Cardiovascular Psychophysiology

Returning to last time

The Polygraph

- Does not assess lying
- Assesses emotion/arousal
- Has an unacceptable high false positive rate
- Especially problematic for low base-rates of deception (e.g., screening)
- Appears to remain in use because it is useful for eliciting confessions
- See the 60-minutes segment: http://www.polygraph.com/media

NRC (2003) Key Conclusions

- "What is remarkable, given the large body of relevant research, is that claims about the accuracy of the polygraph made today parallel those made throughout the history of the polygraph; practitioners have always claimed extremely high levels of accuracy, and these claims have rarely been reflected in empirical research."

- "Almost a century of research in scientific psychology and physiology provides little basis for the expectation that a polygraph test could have extremely high accuracy."

Roadmap

- Abbreviated History and Overview of the Conventional Polygraph
- Limitations to Conventional Polygraphy
- Overview of alternatives: Assessing recognition

The GKT as an alternative to Traditional Polygraph Procedures

- Guilty Knowledge Test (GKT)
  - Devised by Lykken (1959)
  - Can utilize Skin Conductance or other measures (e.g., Event-Related Brain Potentials)

- Sometimes termed “Concealed Information Test” (CIT)
Guilty Knowledge Test (GKT)

- The GKT does not assess lying as indexed by fear of being detected, but probes for guilt as indexed by recognition.
- A series of questions is devised, each having several alternatives, only one of which is true about the crime in question.
- Chances of an innocent person looking guilty on a 10-item GKT are $1/5^{10}$.

Assessing Recognition: For Specific Incidents Investigations

- Used when information about a crime or event is available that only a real culprit would know.
- Series of questions constructed, only one of which has correct critical detail.

<table>
<thead>
<tr>
<th>Regarding the abduction location, do you know for sure it was...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ... at a Toy Store?</td>
</tr>
<tr>
<td>2. ... at a Shopping Mall?</td>
</tr>
<tr>
<td>3. ... at a City Park?</td>
</tr>
<tr>
<td>4. ... at a Friend’s House?</td>
</tr>
<tr>
<td>5. ... at School?</td>
</tr>
<tr>
<td>6. ... at a Restaurant?</td>
</tr>
</tbody>
</table>

- Subject instructed to answer "no" to each item, so that if guilty, subject would be lying to the critical item.
- Critical item never positioned at beginning.
- A consistent peak of physiological response on one critical alternative suggests guilt.

GKT Accuracy: Lab Studies

<table>
<thead>
<tr>
<th>Study (1st Author, Yr)</th>
<th>N</th>
<th>Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lykken '59</td>
<td>98</td>
<td>88 100</td>
</tr>
<tr>
<td>Davidson '68</td>
<td>48</td>
<td>92 100</td>
</tr>
<tr>
<td>Podlesney '78</td>
<td>18</td>
<td>90 100</td>
</tr>
<tr>
<td>Balloun '79</td>
<td>34</td>
<td>61 88</td>
</tr>
<tr>
<td>Gieser '80</td>
<td>40</td>
<td>92 100</td>
</tr>
<tr>
<td>Bradley '81</td>
<td>192</td>
<td>59 89</td>
</tr>
<tr>
<td>Bradley '84</td>
<td>16</td>
<td>100 100</td>
</tr>
<tr>
<td>Iacono '84</td>
<td>55</td>
<td>91 100</td>
</tr>
<tr>
<td>Steller '87</td>
<td>87</td>
<td>85 100</td>
</tr>
<tr>
<td>Iacono '92</td>
<td>71</td>
<td>87 71</td>
</tr>
<tr>
<td>O'Toole '94</td>
<td>45</td>
<td>77 94</td>
</tr>
<tr>
<td>Study Median</td>
<td>48</td>
<td>88 100</td>
</tr>
</tbody>
</table>

GKT – Box Score, and Concerns

- Superior to CQT, especially in protecting the innocent.
- Resistance to use among those in the polygraph community.
- Concern about applicability, especially in high profile cases.
- The GKT for OJ.
- Despite limitations of CQT, may have utility for eliciting confessions.
- Over 5,000 GKT tests given in Japan each year, for example.

Countermeasures to GKT?

- Iacono et al. (1984, 1987) increased incentives and found no effects (relative to placebo) for:
  - Diazepam (widely prescribed tranquilizer)
  - Methylphenidate (stimulant)
  - Meprobamate (tranquilizer)
  - Propranolol (widely prescribed cardiac med. β-blocker that inhibits SNS activity)
- Overall hit-rate for the guilty was >90%
Physical Countermeasures and the CQT

- Honts et al. (1983, 1984)
  - 78% of highly motivated subjects could be trained to "beat" the CQT by biting their tongues or pressing their toes to the floor during control questions
  - Although it took training, motivated suspects could easily obtain it or it could be provided (e.g., antipolygraph.org)
  - The polygraphers were unable to detect these subtle maneuvers
  - "Counter-countermeasures" worked to detect those using countermeasures: 80% could be detected by a blind analysis of EMG recordings
  - Such counter-countermeasures rarely used in field polygraphy

Physical Countermeasures and the GKT

- The rectangularity score of the GKT should -- in theory -- be much less susceptible to these techniques
- GKT and rectangularity scores rarely used in field polygraphy
- Yet Honts et al (1996) found that both Physical (pressing toes to floor) and mental (counting backwards by sevens) countermeasures reduced the validity if the GKT (Overall accuracy dropped from 85% to 25%)

Synopsis

- There is no unequivocal lie response
- Polygraphy:
  - assesses emotional reactions
  - has an unacceptably high false-positive rate
  - Is vulnerable to countermeasures that can reduce true-positive rate
  - Polygraphers overestimate accuracy due to how cases are selected for inclusion in studies
  - Assessing recognition may prove more accurate, but potentially less widely applicable
  - Polygraphs are useful for eliciting admissions and confessions; i.e. “scare the hell out of people”

Science and Pseudo-Science, Debate and Diatribe, Validity versus Vitriol

If I announce to my scientific colleagues that I have invented a new test that can identify schizophrenia with 90% or 95% accuracy, my colleagues will be interested -- but skeptical. I would be expected to support my assertion with experimental evidence and that evidence would be very critically examined. Even if my proofs withstood such scrutiny, many would reserve judgment until an independent investigator had confirmed my findings. All this skepticism about a claim that I can distinguish "crazy people" from normal ones! The tools of the psychologist are not precision instruments; really high accuracy is seldom achieved. Skepticism is appropriate. Nevertheless, when the polygrapher announces that his psychological test can separate liars from the truthful with a validity of 90%, or 95%, or even 99%, the typical reaction is a kind of marveling acceptance. The critic who questions these claims is greeted with surprise and skepticism. Nearly every American has heard of the lie detector; without really knowing what is involved, many assume that it is nearly infallible. So deeply ingrained is this mystique that, gradually over the last 50 years, the burden of proof has somehow shifted to the critic.


Science and Pseudo-Science, Debate and Diatribe, Validity versus Vitriol

Unfortunately, the minute a small handful of psychologists -- one or two pseudo-knowledgeable and one or two completely ignorant of what they were even trying to do -- got into the picture, two expressions, “false positive” and “false negative”, came to light. It appears that some people turn out to be weird ducks. Sadly, when that type of inquirer doesn’t understand something, he is usually prone to attach strange names to it under the guise of professionalism or scientific exploration on both sides of the same coin. By confusing other people more so than himself he feels he can still call himself an “expert.” Those two phrases appeared in a tumor in the brain [sic]. Before then, they had never existed in polygraph language. In all sincerely, however, foul ball psychologists are few and far between.

Ferguson, in Preemployment Polygraphy, 1984

Cardiovascular Psychophysiology

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Ferguson, in Preemployment Polygraphy, 1984
Facts and Functions

- The busy heart
  - Six quarts of blood pumped per minute
  - 100,000 beats per day
  - Try it!
- Functions
  - Transport oxygen from lungs and nutrients from gut
  - Transport waste products
  - Transport regulatory substances (e.g., endocrines)
  - Thermal exchange between core and periphery

Anatomy of the Heart

- Cardiac Muscle (myocardium)
  - Not striated, not smooth
  - Four features distinguish from smooth or striate
    - Muscle has unstable resting potential—basis for intrinsic and rhythmic contraction
    - Action potential freely conducted from one cell to another (lattice-like syncytial) network of cardiac fibers
    - Repolarization lasts about 100 msec
    - Contraction phase = duration of cardiac action potentials (initial depolarization followed by sustained depolarization phase of 0.2-0.3 secs)
- Four chambers
  - Right Atrium
  - Right Ventricle
  - Left Atrium
  - Left Ventricle

Human Circulatory System

Circulation in a bit more realistic detail

Metabolic Demands

Anatomy of the Heart

Heart

Figure 6.1: Systemic and pulmonary circulation. In keeping with usual depictions of the heart, the right side of the heart is on the left side of the printed. Lighter gray areas indicate oxygenated blood, and darker gray areas indicate deoxygenated blood.
Anatomy of the Heart

- Aortic and Pulmonary Valves
  - Respond to relative pressure difference between ventricles and aorta or pulmonary artery
  - As ventricles contract, pressure builds, and forces valves open when pressure exceeds arterial pressure
  - “Dub” in the Lub-Dub sound (sounds are valves closing or “slamming” shut)

Neural Conduction of the Heart

- Two Nodes
  - Sino-Atrial (SA) node – “Primary Pacemaker”
  - Atrial-Ventricular (AV) node – “Yoked”

- Nodes have intrinsic rhythmicity
  - SA node: 105 bpm
  - AV node: 40-60 bpm

- Denervated heart would still beat at over 100 bpm
  - Must be extrinsic influences to slow or speed heart

Neural Conduction of the Heart

- Hierarchy ensures that normally the SA node “drives” the system
  - AV nodes provide a critical delay (allows atria to fully contract before ventricles do)
  - AV nodes have important refractory period to prevent rapid successive ventricular contractions
  - A coordinated wave of depolarization
  - Contraction of 4 chambers of heart must be precisely choreographed

Nodes and Fibers

The SA and AV Nodes in Action

Important: refractory period of the AV node is longer than the time it takes the ventricles to contract
The Schematized EKG waveform

P = Atrial depolarization
QRS = Ventricular depolarization
T = Ventricular repolarization
Note that Atrial repolarization is not visible

The EKG waveform

The Cardiac Cycle

Cardiac Output

\[ CO = HR \times SV \]
Cardiac Chronoptropy

- Heart rate regulated extrinsically
- Vagal (PNS) influence
  - Slows HR
  - So too will dripping ACH on SA node
  - Likely that all changes below 100 bpm are predominately vagally induced
- SNS influence
  - Speeds HR, but impact not as strong as PNS
  - Main effect is to increase contractility

SNS and PNS influences

HR change to simultaneous vagal and sympathetic stimulation

Integrated Control Mechanisms

- Baroreceptor Reflex
  - Pressure sensitive receptors
  - located in the arch of the aorta and carotid sinus nerves
  - Join Vagal and Glossopharangeal nerves
  - Terminate in regulatory centers in medulla
  - With increase in BP, causes compensatory decrease in HR, contractility, and SV
  - Quickly adjusts to maintain BP
- Valsalva Maneuver

Valsalva Maneuver

Cardiac Inotropy

- Contractility is predominately Sympathetically mediated
- Often measured invasively, but can be measured noninvasively
  - EKG plus phonocardiogram
  - Impedance cardiography

Integrated Control Mechanisms

- Respiratory Effects
  - Respiratory Sinus Arrhythmia (RSA)
    - This arrhythmia is not a bad thing!
    - HR acceleration linked to inspiration
    - HR deceleration linked to expiration
  - RSA
    - Indexes strength of Vagal influence
    - More later…

SNS and PNS Integration: A Caveat

- Relatively easy to measure PNS: RSA or other metrics of HRV
- Relatively easy to measure SNS: Contractility via PEP
- BUT… one is measure of chronotropy, other is measure of inotropy
  - Changes in contractility can occur independently of changes in rate
  - SNS inputs for inotropy primarily controlled by left-sided inputs to AV node
  - SNS inputs of chronotropy primarily controlled by right-sided inputs to SA node
- Thus, like “mixing apples and oranges”
Cardiovascular Measures

- Electrocardiogram (EKG)
- Phonocardiogram (PCG)
- Impedance cardiography
- Photoplethysmography
- Ballistocardiography
- Blood Pressure

EKG

AC signal
Sample 200-500 Hz

EKG Demo

Which Time?

- Real time
  - Heart Rate
  - Expressed as beats per time (usually bpm)
- Cardiac time
  - Heart Period; interbeat interval (IBI)
  - Expressed in msec
- Converting

\[
HR = \frac{1}{\frac{HP}{60,000}} \\
HR = \frac{1}{\frac{1}{1000}} \times 60,000 = 60 \text{bpm}
\]
Phonocardiography

- Position microphone over heart
- Lub-Dub is transduced to electrical signal

Photoplethsmography

Three methods, all involve measuring light absorbed by peripheral vasculature

The Photoplethysmographic Output

Photoplethysmograph: Peripheral Vasoconstriction

T1 is onset of constriction
Top Panel: Pulse Volume (recorded with 1 sec time constant)
Lower Panel: Blood Volume (no filter)

Measuring contractility with EKG, PCG, and Photoplethysmography

PEP = Pre-ejection period
LVET = Left Ventricular Ejection Time
= Upward of pressure wave to S2
Electromechanical Systole = Q to S2
PEP = EMS - LVET
PEP reflects sympathetic influence on cardiac contractility

Measuring Blood Pressure

Auscultatory Technique
- Not good for instantaneous readings
- Not good for repeated readings

After Newlin & Levenson (1979) Psychophysiology, 16, 548-553
Ballistocardiography

- Imagine
  - On a chair on a platform on an air hockey table
  - Cardiac events cause movement of platform
- New applications:
  - Finding individuals hiding in vehicles
  - Finding individuals stuck in rubble

Impedance Cardiography

- Low energy high-frequency AC passed through thoracic region
- Changes in impedance to signal created by mechanical events of cardiac cycle, especially changes in thoracic blood volume
- \( \Delta Z \) is change in impedance
- \( \frac{dZ}{dt} \) is 1st derivative of impedance signal \( Z \)
- \( R-Z \) is time from r-wave to peak ventricular contraction indicated in \( Z \) signal
- The “Heather” index - divide \( \frac{dZ}{dt} \) by \( R-Z \) interval; putative measure of heart’s ability to respond to stress

Measuring Vagal Influence

- Descending Vagal Influence slows HR
- Respiration interrupts this vagal influence
- The size of periodic oscillations due to respiration can therefore index the strength of the Vagal influence
- Note, however, that under some circumstances, there can be dissociation between RSA and presumed central cardiac vagal efferent activity (cf., Grossman & Taylor, 2007)
- Concerns over changes in rate, and to lesser extent depth
- See special issue of *Biological Psychology*, 2007 for more in depth treatment of these issues and more!
- Demo with QRSTool

Abbreviated History of HR Variability
(with thanks to Porges, 2007)

- Physiology treated HR as DV, similar to behavior
- Dominance of behaviorism emphasized control over the DV (behavior)
- Changes in HR unrelated to the manipulation considered noise
  - Lacey (1967) and Obrist (1981) had models related to attention, and metabolic demand, but HR variability did not fit in either model
  - Via appropriate experimental design, HR should be entirely under the control of experimental or environmental demands
- Nonetheless, history of quantifying HR variability dates to the 1950’s with case report long before that:
  - 1958: Lacey and Lacey, greater HRV associated with greater impulsivity
  - 1915: Eppinger and Hess, described a vagotonic syndrome with clinical features that included an exaggerated RSA
- Interest in HRV as an individual difference variable, however, really starts with the work of Steve Porges

<table>
<thead>
<tr>
<th>High Variability Subject</th>
<th>Low Variability Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>IBIs (real time)</td>
<td>IBIs (real time)</td>
</tr>
<tr>
<td>12-40 Hz filtered IBIs</td>
<td>12-40 Hz filtered IBIs</td>
</tr>
<tr>
<td>L T</td>
<td>L T</td>
</tr>
</tbody>
</table>
Cardiac Vagal Control and Modulation

  - Reptilian "Dumb": Dorsal Motor Nucleus
    - Massive reduction in HR & conservation of oxygen.
    - Dive reflex — cold water on the face during breath hold
  - Phylogenetically newer "smart" Vagus
    - Originates from Nucleus Ambiguous
    - Modulates influence to:
      - Promote attentional engagement, emotional expression, and communication
      - Mobilizes organism to respond to environmental demands
        - Phasically withdraws inhibitory influence, increasing HR
        - Upon removal of the environmental stressor, resumes its efferent signal
      - Slowing heart rate
  - Allows the organism to self-sooth
- This polyvagal theory is not without its critics (e.g., Grossman & Taylor, 2007).

Tonic Vs Phasic

- Tonic Level indexes capacity
- Phasic change indexes actualization of that capacity
- Attention
  - Higher vagal "tone" was associated with faster reaction time to a task requiring sustained attention
    - Attentional skills improved
    - Appropriate task-related suppression of heart rate variability was observed while performing the task requiring sustained attention
- Emotion
  - Beauchaine (2001):
    - Low baseline vagal "tone" is related to negative emotional traits
    - High vagal withdrawal is related to negative emotional states

Individual Differences in Cardiac Vagal Control (aka “Trait Vagal Tone”)

- Infants
  - Various sick infants have lower vagal tone (Respiratory Distress Syndrome, Hydrocephalic)
  - Infants with higher vagal tone (Porges, various years)
    - More emotionally reactive (both + & -)
    - More responsive to environmental stimuli (behaviorally and physiologically)
- Anxiety Disorders
  - Lower Vagal Tone in GAD (Thayer et al., 1996)
  - Lower Vagal Tone in Panic Disorder (Friedman & Thayer, 1998)
- Depression
  - Depression characterized by lower Vagal tone?
  - State dependent? (Chambers & Allen, 2002)
Can Vagal Control predict development of anxiety following stressors?

Table 1: Significant contrasts among patients, blood phobics, and controls.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Vagal Control</th>
<th>Blood Phobia</th>
<th>Control</th>
<th>F ratio, df, p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR (BPM)</td>
<td>P &lt; 0.05</td>
<td>P &lt; 0.05</td>
<td>P &gt; 0.05</td>
<td></td>
</tr>
<tr>
<td>VAS (cm²)</td>
<td>P &lt; 0.05</td>
<td>P &lt; 0.05</td>
<td>P &gt; 0.05</td>
<td></td>
</tr>
<tr>
<td>MS2 (ths)</td>
<td>P &lt; 0.05</td>
<td>P &lt; 0.05</td>
<td>P &gt; 0.05</td>
<td></td>
</tr>
<tr>
<td>BF (power lin²)</td>
<td>P &lt; 0.05</td>
<td>P &lt; 0.05</td>
<td>P &gt; 0.05</td>
<td></td>
</tr>
<tr>
<td>LF/HF</td>
<td>P &lt; 0.05</td>
<td>P &lt; 0.05</td>
<td>P &gt; 0.05</td>
<td></td>
</tr>
</tbody>
</table>

P: p value; R: blood phobic; C: control.

Chambers and Allen (2002) Psychophysiology

Movius & Allen, 2005

Vagal Control and Defensive Coping

Trait Vagal Tone as Moderator of Response following Bereavement

- Bereavement as a period of cardiovascular risk
- Disclosure as an intervention for Bereavement (O'Connor, Allen, Kaszniak, 2005)
- Overall, all folks get better, but no differential impact of intervention
- BUT… Vagal Tone as moderator
Orienting, Attention, and Defense

Emotional reactivity

SCR (by contrast)

Emotional reactivity

OR Vs DR

OR Vs DR