at issue have yielded consistent results: none of them has shown that the devices are effective in detecting deception. Because there are relatively few of these studies, they will all be discussed here briefly.

The first scientifically acceptable study of the validity of voice stress devices in lie detection was reported by Kubis(18) at Fordham University in 1973, about three years after the prototypical instrument was marketed as a lie detector. Kubis designed an elaborate series of studies to determine the relative effectivensss of the polygraph, the PSE, and

another voice stress device, the Voice Stress Analyzer (VSA), produced by Decision Control, Inc., in detection of deception. Kubis's study consisted of a "mock crime paradigm" in which some college students were assigned the role of thief, some were the lookout, and some the innocent bystander. Kubis's findings showed that neither the PSE nor the VSA was effective in discriminating between the three student roles. The PSE yielded an accuracy of 32% (27/85) in detecting individual's roles in one portion of that study and 38% (24/63) in detecting roles within each three-student grouping in another portion against chance expectancy of 33% in each case; the VSA showed an average accuracy of 36% (39/108) in those same situations. On the other hand, polygraphic analysis in Kubis's experiment showed a highly significant overall detection rate of 76%. It is of some interest to note here that Kubis also found that the conditions of his study were sufficiently motivating to produce observable behavioral differences between truthful and deceptive subjects; persons who evaluated only the subjects' behavior during testing were able to discriminate between truthful and untruthful subjects with greater accuracy (53%) than was obtained with the PSE or the VSA.

In another study, Barland (19) carried out two small-scale projects to determine the accuracy of the PSE in lie detection. In the first, he had a group of 16 college students conceal information; they were then tested with the PSE to determine if the concealed information could be detected. The results of that experiment showed that the accuracy of the PSE was at chance levels, 6.25% (1/16), a finding that Barland believed to be related to the students' lack of motivation to deceive. To investigate that hypothesis, Barland, in his second project, tested 14 actual criminal suspects -- believed to be highly motivated to deceive -- with the PSE and the polygraph. He reported initially that the PSE appeared to indicate reliable changes in the voice associated with deception and that the PSE was more effective in conditions of heightened motivation. In another study, larger in scale and more carefully executed, however, Barland(20) found that the accuracy of the PSE (averaging 51%) did not exceed chance levels (0.50) in detecting deception in criminal suspects, whereas in the same circumstances the polygraph yielded an accuracy of about 90%. Thus, Barland's original hypothesis about the effect of motivation on the effectiveness of voice stress analysis was not supported in his own research.

Nachshon and Feldman(21) reported a series of studies designed to investigate the effectiveness of voice stress analysis in detecting concealed information. In one portion of their study, 20 college students concealed cards chosen from a deck of six cards. The students were then tested with the PSE; evaluation of the PSE data by three trained evaluators yielded an average accuracy rate of 30%, a result not significantly greater than chance expectancy. In another portion of their study, Nachshon and Feldman evaluated the accuracy of the PSE in detecting cards concealed by 19 criminal suspects who were undergoing polygraph examinations. In those presumably more motivating circumstances, Nachshon and Feldman found that the PSE yielded an average accuracy of 19%, ranging between 15% and 26% for the three evaluators; the PSE did not produce an accuracy greater than chance expectancy (0.20).

Two other laboratory-based studies of the accuracy of voice stress analysis were reported by Horvath (22, 23) at Michigan State University. In the first study, 60 college students, 30 male and 30 female, attempted

to conceal numbered cards chosen from a deck of five cards while undergoing simultaneous PSE and polygraph testing. Analysis of PSE response data and polygraphic response data, the galvanic skin response (GSR) in particular, was carried out by two trained evaluators. The detection rates obtained with the PSE averaged 22.5% against chance expectancy of 0.20 and were not significantly affected by subjects' sex, repeated trials of testing, simultaneous use of polygraphic and voice stress equipment, or differences between the two trained evaluators of the PSE data. In that same study, detection rates obtained in scoring GSR responses averaged 68.6% (in the first trial of testing only) against chance expectancy of 0.20, and in all cases the rates were significantly greater than chance.

Horvath(23) also investigated whether or not the accuracy of the PSE could be enhanced by increasing the subjects' motivation to deceive. In this study 64 college students were promised a reward for successfully completing a task involving the concealment of a numbered card chosen from a deck. In spite of the evidence showing that the subjects were indeed considerably motivated by the reward, that motivation did not increase detection rates obtained with voice stress analysis beyond chance levels; the PSE averaged only 18% correct detections against chance expectancy of 0.20. On the other hand, detection rates obtained with only the GSR in that same study averaged 52%, significantly exceeding chance levels.

It is of some interest to note that in both of the studies reported by Horvath, voice stress analysis yielded lower detection rates than were obtained by analysis of each of the three physiological measures recorded polygraphically -- GSR, respiration, and cardiovascular activity(24). Thus, Horvath's findings were remarkably consistent with those reported by Kubis(18); when evaluated in similar contexts voice stress analysis did not yield an accuracy similar to that obtained with the polygraph.

In a recently reported study, Brenner et al(12) carried out a lie detection task in which the PSE was used to detect ten items of personal information concealed by 20 college students. The students were offered a reward if they were successful in avoiding detection of the items. By random scoring of the subject's PSE responses, an average of 20% of the concealed items would have been detected. The results of the analysis showed that the actual detection rates were not significantly different from chance levels. Depending on the manner in which the PSE responses were scored the detection rates varied between 18.6 and 21.0%. When only the clearest voice stress charts were separately evaluated detection rates remained at chance levels; in spite of the large variation noted in the nature of the stress responses, the variation was not related to the experimental manipulations. Brenner et al point out, moreover, that when used to detect concealed information in the same manner as they used the PSE, the polygraph has yielded detection rates as high as 100%.

Objections to the Controlled Studies

The studies discussed to this point represent the bulk of the reliable evidence reported to date about the effectiveness of voice stress analyzers in detecting deception. Although that evidence clearly does not support the claims made about voice stress analyzers, the proponents of such devices challenge that evidence on two major grounds. First and perhaps foremost among the proponents' arguments is that most of the

reliable evidence has been laboratory-based and has involved mere "game playing" situations with low levels of jeopardy. Since, they say, the devices were not designed to be used in such situations it is not surprising that they would be found to be ineffective in them. Although this argument has some ostensible merit, there are a number of points made by the proponents themselves that mitigate its authority.

According to the manufacturers and proponents of the voice stress devices they have the capability to detect absolute stress levels (3-5, 25). Presumably, such a claim suggests that not only can the devices detect whether stress is present but also the degree of stress, a claim, by the way, which is a significant feature of the training program of the manufacturers.[2] If, of course, this claim were true, then whether or not the testing situation involved low or high levels of stress would generally be of little consequence; that is, if the devices did detect absolute stress levels one would expect to be able to determine easily, for instance, which of a group of items yielded the greatest degree of stress. The evidences doe not suggest that possibility.

On the other hand, if there is a certain degree of jeopardy (stress) necessary to obtain valid results with the voice stress devices, as the proponents also claim, what is the threshold and what is the criterion by which one determines it? Is it always present in real life and never in laboratory situations? Those issues have not yet been addressed by the proponents, nor is there any information given about them in training manuals and other material offered by the proponents.(25)[2]

In explaining how the prototypical voice stress device was developed, its coinventor has stated that "We set up a known stress/nonstress situation on tape and ran experimental charts with various types of signal processing to attempt to detect any change which may occur which was notable in the stress or which would differ from the representation in the unstressed area and, proceeding with this into refinement, we were able to increase the effectiveness of this by changes in signal processing (26, p.111)." That testimony about how the first voice stress device was developed and perfected appears to be at odds with the proponents' claim that the device was not designed to detect stress in experimental situations. In that same testimony, in response to a question about what validation studies were done, it was further stated that there was "extensive use of the 'To Tell the Truth' program as broadcast over television, simply because it provided us with a difficult situation where jeopardy of the usual type of lie detection jeopardy was not present. We had singular success with this (26, p.112). ... I think the 'To Tell the Truth' (accuracy) was something like 94.7 percent (26, p.145)." At a later point in the testimony addressing the validity of the device in situations where there is less than real-life jeopardy, it was stated that "the PSE doesn't do particularly well in this unless the individual is specifically trained for that application. Our salesmen can do it. The usual PSE examiner is not taught to do that. That is not what they're using it for (26, p. 129)."

[2] Personal notes from PSE training course, sponsored by Dektor, Inc., Springfield, VA, December 1975. See also Refs 2 and 4.

The inconsistency between the claims for and about voice stress devices, and the proponents' major objection to the laboratory-based studies, is obvious. On the one hand, the devices were not designed to be used in experimental sitautions; on the other, that is precisely how they were developed and validated. On the one hand, the devices are not effective in experimental situations because the stress levels are too low; on the other hand, it is not the devices that are at fault here, since salesmen can apparently be taught how to detect low-jeopardy lies. Thus, it is far from clear why those who have been trained to actually use voice stress devices in detecting deception have been unable to demonstrate their validity in controlled situations.

A second objection made to the studies about voice stress devices is that the opeators in those studies did not use valid chart reading techniques, that is, that they did not analyze the response data in a proper manner(25). This objection, like the one already discussed, does not square with the evidence. In each of the lie detection studies discussed previously (12, 18-24) the response data were analyzed by evaluators trained and certified by a major manufacturer as being qualified to interpret data. Moreover, it is clearly expressed in those studies that the criteria advocated by the manufacturer were indeed those that were applied in analyzing the data.

A more telling point in response to this objection, however, is that regardless of how data are scored there is very little agreement among raters on voice stress responses. Correlation coefficients in the reported studies are generally quite small and strongly suggest, as Brenner et al have reported, that "unreliability is built into the basic scoring procedure and (is) not simply a reflection of inexperience (12, p.352)." In fact, there are at least two reports that show that untrained or inexperienced evaluators agree as often as, if not more often than, experienced evaluators, although neither judge repsonse data very accurately. In one of these reports, an unpublished study by Worth and Lewis,[3] it was found that an untrained evaluator had higher detection rates in a laboratory situation than a trained evaluator, 58% versus 50% where chance expectancy was 0.25. In the second, more recent report it was found that a manufacturer's employee who trains voice stress operators did considerably worse (less agreement with a polygraph-based criterion) in analyzing response data from real life situations than did two trained by less experienced evaluators. In no case did the three raters agree in even 50% of their evaluations, the agreement rate between the two inexperienced evaluators being only 32% whereas the agreement rate between the employee and the other two evaluators averaged only 40% (27). These low rates of agreement, of course, merely reinforce the various findings showing the low validity obtained with the voice stress devices.

Controlled Field Studies

Two reliable, independent studies deserve special mention at this point. Each of these studies involved an evaluation of the PSE in field situations (criminal testing); therefore, there can be no objection to

[3] J. Worth and B. Lewis, "An Early Validation Study with the Psychological Stress Evaluator (PSE)." Unpublished paper, Washington and Lee University, Lexington, VA, 1972.

them on the ground that they were carried out in an artificial setting. Furthermore, in one of these studies the response data were evaluated by three different persons, all of whom were certified as competent analysts by the manufacturers. Thus, there is little doubt that the data were evaluated in a manner consistent with the manufacturer's guidelines.

In the first study, reported by Barland(20), 66 criminal suspects were tested using both polygraphic and PSE equipment. There was no significant relationship between the scores derived from analysis of polygraphic data and those derived from analysis of PSE data. More important, Barland assessed the accuracy of his PSE-based decisions by three criteria: confessions or guilty pleas in court, decisions made by a panel of legal experts on the basis of written documentation in each case, and the outcome in each case in which there was an independent judicial decision made. Barland's results showed that the accuracy of the PSE was not significantly greater than chance expectancy (0.50). Regardless of which of the three criteria as used as the standard of ground truth, the accuracy in each instance averaged about 50%.

A more recent field-based evaluation of the PSE was carried out by the Department of Commerce in Virginia. In that study, the Department of Commence, the Virginia State Police, and Dektor, Inc., agreed on the design of a study in which blind PSE evaluations were compared to results obtained in polygraph examinations of persons involved in actual criminal investigations. For that purpose Dektor, Inc., trained and certified two operators. Those two operators and an employee of Dektor independently analyzed PSE data in 40 cases in which complete data were available. When the PSE results in those 40 cases were compared to the polygraph-based outcomes there was no significant association between the conclusions reached by the two methods; the PSE results agreed with the polygraph outcomes, on the average, in 39% of the cases, compared to the 33% agreement that would be expected by chance(27, p.16). It is of some interest to note that the PSE operators performed slightly better when their results included PSE data that they claimed were "unusable" than when those data were excluded and that "substantially the worst performance was recorded by the Dektor employee"(27, p.17). Thus, the authors of this report conclude that "by all conventional standards of proof we have to regard the validity and reliability of the Psychological Stress Evaluator as unproven. Indeed, it appears that by and large its validity and reliability are not only unproven, but rather are disproven (27, p.19)."

Analysis of the Reports of Voice Stress Users

Although all of the reliable, independent studies have shown consistent results -- whether they were laboratory or field-based -- there are several other reports that, according to the proponents of the voice stress devices, support their claims for the effectiveness of those devices in detecting deception. None of these reports, however, meets generally accepted standards within the scientific community; for that reason alone they are of dubious value. Nonetheless, because these reports are the only ones that buttress the proponents' case they will be briefly discussed here.

In 1972, M. Kradz, in an unpublished paper,[4] reported that he had carried out both polygraph and PSE testing simultaneously on 42 criminal suspects; one additional suspect was tested with the PSE only. Of the 43 suspects tested, 27 were said to be "cleared of suspicion" on the basis of the PSE testing; 21 of those were corroborated as innocent by "independent investigation." Of the 16 suspects "not cleared" by the PSE the guilt of each was said to be established by additional investigation or confession or both. Kradz claimed that his results showed that "100% accuracy was produced in those 36 subject examinations for which complete and concrete corroboration was, or later became, available."

Unfortunately, Kradz's report did not reveal a number of details about his method that are critical to a determination of what his findings might actually suggest. For instance, it was not indicated precisely how the actual guilt or innocence (ground truth) was established for each of the suspects, nor was it clear who carried out the "independent investigation" that apparently established the ground truth criterion Kradz used. When asked how he had ascertained ground truth in his study, Kradz testified that he used "independent physical evidence" such as "fingerprints, finding of the weapon, the deceased, stolen property, and questioned documents, (26, p.196)." And, when asked if he had used confessions to establish ground truth, Kradz replied: "Oh, no, not even eyewitnesses (26, p.197)," although his written report states that an "admission of guilt" was used to corroborate guilt in 13 of 16 cases in which suspects were "not cleared." In fact, according to the written report, in 25% of those cases an "admission of guilt" was made before the "independent" investigation. Kradz further testified that he did not use the outcome of trials in which the suspects were involved because "in two cases we disagreed with that (26, p. 197)." He said he himself determined when the evidence was sufficient to establish that the "PSE was worthy of use in criminal justice (26, p.200)." The latter statement suggests that the independence of Kradz's "independent investigations" is questionable.

Although Kradz has not yet clarified the details of his method,[5] another version of his report,[6] which is distributed as the original study "reproduced verbatim in its entirety," further confounds the issues. This report describes a method and a number of critical details that are different from what the original report described. The second version, for instance, reports that an unspecified number of the PSE charts were evaluated "in the blind," where as the first version pointed out that both the subject and the examiner (Kradz) discussed during the testing what was indicated on the PSE charts. Moreover, the second version is even less clear about how ground truth was established than was the first version.

Because of the conflicts between Kradz's original report, what he has stated in testimony, and the recently distributed copy of his report, it

[4] M. Kradz. "Psychological Stress Evaluator: A Study." First version of an unpublished paper distributed by Dektor, Inc., Springfield, VA, dated 1972.

[5] Personal communication with M. Kradz, Dektor, Inc., Springfield, VA, 24 Jan. 1980, 20 Feb. 1980, and 10 March 1980.

[6] M. Kradz, "Psychological Stress Evaluator: A Study." Second version of an unpublished paper distributed by Dektor, Inc., Springfield, VA, dated 1971.

is not possible to determine what Kradz actually did. The serious and unexplained methodological deficiencies in the Kradz study clearly indicate that that study does not meet generally accepted scientific standards; his reported findings, therefore, are of questionable value in assessing the validity of vice stress analysis.

One of the coinventors of the PSE has reportedly claimed that the device is "96.78 percent effective (7, p.F-2)." That claim apparently is based on a statistic reported by another voice stress proponent, Heisse, as a result of a study he carried out to investigate the "reliability and validity" of the PSE.[7] In his study, Heisse selected 53 cases (contributed by PSE users) in which the PSE was used to determine the truthfulness of the suspects (some of the "suspects" were applicants for employment, not persons involved in criminal investigations). Twenty-six of the suspects were apparently known to have been deceptive (to have shown "some form of deception") during their PSE testing; 27 were known to have been truthful. In each case ground truth apparently was established by a confession that indicated either the deception of the guilty suspect or the truthfulness of the innocent suspect. Of the 53 separate suspects tested, 25 of them were involved in three separate investigations.

Heisse asked 12 PSE users to evaluate the PSE charts of each of the 53 suspects and to determine whether each suspect was "truthful" or "deceptive". He reported his findings thusly: "There are 258 acceptable interevaluator replies. Among the replies there are 10 errors. ... Hence, the interevaluator reliability is 96.12 percent." Later in his paper he reports: "The compliance between evaluators and the known results with 258 evaluation replies is 96.12 percent. If examiners are included in this group ... the reliability jumped to 96.78 percent."

Heisse's report, like that of Kradz, fails to disclose a number of important methodological details. Precisely how the cases were sampled, for example, is not revealed, nor is any procedure identified that would have ensured the independence of those persons who evaluated the response data. Since 25 of the suspects were involved in the same three investigations, it is certain that the tests carried out on those persons in each investigation were not independent; yet, Heisse does not indicate how that issue was dealt with, if at all. Although there are other serious methodological problems evident in the Heisse study, it is also the case that his findings were not correctly interpreted. Heisse himself, for instance, has stated that contrary to what his report suggests his findings only deal with the issue of reliability -- how consistently his evaluators interpreted his data -- and not with validity.[8] But, proponents often use his statistics to support their claim that voice stress analysis is 96.87% accurate. Judging from what was reported by Heisse and Kradz, such a claim is unfounded.

[7] J. Heisse, "Audio Stress Analysis: A Validation and Reliability Study of the Psychological Stress Evaluator (PSE)," unpublished manuscript dated 1 Feb. 1976, available from the author, 144 Cliff St., Burlington, VT.

[8] J. Heisse, Burlington, VT, personal communication, 11 March 1980.

A final study claimed to support voice stress analysis is a paper reported by Dahm,[9] who sent questionnaires to 423 users of the PSE; of those, 46 responded to questions about several characteristics of their use of the PSE. Dahm's major findings were reported as follows. First, he said that polygraph and PSE examinations were in agreement 5037 times in 5045 cases, "for a correlation of 99.84%." Second, "Based upon 10,202 PSE examinations ... there was not one case in which the PSE had been found in error (28, p.231)." It is, of course, clear that Dahm's data represent merely the unsubstantiated opinions of only a small number of PSE users; they are not sufficient to indicate whether or not voice stress analysis is a valid means of detecting deception.

Thus, the Kradz, Heisse, and Dahm reports constitute at best merely testimonial, not scientific, evidence of the effectiveness of voice stress analysis. The merits of those studies notwithstanding, however, it is interesting that all of them were reported by proponents of voice stress analysis after 1971; neither the manufacturers nor the other proponents of voice stress devices have yet produced a report of research which was carried out before the devices were publicly marketed. The developmental research supporting the validity of the devices in lie detection is, curiously, not available. It is also important to point out that the findings in the proponents' studies regarding the accuracy of voice stress analysis have not yet been replicated in any objective, independent research. One manufacturer, asked for proof of the validity of his voice stress analyzer, reportedly sent to author B. Rice(29) a packet of ten studies, all of them very favorable. The studies were unpublished, two were apparently performed by an independent testing firm. When Rice investigated the firm he reportedly found that its president was the manufacturer of the voice analyzer. When that manufacturer was asked who did the other studies, "He replied cheerfully, 'I did. I did them all.' (29, p.72)."

Discussion: The Polygraph and Voice Stress Analysis

In the formative years of field lie detection, a number of the proponents of the method claimed great success using not a polygraph but merely a measure of one physiological response system. As examples, Marston(30) advocated the use of a "systolic blood pressure test." Benussi(31) a test based on respiratory patterns, and Summers(31) a test based on a measure of electrodermal response(GSR).Although it has been demonstrated today that each of those response systems is useful in detecting deception (32,33), it has also been shown that each makes a separate and independent contribution to the process of lie detection(32,33). Thus, the polygraph, which simultaneously monitors a number of physiological systems, represents a technological advance over the devices used earlier. It is also certain, however, that as important as it is to record a number of response systems, the manner in which polygraph testing is administered and the way in which polygraphic data are interpreted are of at least equal importance(34,35). It is recognized today that lie detection is a difficult, complex, and subtle process in

[9] A. Dahm, "Study of the Field Use of the Psychological Stress Evaluator," unpublished paper distributed by Dektor, Inc., Springfield, VA, undated.

which the polygraph instrument itself merely provides the foundation for the structure of what is called the polygraph technique, the art, if you will, of detecting deception with a polygraph instrument. Hence, since the polygraph itself does not detect lies, the technique is not infallible. There is, not surprisingly, considerable controversy about how valid (accurate) the technique is; nonetheless, even the most severe critics acknowledge that the evidence clearly shows an accuracy sufficient to justify the use of polygrah testing for certain purposes.(36)

Voice stress analysis, according to its proponents, promises a technologically advanced, simple, easy, almost infallible method of detecting deception, that uses, moreover, information collected from only one response system, the voice(25). Thus, some of the claims made about voice stress devices are not entirely dissimilar to those made in the formative years of polygraphic instrumentation. There, however, the similarity ends. there is no compelling evidence that any voice stress device actually detects a signal (physiological change) that is the clearly and dependably related to stress resulting from deception or any other cause. In fact, the reliable evidence that does exist shows that there is no relationship between what the voice stress devices detect and deception-induced stress. Given those facts, by the way, federal and state courts and state regulatory agencies(27, 37, 38) have recently ruled against proponents of the voice stress devices who have sought the same recognition afforded those who use polygraphic instrumentation.

The developmental history of the polygraph technique shows a conscious, continuing concern with standards of selection and training of polygraph examiners, in clear recognition of the fact that the technique is a complex endeavor in which the polygraph instrument plays a necessary but relatively subordinate role to the technique itself (29-32). Voice stress proponents deny that developmental history and maintain that voice stress analyzers represent advanced technology that, among other things, "simplifies chart-reading and greatly reduces both the training time required and the subjectivity of the chart reading (25, p.64)." The evidence, of course, most clearly does not support such assertions. It is important to point out, however, that even if the evidence showed a dependable relationship between deception and what is recorded by voice stress analyzers, the historical, scientific, and practical lessons and developments in the lie detection field are proof enough of the falsity of such assertions as those made by proponents of voice stress devices. In other words, there can be no device, no instrument, no new technology that makes lie detection any less complex than it has already been shown to be.

In summary, the promise of voice stress analysis in the lie detection field is not and may never be a reality. All of the reliable evidence now available shows that none of the voice stress devices is useful in detecting deception; the fact that the precise relationship between the components of the voice spectrum and emotional states has not been adequately specified suggests a formidable obstacle to be overcome before analysis of the voice may prove of value in lie detection. The fact that voice stress devices have apparently been accepted rather uncritically by some law enforcement agencies, and for some forensic science purposes, is a development which, judging from the available evidence, cannot now be justified.

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A REPORT OF THE COMMITTEE ON THE POLYGRAPH

STATE OF ISRAEL

Jerusalem, January 1981

Published herein are excerpts from the official judicial committee report prepared for the Government of Israel. The original report was of eighty pages, and published in Hebrew. These excerpts include the summaries of their views on reliability and validity, arguments for and against the polygraph, the Committee's conclusions, their recommendations, and the Table of Contents of the entire report. [Ed.]

Table of Contents

Summary From Hebrew

Notes - Chapters 1 - 4:

Chapter 1 -

The Committee on Polygraph was appointed March 21, 1978 by Israel's Justice Minister.

The Committee held 21 sessions. International experts testified.

Chapter 2 -

Weitzman Institute had tested a device which tests the person without attaching anything to the body - (still in experimental stage).

Another device has been marketed testing voice fluctuations (still tentative, hence not referred to in this report).

Summary of Chapter 5

Reliability and Validity of Polygraph

(a) There's no such thing as a "lie detector". There is only a tool called polygraph which has limited use.

(b) Reliability of polygraph refers to whether different readings analyzed by different testers will lead to identical results.

Validity refers to whether the test leads to the right conclusion regarding tested person's answers.

(c) Tests of polygraph reliability and validity are few and were conducted mainly in lab-type situations, where emotional involvement is minimal, or in field cases, where actual cases of polygraph use were given to another team to produce its own conclusions and were then compared with original conclusions. A jurist team then checked results to determine guilt. Another test was trial outcome. A third test was the suspect's admission of guilt.

These studies, conducted by top polygraph experts in the U.S., show that over 90% of cases gave accurate results, while among the inaccurate results, most were false-positive.

Latest study was Raskin et al.

Studies have been severely criticized. Lab-type studies were called unreliable, while field studies are only reliable where the suspect admitted guilt. Also, it was pointed out that studies were not done by outside, objective scientists.

Detailed criticism of tests can be found in three places.

(1) Supreme Court Justice D.R. Morand, Ontario, Canada, issued a report in June 1976, criticizing the use of polygraph.

(2) In People v. Barbara case the court decided to use polygraph tests with caution, since no objective, reliable tests are available.

(3) The above-mentioned Congressional Committee report takes a stand against polygraph. Raskin found many mistakes and deficiencies in this report. Committee majority opinion was against use of polygraph in any federal institution, while minority opinion suggested using it only for national security.

The Israeli Polygraph Committee decided to take a qualified look at the Congressional Committee report, while taking a more serious view of the Morand and Barbara reports.

The Israeli Committee heard witnesses on the subject, mostly polygraph workers who, as expected, defended the device. In the Barbara case, where many testimonies were given on the subject, polygraph workers supported use while Amici Curiae like the State Defense Attorney's Office, ACLU of Michigan, as well as the General Prosecutor's office, opposed it as acceptable evidence in the Barbara case.

Among witnesses who appeared before the Israeli Committee were:

1. Professor Raskin, a psychologist, who supports polygraph use despite results of less than 100% accuracy, since accuracy percentage is very high. Results should be left to judgment of the court. Device should generally be used for defendants rather than witnesses. The device should be used properly - by experts, using several readings. Guilt cannot be established solely on test and the test is not to be used for employment or job promotion, except in national security cases.

2. Dr. Barland, co-author of Raskin et al. study, a psychologist with a doctorate in polygraph use, points out that proper use of the device produces 80-95% accurate results when the polygraph technique is applied to black and white rather than "gray area" cases. Results of the test can be part of evidence rather than full evidence, and should be checked by an additional, objective examiner. Barland disagrees with Raskin on the use of the test for employment, provided privacy of tested person is not invaded.

3. Dr. Gershon Ben Shakhar, who teaches psychology at Hebrew University, has been conducting psychophysical and other polygraph-related tests since 1965. He maintains there is not sufficient data regarding the validity of polygraph. Some tests were like tossing a coin. Statistical data may lead to wrong conclusions. Example: If tests find that 99 out of 100 suspects are innocent, "success" may be put at 99%! Another problem is contamination, vis-a-vis, examiner's extraneous data and examiner's expectations before results are known. The Control Question Technique does not insure accurate results, since there is no logical or psychological base to assumption regarding a guilty person's focusing on a critical question while an innocent person chooses a control question. Moreover, psychological knowledge shows that physiological reactions to fear, lies, surprise, joy, stress, etc. are not distinguishable. Hence, polygraph errs mostly re false positive, implicating the innocent. The Guilty Knowledge Test, on the other hand, is most accurate, since one who does not know the details will not react differently to the important details than

to unimportant details (like the color of the stolen car). However, this method is not used widely.

Summary of Chapter 6

Arguments for and against Polygraph

a) Pro -

1. High rate of accuracy, reaching 90%.

2. Actual results achieved in discovering data known to subject in the investigated matter.

3. There is hardly a deed or misdeed involving human beings, which is investigated or prosecuted, in which one could not use a polygraph. Moreover, in many cases a person who wants to prove his/her innocence can only do so by means of a polygraph.

4. In many cases a polygraph test led to accurate results which were verified by suspect's confession after the test showed he/she was not telling the truth, or by finding sufficient evidence which proved that the polygraph test was accurate.

5. In many instances, especially in the U.S., polygraph test results were accepted by the prosecution as proof of innocence and led to closing cases.

6. Although polygraph experts admit their results are not always accurate, the usual judicial or legal methods are not always accurate either. These experts maintain that their rate of accuracy is not smaller than, say, graphology or medical testimony about one's physical or emotional state, which are acceptable evidence.

b) Con -

1. There has not been an objective, scientific study to the effect that polygraph tests help tell the truth from the lies, based on physiological reactions.

2. Physiological reactions are affected by various factors and at best show tension which, rather than prove truth or lies, relate to excitement, fear, anxiety, etc. Control questions and similar techniques are primitive, standardized, and do not allow for the special circumstances of each case.

3. Physiological reactions differ in each person, which polygraph does not take into account.

4. There is no scientific proof that one could not control to some extent one's physiological reactions and thus "beat the system."

5. The question of which kind of individual person cannot be tested by polygraph or who may produce erroneous results is yet to be determined.

6. Tests are determined not by the data itself but by the examiner, who is subjective. Hence the test is more psychological than physiological. The verdict is thus given by the examiner rather than the court.

7. The device is primitive and is often found to be technically deficient. Also, outside factors, like temperature, wind, uneasy seating, and faulty connection, may distort results.

8. The polygraph operator has to be highly qualified. Wide use of the device will lead to use by less qualified people.

9. Wider use of polygraph may lead to wider knowledge among those tested as to the Card Test techniques and the covert observation of the person tested. This may affect the effectiveness of this technique, as well as the fictitious situation and the Control Question technique.

10. Studies on reliability and validity of polygraph are not highly reliable. Other studies have shown that polygraph tests produce arbitrary results.

11. Polygraph is still in the experimental stage and is yet to be recognized by scientists.

12. Use may abridge civil rights, such as self-incrimination, or privacy. Albeit a person has to consent, often one is pressured to consent by circumstances. Once consent is given, it is too late to change one's mind.

Summary of Chapter 7

Committee Conclusions

a) Licensing Polygraph Examiners

All witnesses agreed that polygraph examiners should be licensed by the state (of Israel) to insure professional standards and high moral character. The question was raised regarding licensing private investigators. The Committee is in favor of separating the two professions to avoid contamination.

As for qualifications for examiners, the question was raised whether a bachelor's degree in psychology, physiology or sociology was sufficient, or was a master's necessary. It was decided to make do initially with a bachelor's degree.

In drafting a bill for licensing polygraph examiners, attention was given to defending the rights of the examined person. The relevant section (#7) in the Private Investigators Law was used.

b) Reliability and Validity of Polygraph

1. The widespread belief that polygraph is a sure method of arriving at the truth is unfounded. Not even polygraph advocates are willing to support it. Such a belief may lead to false expectations among the public.

2. All pros and cons for the use of polygraph have been weighed, and the Committee decided that in light of the fact that no advanced country uses such tests as conclusive evidence, Israel cannot be the first country to do such a thing. It is more useful in legal or quasi-legal situations outside the court, where civil rights are in question, must be limited.

3. Despite the above reservations, the Committee regards the polygraph as being useful for criminal investigations, especially, but also for civil investigations. As for use for employment, there has been such use in a limited way, and there is no reason to stop it.

4. In view of the above, polygraph tests are not to be used as evidence in criminal cases. Nor should the court be told whether the defendant agreed or not to be tested, even if the defense and prosecution agree on the matter. The test cannot be used to reach a verdict.

5. In civil cases, where parties are allowed to decide on their civil rights, test results can be used as proof before the court by mutual consent. Also, by mutual consent, the court may rule according to such results. The examiner is to be agreed upon by the parties.

6. In deliberations of judicial or quasi-judicial bodies which must follow evidence laws as the court does, polygraph tests cannot be used as proof. Bodies which can deviate from evidence laws can use such tests as proof. Judicial bodies which are not governed by evidence and arrest and search laws may use the tests.

7. There is no need to legislate regarding use of polygraph by legal public bodies without judicial authority.

8. The Committee looked into the question of whether a distinction should be made between the acceptability of tests in cases of determining truth and lie and in cases of determining the data suspect may have by using the Peak of Tension technique, since the latter technique is more accurate. It was decided that not enough data about the technique is yet available in Israel, and as Israel Police expands use of this technique, a more accurate determination on this question will be possible at a future date. In the meantime, no distinction will be made.

9. Committee member, Police Commander Kaplan, differs on some of the Committee's conclusions about the validity and realiability of the polygraph. His divergent opinion follows.

Summary of Chapter 8

Committee Recommendations

a) To pass a law on licensing of polygraph examiners. A sample bill is enclosed.

b) To amend evidence order. Text enclosed.

c) Commander Kaplan proposes that the evidence order will state that Peak of Tension test results be accepted as evidence, as explained in his ensuing opinion.

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THE POSITIVE CONTROL CONCEPT AND TECHNIQUE

By

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This paper presents the "Positive Control" concept, its history, theoretical foundation, flexibility, and applicability as a field lie detection technique.

For more than a quarter of a century the polygraph profession was dependent upon two general types of interrogation techniques; (1) the Relevant-Irrelevant Technique (RIQ), and (2) the Peak of Tension Test (POT). Polygraphists such as John Larson, William Marston, Leonarde Keeler, and Clarence Lee used these techniques extensively in the laboratory and in the field.

Around 1943, John Reid, an attorney and polygraphist, proclaiming the RIQ contained a weakness was inspired to develop the "comparative response" question (Reid, 1947). Today this question is known as the "earlier in life" control question. This innovation offered an alternative and is considered to be one of the major contributions to our profession. Several major techniques developed over the next twenty-five years made use of this control concept. The era of the control technique has brought forth other developments in our profession. However, there are problems inherent in the concept.

If one is going to compare an examinee's psychophysiological reactions to different questions to determine which reaction is greater, one must first be able to say that the questions were equal at the beginning of the examination; that the control and relevant questions were balanced. However, to accomplish this the examiner would have to have a way of ascertaining the examinee's life experiences, thoughts, and fears. This is impossible. Therefore, we have no valid way of determining if the control and relevant questions which are to be compared at the end of the examination were balanced at its beginning. Herein lies the inherent weakness. The examiner must strengthen or weaken the control question by the addition or omission of certain emotional words, or by the emphasis or lack of emphasis on the control question in the pre-test interview. These decisions are based on the examiner's opinion of the subject's perception of the emotional importance of the control question as it relates to the subject's perception of emotional importance to the relevant question. Addition difficulties with control question formulation stem from difference of opinion regarding the proper development and wording of the control question.

The "positive Control" concept in the detection of deception involves dichotomous answers to identical questions, one of which must be truthful and one of which must be a lie (Reali, 1978). This dichotomous approach

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is not new or unique since it can be traced to Leonarde Keeler (Lee, 1953).

Keeler theorized a technique consisting of the following four questions and mandatory examinee responses:

1. Are you innocent? "YES"

2. Are you guilty? "YES"

3. Are you innocent? "NO"

4. Are you guilty? "NO"

Questions one and two, and questions three and four, each make up a dichotomous set; only one answer in each set can be true and the other answer must be a lie.

Keeler theorized the truthful examinee would show a greater psychophysiological reaction to questions two and three. The truthful examinee would not only be lying to these questions, but would, in essence be confessing to a crime he did not commit.

Keeler believed the deceptive examinee might react in one of two ways:

1. Greater reaction to questions one and four, since they would be denials of wrongdoings, and lies.

2. Great or equal reactions to all four questions; to questions one and four because they are lies, and to questions two and three because here the deceptive examinee is actually confessing to the wrongdoing. In other words, Keeler theorized that inconclusive results, using this dochotomous approach, were indicative of deception.

At a later date polygraphists began experimenting with variations of "yes-no" type techniques. These techniques usually consisted of asking questions after the exmainee was instruction to answer all of them "yes". The same questions were then repeated with the examinee being instructed to answer all of them "no". Comparisons were made between the examinee's psychophysiological reactions to the "yes" and "no" responses to each question. This technique had two very apparent weaknesses which led to its extinction:

1. Being instructed to answer "yes" or "no" to a question, even if it was a lie, lacked the psychological impact of an examinee cognitively deciding to offer a deceptive response.

2. The litany of all "yes" or "no" answers afforded the examinee a very good opportunity to disassociate his thoughts from the issue.

In the late fifties or early sixties, a technique known as "The Forced Confession Technique" was developed. Due to the negative connotations of its name, Forced Confession, the technique was renamed the "Comparative Response Technique". This technique requires each question to be

asked twice during a single chart. The first time a question is asked the examinee is instructed to answer with is alleged truth. After sufficient time to allow for reactions, the question is repeated and the examinee, as previously instructed, answers with an alleged lie. Comparisons are then made between the examinee's psychophysiological reactions to each question's alleged truth and lie answer. If the reactions to the alleged truth is greater than the reaction to the alleged lie the examinee is diagnosed as being deceptive, and visa-versa, regarding that question. For example:

Question	Response	Reaction	Determination
Did you kill John?			
Alleged Truth	No		Truthful
Alleged Lie	Yes		
Did you kill John?			
Alleged Truth	No		Deceptive
Alleged Lie	Yes		

In 1969 Richard Golden presented a paper on a "Yes-No" technique he attributed to Morton Sinks. Golden's description of the technique was identical to that of the Comparative Response Technique. However, Golden discarded Sinks' method of chart interpretation. Where as Sinks compared the reactions to each alleged truth and lie response, Golden compared the overall reactions in the relevant question sets with the overall reactions to "earlier in life" control question sets. Golden concluded that the technique was as accurate as existing techniques in detecting deception, and more accurate in identifying truthful examinees.

In 1978, Silvestro F. Reali wrote a paper explaining a technique he developed in 1971. This technique is similar to the Sinks and Comparative Response Techniques. Reali completely omitted the "earlier in life" control questions from the test structure, and instructed the examinee to answer each question first with their alleged lie, and then to answer with an alleged truth when the question was repeated.

The Positive Control concept is easy to understand and apply. As in the Reid control concept, the Positive Control concept can be adapted to any technique test structure. The following are examples of existing test structures using the Positive Control concept:

BACKSTER "YOU" PHASE

		Subjective Lie	Subjective Truth
14 C	Were you born in the U.S.?	NO	
14 R	(Repeat 14 C)		YES
25 C	Are you convinced that I will not ask you a question during		

	this test that has not already been reviewed?	NO	
25 R	(Repeat 25 C)		YES
39 C	Do you intend to answer each question truthfully regarding the death of John Doe?	NO	
39 R	(Repeat 39C)		YES
33 C	Did you kill John Doe?	YES	
33 R	(Repeat 33C)		NO
35 C	Regarding the death of John Doe, did you kill him?	YES	
35 R	(Repeat 35C)		NO
26 C	Is there something else you are afraid I will ask you about, even though I told you I would not?	YES	
26 R	(Repeat 26C)		NO

ARTHER KNOWN LIE TEST

1 C	Do you live in the U.S.?	NO	
1 R	(Repeat 1C)		YES
3T C	Did you conspire with Ralph Bald to kill John Doe?	YES	
3T R	(Repeat 3T C)		NO
3K C	Do you know for sure who killed John Doe?	YES	
3K R	(Repeat 3K C)		NO
5 C	Did you kill John Doe?	YES	
5 R	(Repeat 5C)		NO
8 C	Were you present when John Doe was killed?	YES	
8 R	(Repeat 8C)		NO
9 C	Did you shoot John Doe?	YES	
9 R	(Repeat 9C)		NO
11 C	Are you now telling me the entire truth about the death of John Doe?	NO	
11 R	(Repeat 11C)		YES

Each question in the structure is asked twice. The first time the question is asked the examinee is instructed to answer with an alleged lie. When the question is repeated the examinee is instructed to answer

with the alleged truth. Some examiners,however, instruct the examinee to answer first with the alleged truth and then with the alleged lie. The answers to each question are called the "Subjective Lie" and "Subjective Truth", which together make up a "Control Set" (Reali, 1978). As in the original Sinks Technique, and the Comparative Response Technique, if the psychophysiological reaction to the "subjective lie" is greater than that emitted to the "subjective truth" the examinee is interpreted as truthful to that control set, and visa-versa.

The foundation of the "Positive Control" concept is in the following four principles:

1. The control and relevant question wording in each "control set" is exactly the same, hence, they are balanced.

2. The "earlier in life" control mechanism is no longer artificially produced by the examiner.

3. Stimulation of the control question by the examiner is not necessary.

4. Due to the first three principles, examiner input is minimal, therefore, examiner error in control question wording, stimulation, and introduction is minimal and any difference in the psychophysiological reactions to the "control" or "relevant" question of the "Control Set" is solely due to what threatens the examinee the most: the "subjective lie" or the "subjective truth".

As a theory, Positive Control is easier to comprehend than other existing techniques because its control mechanism is easier to conceptualize. There are generally three psychological theories offered to explain why lie detection works: Classical Conditioning, the Conflict Model, and Psychological Set. Of these three explanations the theory of Psychological Set is the most widely accepted. It holds that a person will "psychologically set", and exhibit the greatest reaction to whatever holds the greatest threat to his general well-being (Backster). In an "earlier in life" control type technique the truthful examinee will be most threatened by the control questions in the test structure and will "psychologically set" there, while the deceptive examinee will be most threatened by the relevant questions and will "psychologically set" there. In Positive Control "psychological set" is related to that which is more threatening in each control set; the subjective lie, or subjective truth. For the truthful subject the subjective lie will be more threatening and they will "psychologically set" there. As in the theory Keeler presented, not only are they lying to this question, but they are also making a statement against their own well being by confessing to a crime they did not commit; in legal terminology, "a statement against interest". For the deceptive examinee the subjective truth is the most threatening and they will "psychological set" there.

Since the wording of the control question (subjective lie) and the relevant question (subjective truth) are exactly the same in Positive Control, many of the problems inherent in other control techniques are either eliminated or neutralized. The examiner is completely relieved of having to properly select, word and introduce the "earlier in life" control

question. All "earlier in life" techniques were designed for use with single issue examinations and have not been validated for multiple issue examinations such as pre-employment tests. The Positive Control technique easily corrects this problem.

Emotional words which are often difficult to eliminate from relevant questions create no problems for Positive Control since the same emotional words also appear in the control question. General nervous tension and outside issues are often completely neutralized. In addition, both the layman and examinee have no problem understanding how "lie detection" works; never again to hear an examinee say, "I refuse to answer any questions which are not directly related to the issue!", as you try to establish a control question.

There are four identifiable inherent weaknesses with the Positive Control technique. If you are going to use the technique effectively you should be aware of them.

The major problem is a tendency for that portion of the control set (the subjective lie or subjective truth), which is asked first, to elicit a listening and/or surprise reaction. In other words, just hearing each question for the first time may elicit a reaction. Therefore, if the examinee is required to give the subjective lie first, there is a tendency for the diagnosis to lean toward truthfulness. If instead the examinee is instructed to answer first with the subjective truth there is a tendency for the diagnosis to lean toward deception.

The second problem that both the subjective lie and subjective truth cause an emotional imbalance for the deceptive examinee. The imbalance is created by the examinee first admitting and then denying the wrongdoing. This is one of the outcomes Keeler predicted in his dichotomous concept. In addition it is possible that the deceptive examinee should give the maximum reaction upon hearing each question in the control set for the first time. This could result in the charts being diagnosed deceptive if the examinee had been instructed to answer first with the subjective truth to each control set. However, it could result in a truthful diagnosis if the deceptive examinee had been instructed to answer each control set with a subjective lie first.

The third problem occurs when one of the control set questions in the structure becomes so threatening that the examinee becomes "psychologically set," and upon hearing that question for the first time produces a maximum reaction, regardless if the first response was to be the subjective lie or subjective truth. This problem occurs most frequently in multi-issue examinations.

The fourth problem involves the very simplicity of the concept itself. Since the examinee understands the basic principles of the concept, he or she may deliberately try to produce a "lie reaction" in the appropriate places (subjective lies). As in the Reid "Yes Test" these countermeasures are apparent and easily recognized by competent examiners.

To correct the first three problems reported the examiner can use two methods. First, administer two charts, one "lie-truth" and the other "truth-lie". This eliminates any "test lean" factor from effecting the

test outcome. Other writers using Positive Control technique have experienced only one examinee who consistently reacted on each chart to whichever part of the control set was asked first. This resulted in one clearly truthful chart and one clearly deceptive chart. The results were totally inconclusive. Examiners utilizing some earlier in life techniques traditionally would interpret these results as leaning toward truthfulness due to a weak control question. With the Positive Control technique the control and relevant question are identical, therefore, as Keeler suggested with the dichotomous concept, inconclusive results must be viewed as deceptive. In the case cited the examinee was deceptive, and later confessed. Illustration 1A represents control sets two and three of this examinee's test. She had been instructed to answer first with her subjective lie and then with her subjective truth. In control set two the greater reactions occurred in the pneumo and cardio of the subjective lie (2C) rendering an interpretation of truthful. In control set three the greater reactions occurred in the GSR and cardio of the subjective lie (3C), again rendering an interpretation of truthful. Illustration 1B is the second chart of the same examinee with the control sets reversed; she answered first with her subjective truth and then with her subjective lie. As you can see, in control set two the greater reactions now occur in the pneumo, GSR and cardio of the subjective truth (2R) rendering an interpretation of deceptive. In control set three the greatest reactions again occur in all three parameters of the subjective truth (3R) rendering an interpretation of deceptive.

Illustration 2A shows another examinee's chart at control set three, the "did you" question. This was chart one, and the examinee had been instructed to lie first, and then tell the truth. Both 3C and 3R show reactions taking place. However, illustration 2B, chart two of the same examinee, clearly shows deception (greatest reaction to 3R) when he was instructed to answer first with the subject truth and then with the subjective lie.

The examiner may also elect to start off testing with a Silent Test consisting of the questions to be asked in the Positive Control structure. This is extremely effective for multi-issue examinations such as pre-employment tests since it offers the examiner feedback as to whether there are any issues in the structure which are extremely threatening, and to observe what the examinee's tracings look like should he attempt some type of countermeasure. Illustration 3A is a pre-employment examination where the examinee emitted a good reaction in the lower pneumo to question 7 during the silent test. Illustration 3B shows question 7 in the examinee's Positive Control chart. The greater reaction is to the subjective lie (7C). Knowing the examinee reacted to question number 7 in the silent test, which indicated that the question may have been an intense issue for the examinee, the examiner wondered whether the reaction was indicative of truthfulness or if it resulted from hearing a perceived threatening question for the first time. Therefore, the examiner coughed, causing a deliberate distortion, and instructed the examinee that the question would have to be repeated. Illustration 3C shows question 7 being repeated and the clearly deceptive reactions (greatest reactions to 7R) the examinee produced.

Summary

The Positive Control technique is currently being used as a primary technique by several hundred examiners throughout the country. In this paper the writers have attempted to give a complete report of the history, theory, and applicability of Positive Control. Four problems that have been experienced by examiners in the field have been discussed. The causes of and the solutions to these problems have been explained. It is hoped that this paper will stimulate fellow examiners to consider the use of the Positive Control technique as an alternate control method of testing.

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ILLUSTRATION TWO(A)

NG CHICAGO, IL. STOELTING CHICAGO, IL. STOELTING CHICAGO, IL.

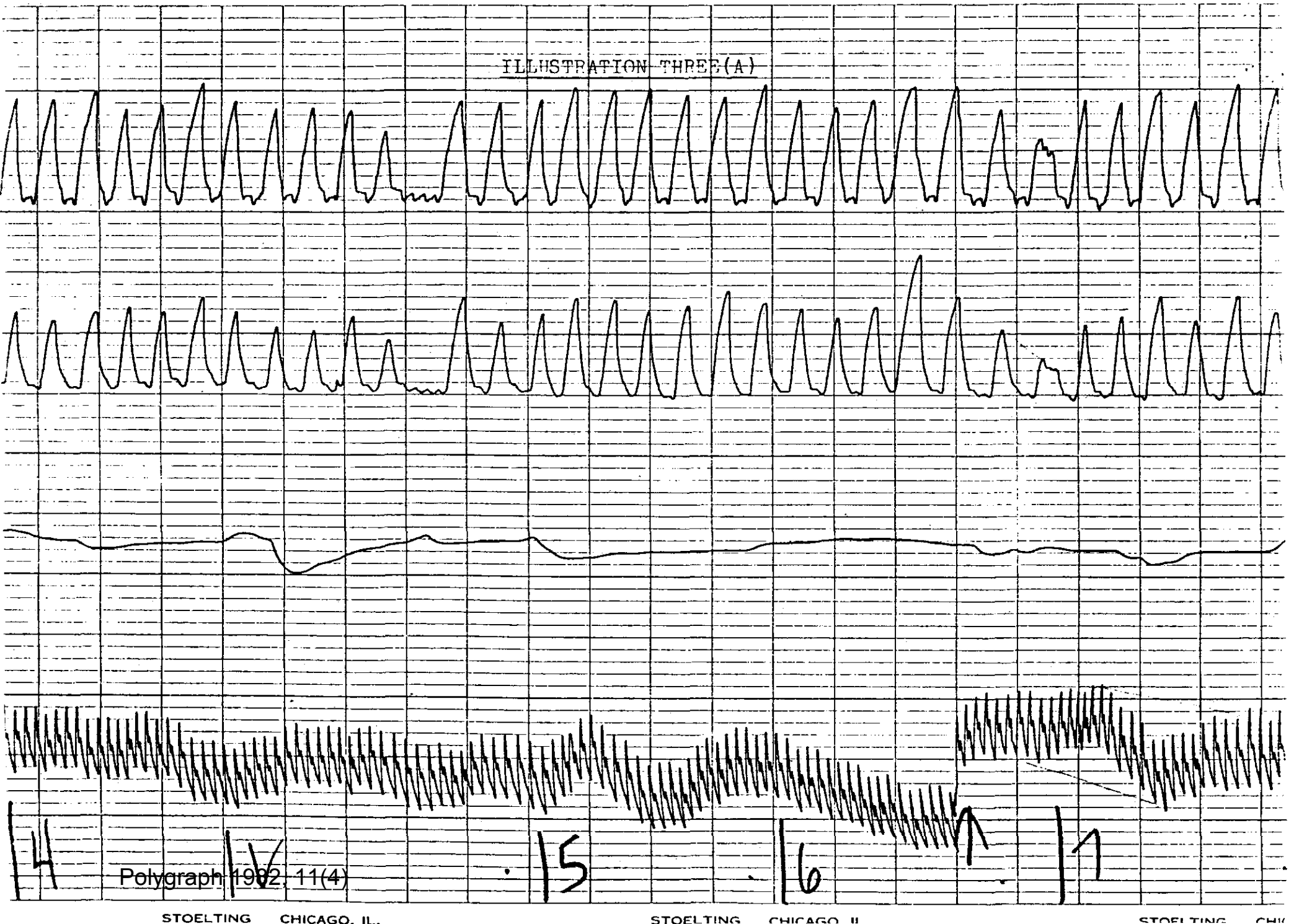
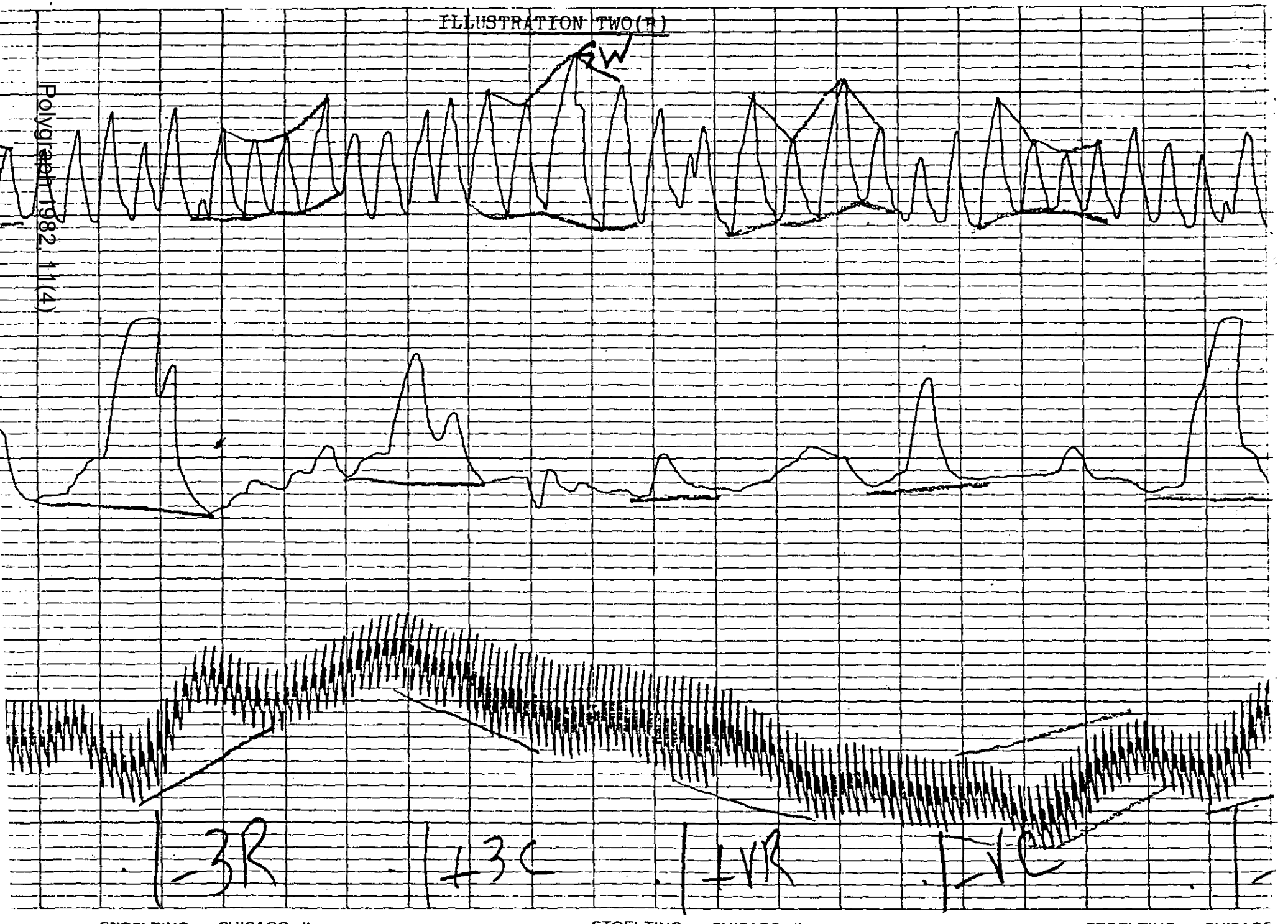


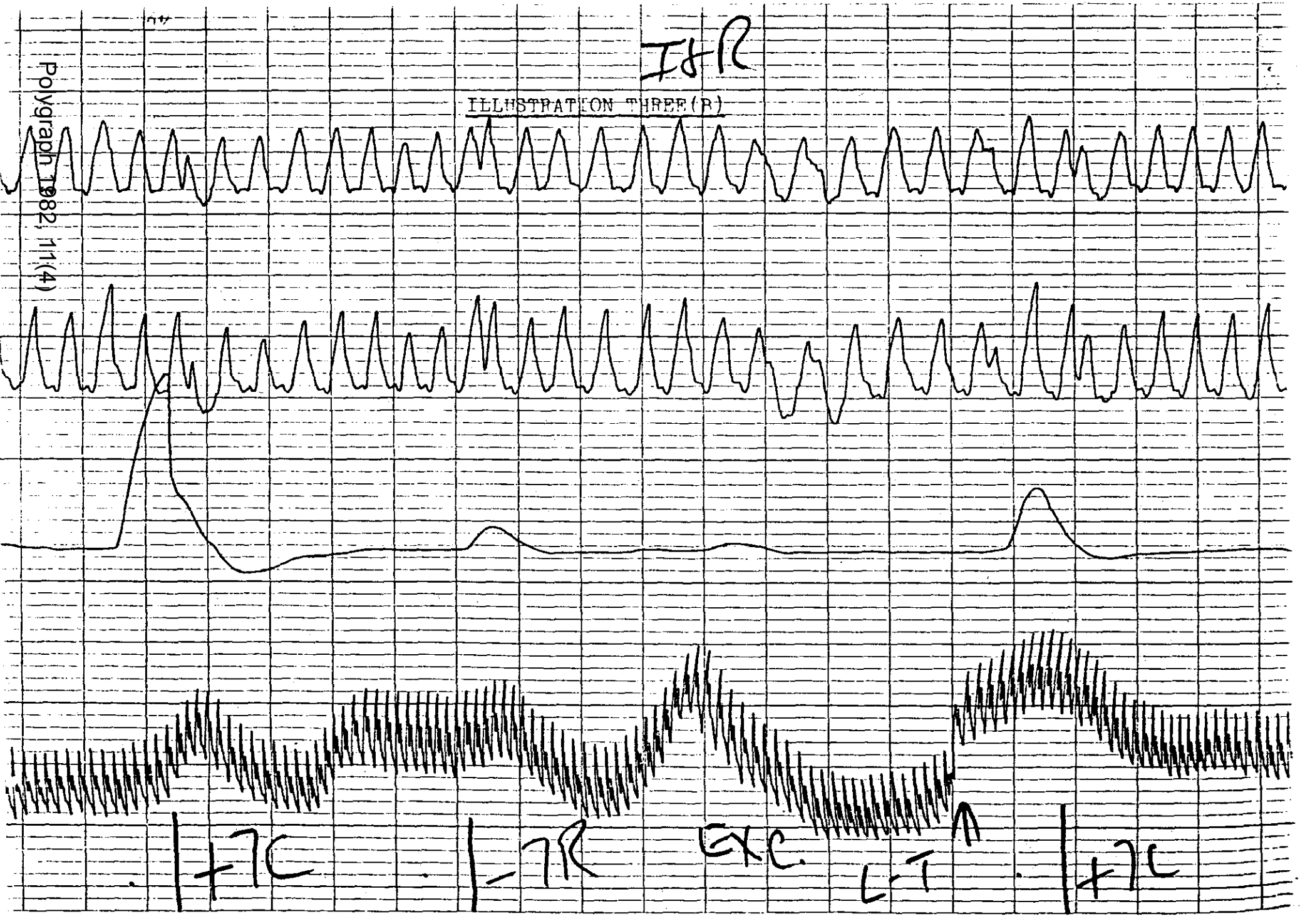
ILLUSTRATION THREE(A)
14
15
16
17

ILLUSTRATION TWO(R)



Polygraph 1982, 11(4)

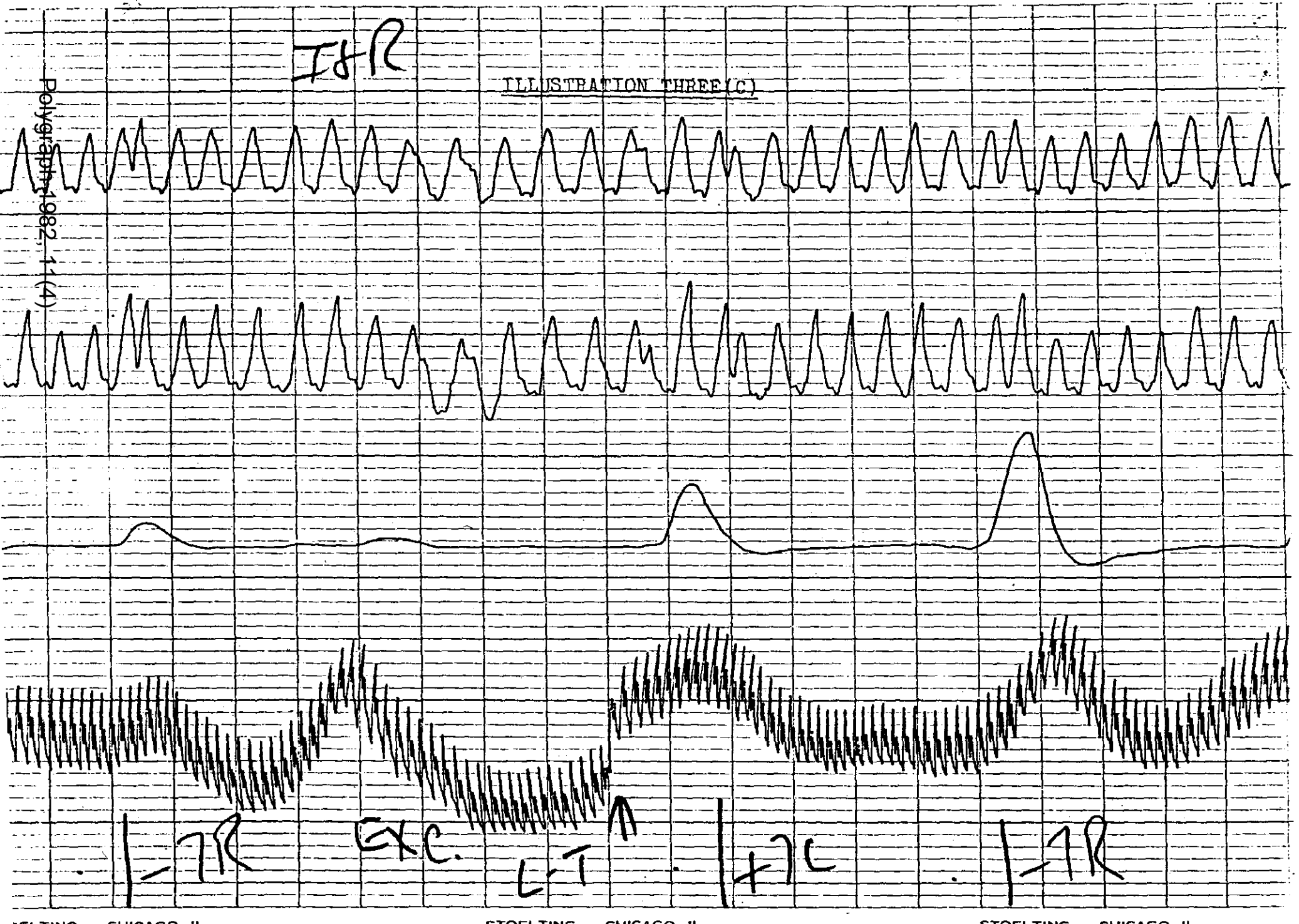
STOELTING CHICAGO, IL. STOELTING CHICAGO, IL. STOELTING CHICAGO


I&R
ILLUSTRATION THREE(B)
Polygraph 1982; 11(4)
I+C
I-R
EXC.
I+C
STOELTING CHICAGO, IL.
STOELTING CHICAGO, IL.

I & R

ILLUSTRATION THREE(C)

Polygraph, 1982, 11(4)



Clinical Biofeedback: Efficacy and Mechanisms, edited by Leonard White and Bernard Tursky. New York: The Guilford Press, 1982.

A Review

By

Douglas Grimsley*

The recent interest in behavioral medicine and biofeedback has resulted in many new books dealing with these issues. One of the most authoritative discussions presented recently can be found in the new publication by White and Tursky. It contains the proceedings of a research symposium held at the State University of New York at Stony Brook in May 1980. Prominent scientists from psychology, psychiatry, behavioral medicine, and related fields met to discuss biofeedback. All formal presentations were circulated to the participants in advance of the meeting and so the discussants had ample opportunity for preparation and organization of their comments. This book contains the formal papers circulated by the speakers, many of the discussions which followed the presentation of a summary version of the papers, and an edited round-table discussion which followed groups of papers.

The book begins with the keynote address delivered by Neal Miller in which he summarizes many of the significant issues facing behavioral medicine today and effectively and appropriately places biofeedback into this context. He also discusses many of the significant research issues, what is learned in biofeedback, and the relevance of these issues to clinical practice.

The chapters which follow deal in detail with the topics introduced by Dr. Miller. Included are many discussions concerned with the psychological mechanisms in biofeedback, research design and evaluation, classical and operant conditioning issues, and the results of an engineering approach to biofeedback.

Later chapters of the book deal extensively with detailed evaluation of biofeedback approaches to cardiovascular disorders, central nervous system disorders, and stress and anxiety. An excellent summary, evaluation, and prognosis is offered in the two concluding chapters written by John Lacey and Martin Orne.

Much of the strength of this excellent book lies in the authoritative exchanges occurring between the participants following the presentation of a topic. The discussions help to clarify a number of methodological and process issues as they have arisen in the biofeedback area. Careful attention was paid to referencing and citations are readily provided to the reader.

While this book covers many of the controversial issues in biofeedback, it deals especially well with methodological problems. There are discussions of headache classification, measurement of stress and anxiety

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reduction, control groups, session effects, and much more. Placebo effects are analyzed and placed in their proper context. ("One man's placebo is another man's treatment.")

For examiners who are interested in, and concerned about, biofeedback training as a countermeasure; and who want to become familiar with the biofeedback literature, this book offers a valuable one source, sophisticated discussion of the issues. It is current, relevant, and will clearly serve a valuable heuristic function for a wide variety of disciplines. To knowledgeable and experienced biofeedback practitioners, it offers a state of the art summary of the field and a glimpse into the future. It is a book which offers a wealth of information concerning a wide range of issues.

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Errata

The following errors occurred in the article by Gordon H. Barland in the September 1982 issue of Polygraph. Readers are urged to make the following corrections in their copy of the journal.

1. In the second paragraph on page 258, the sentence "However, a degree in psychology does not necessarily confer an accurate understanding of polygraph procedures and techniques, or that it make one immune ..." is incorrect.

The words "or that" should be replaced by the words "nor does".

2. In the last complete paragraph on page 270, the sentence "This test offers a number of advantages over previous test procedures in that it is the first testing technique ever developed in which one can calculate the precise probability of a false negative error." is incorrect. The word "negative" should be replaced by the word "positive".

3. The second paragraph under the headings ASSUMPTIONS OF POLYGRAPH TESTS on page 266 quotes from Dr. Lykken's book. The first sentence starts "And we must be caseful ..." The sentence should read "And we must be careful ..."

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