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

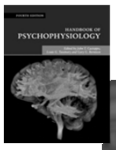
Administrivia

- 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

Main Text



Cacioppo, J.T., Tassinary, L.G. , & Berntson, G.G (2016). *Handbook of Psychophysiology* (4th edition). Cambridge, UK: Cambridge University Press.

John T. Cacioppo
1951-2018

Gary G Berntson

Louis G Tassinary

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

General Issues

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

Definition

Psychophysiology

Definition

- Darrow (1964) Presidential Address:
  - the science which concerns physiological activities which underlie or relate to psychic events
- Ax (1964) Opening Editorial, *Psychophysiology*

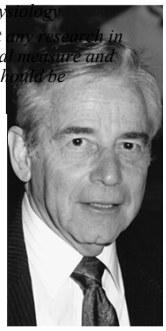
Psychophysiology is a research area which extends observation of behavior to those covert proceedings of the organism relevant to a psychic state or process under investigation and which can be measured with minimal disturbance to the natural functions involved. Modern psychophysiology is a response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



July, 1964 TOWARD A DEFINITION OF PSYCHOPHYSIOLOGY 91

TABLE 1

	Independent variable	Dependent variable
Physiological psychology	Brain lesion Brain stimulation Drug administration Diet manipulation	Learning—behavioral Performance Conditioning Food selection
Psychophysiology	Auditory stimulation Vigilance experiment Sleep deprivation Psychologic or psychiatric state (fear, anxiety, depression, etc.) Dreaming	Habituation of orienting response EEG evoked response Background EEG Conditionability of physiological system Physiological correlates

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

Definition

www.youtube.com/watch?v=w06zvM2x_lw

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 pupilometric measures
- Electromyographic activity
- Respiration
- Gastrointestinal activity
- Penile and vaginal plethysmography
- Electroencephalographic oscillatory measures (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

Manipulations

- Classical Biofeedback
- Transcranial Magnetic Stimulation
- Transcranial Direct Current Stimulation
- Transcranial Alternating Current Stimulation
- Transcranial Ultrasound

Thematic x Systemic Psychophysiology

	Cognitive psychophysiology	Developmental psychophysiology	Clinical psychophysiology	Social psychophysiology	Applied psychophysiology
Electrodermal psychophysiology	fMRI duing emotion				Lie Detection
Cardiovascular psychophysiology			Cardio effects prejudice		
Electroencephalographic psychophysiology		EEG Asym Inhibited kids			Neurowear!
Electromyographic psychophysiology					
Hemodynamic psychophysiology	fMRI duing emotion				
Etc…					

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, Metcalf, & Beebe-Center, 1937, p. 385) or her

Problems of Inference

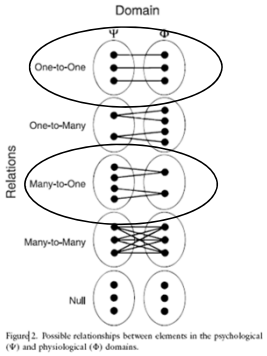


Figure 2. Possible relationships between elements in the psychological (Ψ) and physiological (Φ) domains.

From Cacioppo, Tassinary, & Berntson, 2000, 2007, 2016

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

Reducing the Complexity

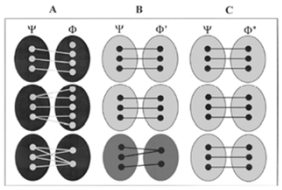


Figure 1. Depiction of logical relations between elements in the psychological (Ψ) and physiological (Φ) domains. Left panel: Links between the psychological elements and individual physiological responses. Middle panel: Links between the psychological elements and the physiological response pattern. Right panel: Links between the psychological elements and the profile of physiological responses across time.

From Cacioppo, Tassinary, & Berntson, 2000

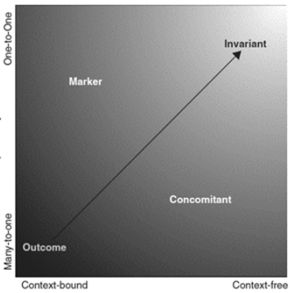
Typical Scenarios

- 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.,
    - fMRI = P(Φ|Ψ)
    - Lesion = P(Ψ|Φ)
    - Stimulation = P(Ψ|Φ)

The Taxonomy of Φ and Ψ

One-to-one, Context Dependent
Example: medical tests (fasting glucose)
Inference given Φ: yes, if conditions were met
Utility: with sufficient sensitivity and specificity can indicate presence of Ψ *in this context;* RDoC?

Many-to-one, Context Dependent
Example: affect and HR in IAPS paradigm
Inference given Φ: none
Utility: Informs and tests theories; absence of Φ can be informative

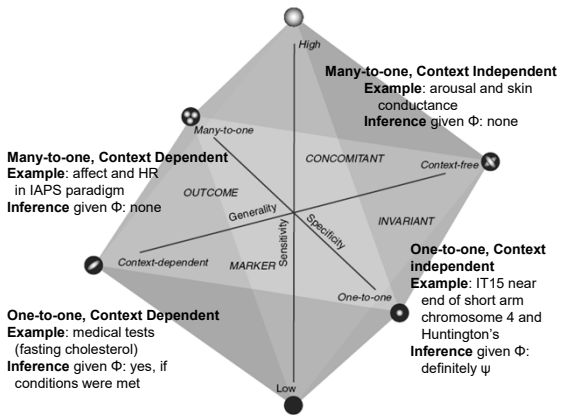


One-to-one, Context independent
Example: IT15 near end of short arm chromosome 4 and Huntington's
Inference given Φ: definitely ψ
Utility: This is the Holy Grail that gets you the Nobel prize!

Many-to-one, Context Independent
Example: arousal and skin conductance (SC); orienting and SC; familiarity and SC
Inference given Φ: none
Utility: Limited: control the context! Might absence of Φ be informative?

Figure 1.1 Taxonomy of psychophysiological relationships.

From Cacioppo, Tassinary, & Berntson, 2016



Many-to-one, Context Independent
Example: arousal and skin conductance
Inference given Φ: none

Many-to-one, Context Dependent
Example: affect and HR in IAPS paradigm
Inference given Φ: none

One-to-one, Context independent
Example: IT15 near end of short arm chromosome 4 and Huntington's
Inference given Φ: definitely ψ

One-to-one, Context Dependent
Example: medical tests (fasting cholesterol)
Inference given Φ: yes, if conditions were met

The Inference Problem Illustrated

Azari et al. (2001). Neural correlates of religious experience. *European Journal of Neuroscience*, *13*, 1649-1652.

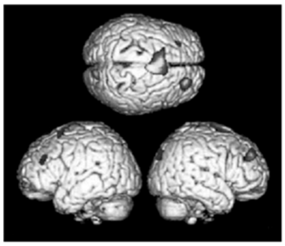


FIG. 1. Significant activations for the contrast 'religious-recite' vs. 'rest' in religious subjects, rendered onto canonical T1-weighted image of SPM97d ($P < 0.001$, uncorrected for multiple comparisons) (see also Table 2). Shown are the left, dorsal and right view of the brain. Scans for each subject were realigned and spatially normalized onto the PET template, and smoothed using an isotropic Gaussian kernel with FWHM set at 20 mm. The SPM grey matter threshold was set to its default value. For task comparisons, an ANCOVA (analysis of covariance) model was fitted to the data for each voxel.

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 …

Kanai et al. (2011). Political orientations are correlated with Brain Structure. *Current Biology, 21*, 677–680.

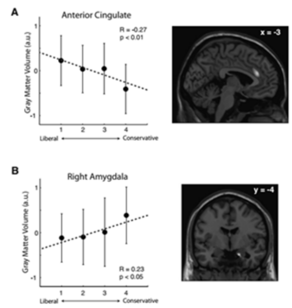


Figure 1. Individual Differences in Political Attitudes and Brain Structure
(A) Regions of the anterior cingulate where gray matter volume showed a correlation with political attitudes (see Experimental Procedures for full details) are shown overlaid on a T1-weighted MRI anatomical image in the stereotactic space of the Montreal Neurologic Institute Template [29]. A statistical threshold of $p < 0.05$, corrected for multiple comparisons (see Experimental Procedures), is used for display purposes. The correlation (left) between political attitudes and gray matter volume (right) averaged across the region of interest (error bars represent 1 standard error of the mean, and the displayed correlation and p values refer to the statistical parametric map presented on the right) is shown.
(B) The right amygdala also showed a significant negative correlation between political attitudes and gray matter volume. Display conventions and warnings about overinterpreting the correlational plot (left) are identical to those for (A).

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?

Available online at www.sciencedirect.com
SCIENCE @ DIRECT
NeuroImage
NeuroImage 20 (2003) 2119–2125
www.elsevier.com/locate/ynimg

One brain, two selves

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Abstract

Having a sense of self is an explicit and high-level functional specialization of the human brain. The anatomical localization of self-awareness and the brain mechanisms involved in consciousness were investigated by functional neuroimaging different emotional mental states of core consciousness in patients with Multiple Personality Disorder (i.e., Dissociative Identity Disorder (DID)). We demonstrate specific changes in localized brain activity consistent with their ability to generate at least two distinct mental states of self-awareness, each with its own access to autobiographical trauma-related memory. Our findings reveal the existence of different regional cerebral blood flow patterns for different senses of self. We present evidence for the medial prefrontal cortex (MPFC) and the posterior associative cortices to have an integral role in conscious experience.
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N=11, PET

"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." page 2124

A.A.T.S. Reinders et al. / NeuroImage 20 (2003) 2119–2125 2123

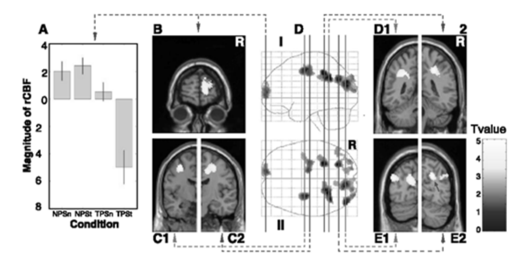

Fig. 1. Brain regions showing a significant response on the autobiographical trauma-related script in Neutral Personality State (NPS) as compared to Traumatic Personality State (TPS). (A) Mean regional cerebral blood flow (rCBF) changes at the voxel of maximum activation ($x = 12, y = 63, z = 8$) in the right medial prefrontal cortex (MPFC, Brodmann's area (BA) 10) for the four conditions of our study, i.e., exposure to a neutral (minor character n) and trauma (minor character t) memory script while remaining in NPS or TPS. Bars represent standard errors. The response shown is typical for the areas depicted in parts B through E. (B, C, D, E) Coronal slices of the brain regions involved in the functional neural network of autobiographical self-awareness. Slices are shown at the level of the most significant activation: part B (right BA 10; $x = 12, y = 63, z = 8$), C1 (left BA 6; $x = -30, y = -4, z = 46$), C2 (right BA 6; $x = 30, y = -11, z = 47$), D1 (left BA 7/40; $x = -24, y = -45, z = 37$), D2 (right BA 7/40; $x = 28, y = -37, z = 42$), E1 (left BA18/precuneus; $x = -8, y = -76, z = 24$ and BA19; $x = -44, y = -76, z = 30$), and E2 (right BA18/precuneus; $x = 26, y = -62, z = 33$ (as indicated with the small red arrow)). See also Table 1. (I and II) Parts I (sagittal view) and II (transaxial view) show the statistical parametric maps (the glass brains) of significant areas. Red and green lines represent the various brain levels, where the activations depicted in parts B through E of the figure have their peak significance value. Red lines are used for clusters located in the right hemisphere, while green lines are used for clusters in the left hemisphere. The letter R indicates the right side of the brain.

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?

Problems and Prospects for Psychophysiology

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 investigators
- 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 generalize 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 peoples' 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

Leonardo

Bauer (1984): Neuropsychologia

- 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)

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Öhman & Soares (1993) Journal of Abnormal Psychology

- Hypothesize that information processing of the phobic stimulus is rooted in archaic 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

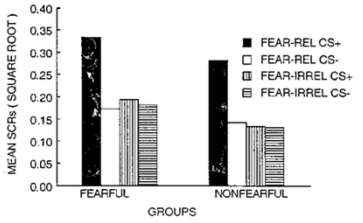

Figure 1. Mean skin conductance responses (SCRs) (square-root transformed) to fear-relevant (snakes, spiders, and rats) or fear-irrelevant (flowers and mushrooms) stimuli previously followed (CS+) or not followed (CS−) by an electric shock unconditioned stimulus among the fearful and nonfearful groups of subjects during extinction.

Öhman & Soares' Conclusions

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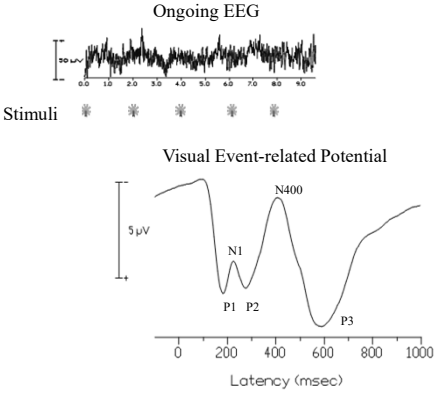
Speigel, Cutcomb, Ren, & Pribram. (1985)
Journal of Abnormal Psychology

- 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

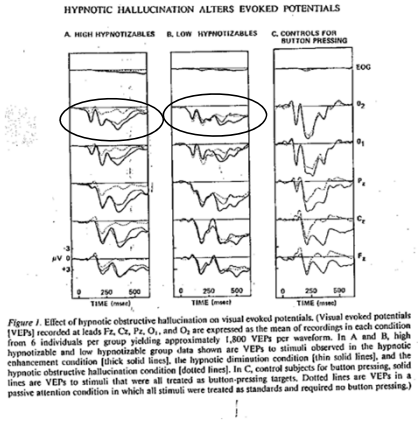


Figure 1. Effect of hypnotic obstructive hallucination on visual evoked potentials. (Visual evoked potentials [VEPs] recorded at leads Fz, Cz, Pz, O_1, and O_2 are expressed as the mean of recordings in each condition from 6 individuals per group yielding approximately 1,800 VEPs per waveform. In A and B, high hypnotizable and low hypnotizable group data shown are VEPs to stimuli observed in the hypnotic enhancement condition [thick solid lines], the hypnotic diminution condition [thin solid lines], and the hypnotic obstructive hallucination condition [dotted lines]. In C_s control subjects for button pressing, solid lines are VEPs to stimuli that were all treated as button-pressing targets. Dotted lines are VEPs in a passive attention condition in which all stimuli were treated as standards and required no button pressing.)

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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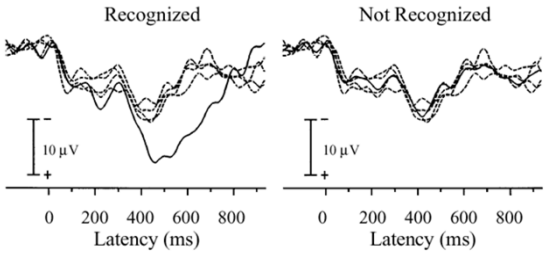
Farwell & Donchin (1991) Psychophysiology

- 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")
  - …

Rationale



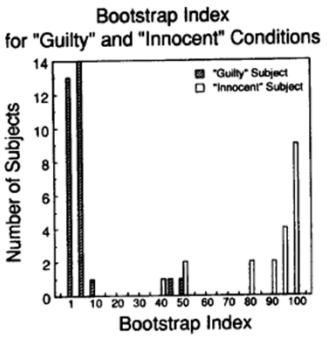
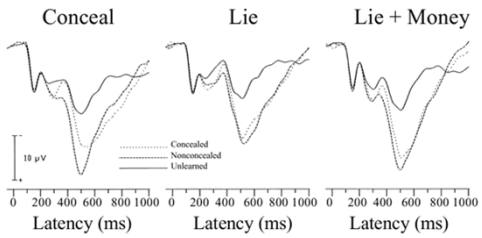


Figure 2. The distribution of the bootstrap statistic for all 40 tests conducted in Experiment 1. Dark bars indicate the number of subjects who were "guilty" and were assigned a given bootstrap value. Light bars show the same data for the "innocent" subjects.

Table 2
2A: ACCURACY OF DETERMINATIONS

Decision	Subject State: Guilty	Subject State: Innocent	Total
Guilty	18	0	18
Innocent	0	17	17
Indeterminate	2	3	5
Total	20	20	40

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

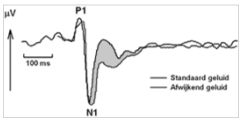
Persistent Vegetative State

- 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

Levels of Consciousness (LoCs)

Global level	Score	Description of the levels
Coma		*Eyes are closed all the time. No sleep–wake cycles present.*
	1	All major body functions such as breathing, temperature control, or blood pressure can be disturbed. Generally, no reactions are noticed after stimulation. Sometimes reflexes (stretching or flexing) can be observed as a reaction when strong pain stimuli have been applied. No other reactions present.
Vegetative State (VS)		*Patient has some sleep–wake cycles, but no proper day–night rhythm. Most of the body functions are normal. No further ventilation is required for respiration.*
	2	**Very little response (hyporesponsive)** Generally no response after stimulation. Sometimes delayed presentation of reflexes is observed.
	3	**Reflexive state** Often stimuli result in massive stretching or startle reactions, without proper habituation. Sometimes these reactions evaluate into massive flexing responses. Roving eye movements can be seen, without tracking. Sometimes grimacing occurs after stimulation.
	4	**High active level and/or reactions in stimulated body parts** Generally spontaneous undirected movements. Retracting a limb following stimulation. Orienting towards a stimulus, without fixating. Following moving persons or objects, without fixating.
Minimally Conscious State (MCS)		*Patient remains awake most of the day.*
	5	**Transitional state** Following and fixating of persons and objects. Generally more directed reactions to stimuli. Behaviour is automatic, i.e. opening of the mouth when food is presented, or reaching towards persons or objects. Sometimes emotional reactions are seen such as crying or smiling towards family or to specific (known) stimuli.
	6	**Inconsistent reactions** Sometimes, but not always, obeying simple commands. Totally dependent. Patient has profound cognitive limitations; neuropsychological testing is impossible. Level of alertness is fluctuating, but in general low.
	7	**Consistent reactions** Patient obeys simple commands. The level of alertness is high and stable. Many cognitive disturbances remain. Patient is totally dependent.
Consciousness	8	Patient is alert and reacts to his/her environment spontaneously. Functional understandable mutual communication is possible, sometimes with technical support. As yet, cognitive and behavioural disturbances can be present.

Mismatch Negativity



- Discovered by Näätänen, Gaillard, & Mäntysalo, 1978
- Rare deviant ("Afwigkend 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)

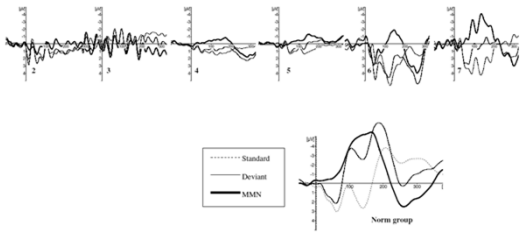


Fig. 2. Grand averages of MMN (Fz-linked Mastoids, 0.15–30 Hz, 48 dB/octave) for each Level of Consciousness according to the levels in Table 2 versus the norm group. Potentials related to the standard stimuli, potentials related to the deviant stimuli, and the MMN (difference between the deviant and standard).

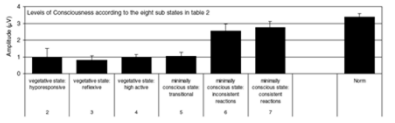
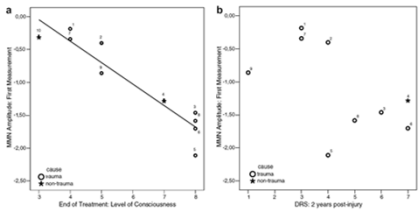


Fig. 1. Longitudinal measurements: mean MMN-amplitude (Fz) and standard error for each Level of Consciousness according to the levels in Table 2 versus the norm group. For number of measurements see Table 3.

Longitudinal Study

- Predictive value?
  - MMN during first assessment strongly predicted level of consciousness at discharge (β=-.94, p<.00001)
  - Also predicted functional outcome two years later



Another approach

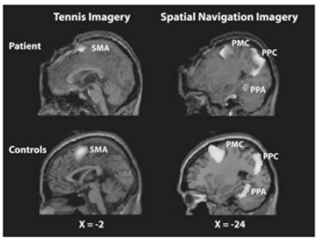


Fig. 1. We observed supplementary motor area (SMA) activity during tennis imagery in the patient and a group of 12 healthy volunteers (controls). We detected parahippocampal gyrus (PPA), posterior parietal-lobe (PPC), and lateral premotor cortex (PMC) activity while the patient and the same group of volunteers imagined moving around a house. All results are thesholded at $P < 0.05$ corrected for multiple comparisons. *X* values refer to distance in mm from the midline in stereotaxic space (SOM text).

"These results confirm that, despite fulfilling the clinical criteria for a diagnosis of vegetative state, this patient retained the ability to understand spoken commands and to respond to them through her brain activity, rather than through speech or movement."

"… 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."

Owen,A.M., Coleman, M.R., Boly, M., Davis,M.H., Laureys, S., & Pickard, J.D. (2006). *Science*

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

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

CRT Display Used in the Mental Prosthesis

MESSAGE

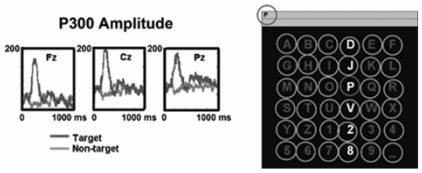
BRAIN

Choose one letter or command

A	G	M	S	Y	*
B	H	N	T	Z	*
C	I	O	U	*	TALK
D	J	P	V	FLN	SPAC
E	K	Q	W	*	BKSP
F	L	R	X	SPL	QUIT

Fig. 1. CRT display used in the mental prosthesis. The rows and columns of the matrix were flashed alternately. The letters selected by the subject ('B-R-A-I-N') were displayed at the top of the screen in the pilot study.

c P300 –Brain-Computer-Interface (BCI)



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).

Figure from Birbaumer, 2006

Can't we speed things up?

http://www.youtube.com/watch?v=2KtMCX7FfZ0
https://www.youtube.com/watch?v=zqYJQGk5I4M

Operant methods (Birbaumer et al.)

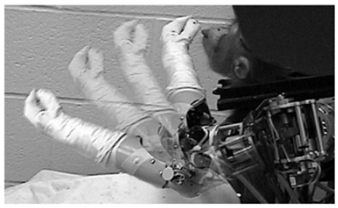


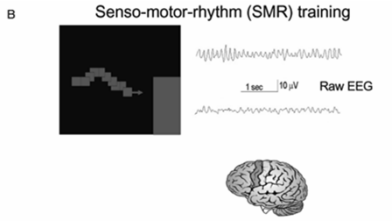
Fig. 4. A monkey is feeding himself with the aids of a robotic arm by producing the same pattern of neural activity in the motor cortex as would be required to move his own limb. The trajectory of the robot arm is depicted sequentially. In expectancy of the piece of an apple, the monkey protrudes his tongue. From the monkey only the head is visible. (We thank Dr. Andrew Schwartz, from the School of Medicine, University of Pittsburgh, Pittsburgh, USA, for this picture and for the permission of reproduction.)

From Ku¨bler& Neumann (2005), *Progress in Brain Research*, *150,* 513-525

Brain-Computer Communication and Slow Cortical Potentials

Thilo Hinterberger*, Stefan Schmidt, Nicola Neumann, Jürgen Mellinger, Benjamin Blankertz, Gabriel Curio, and Niels Birbaumer

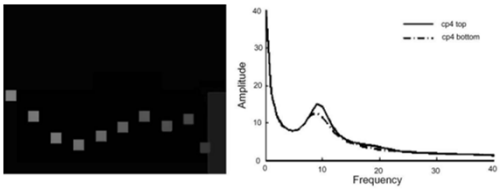
Senso-motor Rhythm Training



Top right: Senso-motor-rhythm (SMR) oscillations fromsensorimotor cortex during inhibition of movement and imagery or execution of movement (EEGtrace 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 curser reflecting the actual SMR is depicted in red moving from the right side of the screen toward the target goal.

Birbaumer, 2006

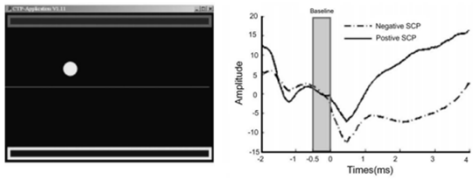
Senso-motor Rhythm Training



- 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, 2008, *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

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

Hinterberger .. Birbaumer, 2004, *IEEE Transactions of Biomed Engr, 51*

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

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