PSYC401A/501A: Principles of Psychophysiology

Spring, 2019, Mondays, 1:00-3:45 p.m.
Room 323 Psychology

Course Resources Online:
jallen.faculty.arizona.edu
Follow link to Courses

Main Text

Main Text

John T. Cacioppo
1951-2018
Gary G Berntson
Louis G Tassinary

http://circleofwillispodcast.com/remembering-john-cacioppo

Administrivia

➢ Drops and Adds
➢ Overview of Syllabus
➢ Class Format

Substantive Topics

➢ General Definition and Interpretive Issues
➢ Review of studies that highlight the utility of a psychophysiological approach

General Issues

➢ Definition
➢ Scope
➢ Problems of inference
➢ Problems and Prospects for the field

Definition

Psychophysiology

Psychophysiology is a research area which extends observation of behavior to those covert proceedings of the organism relevant to a psychic state or process under investigation and which can be measured with minimal disturbance to the natural functions involved. Modern psychophysiology is a response to the challenge inherent in the full realization of the complex nature of the human organism.

Psychophysiology provides a method for bringing both physiological and psychological aspects of behavior into a single field of discourse by which truly organismic constructs may be created.
Definition

- Stern (1964), also in the 1st issue of Psychophysiology
  I would like to offer as a working suggestion that any research in which the dependent variable is a physiological measure and the independent variable a “behavioral” one should be considered psychophysiological research.

Yet he concludes… “I wish our editor the best of luck in defining the scope of articles acceptable for our journal.”

Definition

- Cacioppo Tassinary & Berntson (2016):
  - the scientific study of social, psychological, and behavioral phenomena as related to and revealed through physiological principles and events in functional organisms

- Allen (2019, this very moment):
  - The use of a particular set of physiologically-based dependent or independent variables to gain insights into psychological questions; when done well, psychophysiological methods
  - provide an independent method (to behavior and self-report)
  - provide information that is not accessible through other psychological methods
  - link behavior and experience to underlying systems, by using paradigms with solid theoretical foundations

- Distinguished from: Physiological psychology, Behavioral Neuroscience

Scope

- “Classic Measures”
  - Skin Conductance (level and response)
  - Cardiac measures (heart rate, variability, contractility, both SNS and PNS measures, blood pressure, plethysmography)
  - Oculomotor and pupillometric measures
  - Electromyographic activity
  - Respiration
  - Gastrointestinal activity
  - Penile and vaginal plethysmography
  - Electroencephalographic activity (frequency domain EEG and sleep psychophysiology)
  - Event-related brain potentials
  - Event-related frequency changes

- “Newer Measures”
  - Hormonal and Endocrinological measures
  - Immune function
  - Functional neuroimaging
  - PET
  - fMRI
  - Optical Imaging
  - MEG
  - Classical Biofeedback
  - Transcranial Magnetic Stimulation
  - Transcranial Direct Current Stimulation
  - Transcranial Ultrasound

Thematic x Systemic Psychophysiology

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More Applied Psychophysiology

Chaotic Moon’s mind-controlled skateboard
Problems of Inference: 
Correlate Vs Substrate

➢ Is observed physiological activity a substrate of observed behavior? BEWARE

➢ Helpful Criteria

➢ Is Φ necessary for behavior?
➢ If Φ removed, would behavior be altered?

➢ But ultimately, not easily resolved

A scientific theory is a description of causal interrelations. Psychophysiological correlations are not causal. Thus in scientific theories, psychophysiological correlations are monstrosities. This does not mean that such correlations have no part in science. They are the instruments by which the psychologist may test his theories. (Gardiner, Muttalif, & Hebe-Center, 1937, p. 385)

Problems of Inference


Only these types of relationships would allow a formal specification that psychological elements are a function of specific physiological elements

Reducing the Complexity

From Cacioppo, Tassinary, & Berntson, 2000

The Taxonomy of Φ and Ψ

From Cacioppo, Tassinary, & Berntson, 2016

Figure 1. Taxonomy of psychophysiological relationships, From Cacioppo, Tassinary & Berntson, 2016

One-to-one, Context Dependent
Example: medical tests (fasting glucose)
Inference given Φ: yes, if conditions were met
Utility: Informed and well-tested.

One-to-one, Context Independent
Example: IT15 near end of short arm chromosome 4 and Huntington’s
Inference given Φ: definitely ψ
Utility: This is the Holy Grail that gets you the Nobel prize!

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Inference given Φ: none
Utility: Limited usefulness.

Many-to-one, Context Dependent
Example: affect and HR in IAPS paradigm
Inference given Φ: none
Utility: Informative and tests usefulness.

Many-to-one, Context Independent
Example: arousal and skin conductance
Inference given Φ: none
Utility: This is the Holy Grail that gets you the Nobel prize!

Many-to-one, Context Dependent
Example: arousal and skin conductance
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Typical Scenarios

➢ Typical structure/assumption of psychophysiological or imaging study:
  P(Φ|Ψ) > 0

➢ Typical structure/assumption of biofeedback study:
  P(Ψ|Φ) > 0

➢ Typical hunt for “markers” or biological substrate
  Study begins P(Φ|Ψ) > 0
  Desirable (but often invalid) inference
  P(Ψ|Φ) > 0
  Only valid given 1:1 relationship of Ψ and Φ
  Use complementary approaches; e.g.,
  IMER = P(Ψ|Φ)
  Lesion = P(Ψ|Φ)
  Stimulation = P(Ψ|Φ)

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The Inference Problem Illustrated

During religious recitation, self-identified religious subjects activated a frontal-parietal circuit, composed of the dorsolateral prefrontal, dorsomedial frontal and medial parietal cortex. Prior studies indicate that these areas play a profound role in sustaining reflexive evaluation of thought. Thus, religious experience may be a cognitive process which, nonetheless, feels immediate.

Ten Years Later, and …

Although our data do not determine whether these regions play a causal role in the formation of political attitudes, they converge with previous work to suggest a possible link between brain structure and psychological mechanisms that mediate political attitudes.

How to Interpret this?

“Our data confirm the emergence of conscious versus unconscious experience in the neural network of superior and inferior parietal lobule, left occipital cortex, precuneus, and frontal brain areas including BA 6 and BA 10.”

Problems and Prospects for Psychophysiology

**Problems/Challenges**
- Interpretive ambiguity
- Time resolution and time courses of various systems/measures differ substantially
- Spatial resolution
- What is the functional significance of the observed physiological measure?

**Prospects**
- Non-invasive
- Measures of real-time information
- May be sensitive to things that we ourselves cannot be
- Ideally suited for populations that have limited verbal/cognitive capacity
- May tap function at roughly the proper level of the nervous system to be useful to psychological investigations
- Psychophysiology is now more integrated into psychology as a whole -- you will see it in "nonspecialty" journals
- More and more "canned" packages make it accessible to the novice, but novices need advice and consultation!
- Even though there will always be newer technologies (e.g., PET, SPECT, MEG/SQUID, MRI, Functional MRI, etc.), traditional psychophysiology has generally excellent real-time resolution
- Is flexible
- Is cost-effective
- Can be integrated with many of the newer technologies
- Principles generalized across many measures
- Newer technologies nonetheless based on fundamental principles of psychophysiology, and are in fact, psychophysiological measures
- When you tell folks at a party that you are a psychophysiologist rather than a psychologist, you are spared hearing the history of people's family pathology
A few selected studies to highlight the utility of a psychophysiological approach

- Bauer (1984): Prosopagnosia
- Öhman & Soares (1993): Phobias
- Speigel (1985): Hypnosis
- Deception Detection studies
- Investigation of Persistent Vegetative State
- Brain-Computer Interfaces for assisted communication

Bauer (1984): Neuropsychologia

- Prosopagnosia
- Administered a version of the Guilty Knowledge Test (GKT)
  - As administered to the prosopagnosic patient
  - Set A consisted of 10 photographs of very famous folks; Set B consisted of 8 family members
  - During the display, five choices for the correct name were presented auditorially

Results
- Patient naming: 0/10 famous faces, 0/8 family members
- Controls naming = 9/10 famous, 0/8 of patient's family members
- Electrodermally, patient produced largest SCR to correct alternative
  - for 60% of famous faces (controls 80%, ns difference),
  - for 62.5% of family members (controls 37.5%)

Conclusions
- Dissociation between psychophysiological and behavioral measures - psychophysiology told us something that the patient could not
- Patient can, at an autonomic level, properly identify faces
  - viz. that "prosopagnosia involves a functional defect not at the perceptual level itself, but at a stage of processing where adequate perceptual information is utilized in complex decisions about the stimulus identity" (p.463)

Öhman & Soares (1993)
Journal of Abnormal Psychology

- Hypothesize that information processing of the phobic stimulus is rooted in archeic information processing mechanisms outside of the control of conscious intentions
- Use a CS+/CS- paradigm for fear-relevant and fear-irrelevant stimuli
  - Fear relevant is snake/spider, irrelevant is a flower or mushroom
  - During acquisition trials, CS+ is shocked, CS- is not
  - This leads to larger SCR to CS+ than CS-, and when stimuli are presented above threshold with awareness, no difference between fear-relevant and fear-irrelevant
- After acquisition, masked presentations (30 msec, followed by 100 msec mask)
  - Electrodermally, masking effectively eliminates the difference between CS+ and CS- for fear-irrelevant stimuli, but the difference between CS+/CS- is preserved for fear-relevant stimuli
Öhman & Soares (1993)
Journal of Abnormal Psychology

- Fear conditioning to nonprepared stimuli may involve conscious mechanisms.
- Fear conditioning to prepared stimuli may be possible through mechanisms outside of conscious/controlled information processing.
- Latter system may be fast and sensitive to danger cues.
- May also explain why exposure therapy is critical to decrease the autonomic responses.

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Speigel, Cutcomb, Ren, & Pribram. (1985)
Journal of Abnormal Psychology

- Hypnosis
  - individual difference variable, assessed via responsiveness to suggestions
- Two issues recurrently arise in hypnosis:
  (1) Do the effects have veracity?
  (2) If so, how are they accomplished?
- ERPs 101: Signal averaging

Speigel, Cutcomb, Ren, & Pribram. (1985)
Journal of Abnormal Psychology

- The study design
  - Very high or very low hypnotizable subjects selected
  - Given three suggestions:
    - Hypnotic enhancement
    - Hypnotic diminution
    - Hypnotic obstruction
  - An additional button-pressing control group
Hypnosis and Speigel continued

- Subsequent study using somatosensory ERPs found that suggestion to block mildly painful stimulus reduce P1 and P3 amplitudes in high- but not low-hypnotizable subjects.
- Also found that suggestions to increase intensity resulted in increase in P1 amplitude, but again, only in the high hypnotizable subjects.
- Collectively these studies may suggest alterations at the level of signal detection, not simply interpretation of the signal.

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Farwell & Donchin (1991) Psychophysiology

- Conventional Polygraphy unacceptably inaccurate
- Rather than rely on autonomic arousal, could rely on a cognitive response of recognition
- Mock Crime Scenario, multiple choice (variant of Guilty Knowledge Test)
  - Clothing of contact (“Green Hat”)
  - Name (“Tim Howe”)
  - Operation codename (“Op Pig”)
  - Location (“Shark Street”)
  - ...
Allen, Iacono, & Danielson (1992)  
Psychophysiology

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Persistent Vegetative State

- PVS patients typically are not non-responsive
  - But responses to varied stimuli lack:
    - voluntary components
    - cognitive aspects
    - evidence of awareness of self
    - evidence of awareness of surroundings.
    - No meaningful communication
- MCS (Minimally Conscious State) by contrast:
  - Minimal, if even highly inconsistent, signs of conscious behavior can be observed

Persistent Vegetative State

- Diagnostic errors in PVS up to 40% (Andrews et al., 1996)
- Might psychophysiological assessment help?
  - How best to validate such new measures against some gold standard when diagnostic errors are so common?
- Create continuous measure and link to physiology (Wijnen, van Boxtel, Eilander, & de Gelder (2007) Clinical Neurophysiology)
- Range from complete non-response to normal consciousness

Mismatch Negativity

- Discovered by Näätänen, Gaillard, & Mäntysalo, 1978
- Rare deviant (“Afwikend geluid”) elicits sustained negative voltage at scalp, maximal at fronto-central sites
  - Regardless of whether the stimuli are attended
  - Can vary in pitch, loudness, duration
Longitudinal Study

- Create continuous measure and link to physiology (Wijnen, van Boxtel, Eilander, & de Gelder (2007) Clinical Neurophysiology)
- Ten severely brain-injured patients (age 8-25)
- Longitudinal assessment starting 9 days after admission (and then every 2 weeks)

Longitudinal Study

- Predictive value?
  - MMN during first assessment strongly predicted level of consciousness at discharge \((\beta=-0.94, p<.00001)\)
  - Also predicted functional outcome two years later

Another approach

“...suggests a method by which some noncommunicative patients, including those diagnosed as vegetative, minimally conscious, or locked in, may be able to use their residual cognitive capabilities to communicate their thoughts to those around them by modulating their own neural activity.”

Öhman & Soares (1993): Phobias

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Syndromes where interaction with environment difficult or impossible

- Amyotrophic lateral sclerosis (ALS)
- Vegetative States
Farwell & Donchin (1988) *Electroencephalography and clinical Neurophysiology*

- Attempted to develop an applied ERP system for communication without motor system involvement
- For “locked in” patients

P300-BCI. Rows and columns of letter strings are lighted in rapid succession. Whenever the desired letter (P) is among the lighted string, a P300 appears in the EEG (after Sellers & Donchin 2006; Piccione et al. 2006).

Can’t we speed things up?

[Video links]

Operant methods (Birbaumer et al.)

From Kübler & Neumann (2005), *Progress in Brain Research, 150*, 513-525
Senso-motor Rhythm Training

Top right: Senso-motor-rhythm (SMR) oscillations from sensorimotor cortex during inhibition of movement and imagery or execution of movement (EEG trace below). On the left part of the picture is the feedback display with the target goal on the right side of the screen indicating the required SMR increase (target at bottom) or SMR decrease (target at top). The cursor reflecting the actual SMR is depicted in red moving from the right side of the screen toward the target goal.

Senso-motor Rhythm Training

- Patients’ task is to move the cursor into the target.
- Cursor movement is indicated by the squares (only one square is visible).
- The cursor moves steadily from left to right, vertical deflections correspond to the SMR amplitude.
- EEG frequency power:
  - Bold line: frequency power spectrum when the cursor had to be moved toward the top target
  - Dashed line: cursor had to be moved toward the bottom target.

Kübler & Birbaumer, 2006, Clinical Neurophysiology 119, 2658–2666

Slow Cortical Potentials (SCP)

- Targets are presented at the top or bottom of the screen.
- Patients’ task is to move the cursor (yellow dot) toward the target.
- Cursor moves steadily from left to right and its vertical deflection corresponds to the SCP amplitude.
- A negative SCP amplitude (dashed line) moves the cursor toward the top, positive SCP amplitude (bold line) toward the bottom target.
- Before each trial, a baseline is recorded indicated by the green bar.
- At time point -2 s the task is presented, at -500 ms the baseline is recorded and at zero cursor movement starts.

Kübler & Birbaumer, 2008, Clinical Neurophysiology 119, 2658–2666

Many Methods

- Many EEG DVs
- Many features to extract
- Many classification algorithms
- See it in Action:
  - https://www.youtube.com/watch?v=x_Ba1aEjxp0

See it in Action

- BCI using slow cortical potentials (SCP depicted at the top). Patient selects one letter from the letter string on screen (right below) with positive SCPs, the spelled letters appear on top of the screen.


https://www.youtube.com/watch?v=x_Ba1aEjxp0
Coming Up:

- Next session (in 2 weeks) … Reviews of:
  - Basic Electricity
  - Basic Neurophysiology and Neuroanatomy

- Don’t forget to turn in your 3x5 cards
  - Name
  - Email
  - Section (401 or 501)
  - Questions/Comments